

KANSAS GEOLOGICAL SURVEY
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Stratigraphy of the Douglas Group (Pennsylvanian, Virgilian)
in the Northern Midcontinent Region

by

Stanton M. Ball

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Open-file Report

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STRATIGRAPHY OF THE DOUGLAS GROUP (PENNSYLVANIAN, VIRGILIAN)
IN THE NORTHERN MIDCONTINENT REGION

VOLUME I
(Text)

by

Stanton M. Ball

B.S., University of Kansas, 1956

M.S., University of Kansas, 1958

Submitted to the Department of
Geology and the Faculty of the
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of Kansas in partial fulfillment
of the requirements for the degree
of Doctor of Philosophy.

Advisory Committee:

R. C. Moore
Chairman

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Theodore H. Eaton

May, 1964

DEDICATION

To my wife, Artis, and
our children, Rebecca Lynn
and David Stanton.

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ABSTRACT

A stratigraphic study was made of the Douglas Group (Upper Pennsylvanian, Virgilian) in the northern Midcontinent region, and approximate correlatives, in a part of eastern Oklahoma north of the Arbuckle Mountains. In Oklahoma, the Douglas as currently defined is approximately correlative with the Barnsdall, the Tallant, and the lower part of the Vamoosa Formations.

Within the northern Midcontinent, Douglas rocks comprise a shale-sandstone facies on the south and southeast and a shale-limestone facies to the northwest. On the whole, the Douglas forms a predominantly terrigenous detritus, imperfect and incomplete wedge that thins to the north and to the northwest. The combined Barnsdall-Tallant-Vamoosa section displays over-all southward thinning, which is believed to have resulted largely from multiple erosional disconformities. Stratigraphic record of the strata studied is progressively more imperfect southward from Osage County to Pontotoc County, Oklahoma outcrops.

The regional sedimentational framework is reconstructed as a part of a single sedimentary basin bordered on the south by the Arbuckle Mountains region and on the southeast by the Ozark Dome area, and possibly the Ouachita Mountains region. Pre-Douglas Pennsylvanian terranes exposed to the south and southeast are judged to have been of primary and secondary importance respectively as immediate sources for Douglas quartz sands and large volumes of clay-size detritus. Pre-Pennsylvanian Paleozoic terranes exposed in the Arbuckles and questionably in the Ouachitas region are regarded as important immediate sources for the coarse constituents

of the Vamoosa Formation of east-central Oklahoma outcrops. Influx of terrigenous detritus rather than such things as depths of deposition, is judged to have been of primary importance regarding the spatial distribution of Douglas sediment types.

The vast majority of Douglas rocks are believed to have been deposits of marine and mixed environments. It seems probable that southern shores of the Douglas sedimentary basin were persistently within the latitudes spanned by the present Creek-Seminole Counties, Oklahoma area. Southeastern shores were generally not far southeast of present outcrops and extended to within the area of study during part of Douglas deposition. Eastern, northeastern, and northern shores are believed to have been largely outside the area of study. However, when wholesale facies differences of the Iowa section are better known and more firmly related to the Missouri and Nebraska sections, it may be established that these differences were conditioned by proximity to northeastern shores.

INTRODUCTION

Purpose and Scope of Investigation

The purpose of this study is threefold: to describe Douglas Group (Upper Pennsylvanian, Virgilian) rocks of the northern Midcontinent, to develop a classification utilitarian for both surface and subsurface studies, and to present a three-dimensional stratigraphic perspective useful for interpretation of historical geology and as a framework for more detailed investigations.

Study was initiated in 1958 after the author had opportunity to study the outcropping rocks of Franklin County and adjacent parts of northeastern Kansas. Scope of the project was determined after reconnaissance study and with the advice of J. M. Jewett and R. C. Moore of the State Geological Survey of Kansas and the Department of Geology, University of Kansas. The area of detailed study is shown in Figure 1. Reconnaissance study was conducted southward to the Arbuckle Mountains region. Special emphasis has been placed on stratigraphic correlation and description of the various rock units within the Douglas Group, which, as redefined (Ball, in O'Connor, 1963, p. 1876-1877), extends from Lansing Group top below to Shawnee Group base above.

Insofar as possible, attempt has been made to isolate descriptive from interpretative discussion. Therefore, interpretation is included largely under the headings, Classification and Historical Geology.

About 350 outcrops were studied, of which some 200 were measured and described in either a detailed or a reconnaissance manner; 77 are included in the stratigraphic sections in the appendix. Degree of completeness,

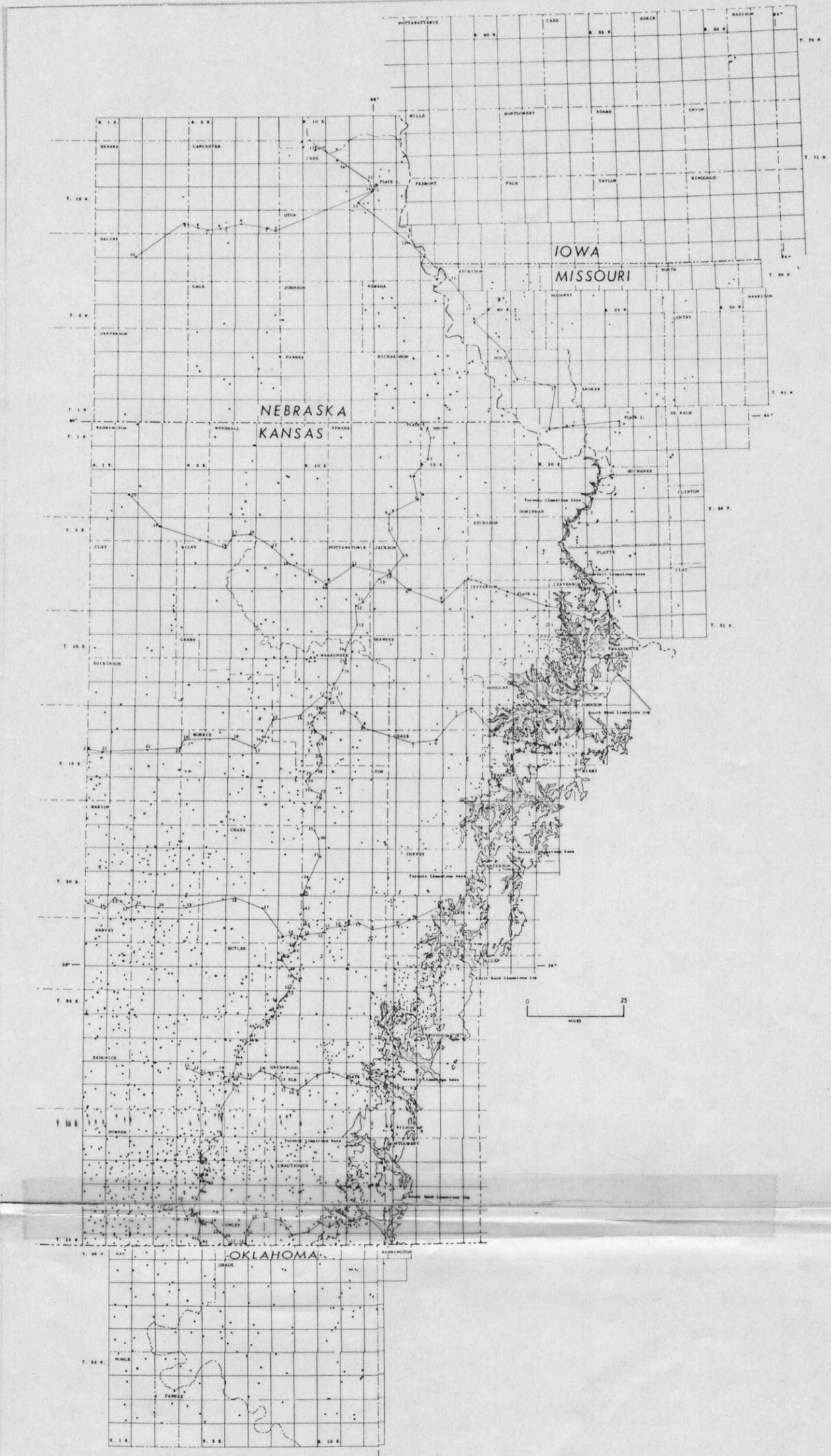
quality, and geographic spacing determined the selection of sections for detailed study. About 2,500 subsurface control points were utilized. Control is located and qualified and individuals whose work was used are credited on Figure 1.

Field and Laboratory Techniques

Field study comprised outcrop measurement, description, photography, and sampling as well as geologic mapping on aerial photographs and topographic sheets.

Much of the technique involved is common in any stratigraphic study and therefore is not described. The geologic map is a compilation of the efforts of various geologists and is so indicated (Fig. 1).

In a study that covers a relatively large area and strives for a reasonably detailed description of the rocks under consideration, the problem of sampling is encountered. Attempt was made to sample type sections of limestone units as completely as possible. Extension of sample control laterally was accomplished by sampling each lithologic change discernible in the field and retaining a maximum vertical spacing of 1 to 2 feet. Where entirely different facies were noted in tracing units laterally, attempt was again made to sample as completely as possible. All limestone samples taken were sawed for etched block study and acetate peel preparation. Samples to be thin-sectioned were chosen in the following manner: (1) hand samples and enlarged negative prints of corresponding acetate peels from limestone type sections were arranged in stratigraphic order on tables in the laboratory; (2) after megascopic and binocular microscope study, samples representative of certain footages



EXPLANATION

- Outcrop sections (author)
- ⊕ Logs of cable tool cuttings (author)
- Logs of Kansas Sample Log Service
- Electric and radioactivity logs
- Drillers logs
- ⊕ Surface stratigraphic section, logs of rotary cuttings, logs of cable tool cuttings, and logs of cores; data represent work of individuals listed below; from files and literature of various geological surveys
- ⊕ Where two log types for the same well are shown, the symbol other than that of the Kansas Sample Log Service log marks the location

| Kansas | Missouri | Nebraska | Oklahoma |
|-------------------------|------------------------|----------------------|---------------------|
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Work of others in Iowa is credited in appropriate parts of the text

FIGURE 1.-- Map showing lines of surface-subsurface cross sections (Plate, section, and well numbers shown except the initial sections in cases in which surface sections were composited across more than one township) and distribution of control points within the area of detailed study. Surface sections studied in the Creek - Seminole Counties, Oklahoma area are not shown but are referenced in the text. Approximate map traces of South Bend Limestone top (bounds Douglas Group below), Haskell Limestone base (bounds Lawrence Formation below), and Toronto Limestone base (bounds Douglas Group above) are shown for Kansas. Areas of thick Pleistocene and Recent cover are shaded. Mapping by the geologists indicated by arrows in the explanation was utilized in various areas and has been incorporated in the forthcoming edition of the State Geologic Map of Kansas (in press).

of section were selected; (3) selection of additional samples in an attempt to delimit geographic extent of different rock types; and (4) reversion to steps (1) and (2) in cases of facies development entirely different from that of the type section. The procedure used for limestone samples involved preparation of large numbers of acetate peels (about 1,500) and a minimum of thin sections (about 100). Thin sections were cut by Fred Roberts Petrographic Section Service. The method used for preparing acetate peels is essentially that of Herbert Mendoza and is described by Harbaugh (1959, p. 295-296). Having both thin sections and acetate peels of some samples to compare with samples for which peels only are available, was deemed the least time consuming and least expensive means of gaining adequate control.

Shale and sandstone sampling was conducted in much the same manner as for limestones but fewer samples were taken. Type sections of shale units were sampled with a maximum vertical spacing of 5 feet and a minimum vertical spacing determined by sampling between color changes and by relative thinness of the unit sampled. No maximum vertical spacing for sampling sandstone units was utilized; megascopic bedding characteristics that enabled unit differentiation in the sandstones determined the vertical spacing of samples taken. Geographic spacing of shale and sandstone samples was determined largely by the degree of precision to which samples taken could be referred to marker beds. About 50 sandstone thin sections have been cut for petrographic examination as a supplement to outcrop and hand-sample descriptions.

Clay minerals in the shale samples were dispersed in distilled water (with a 1- to 3-drop NH_4OH additive for some samples) and allowed to settle

for about 4 hours. The less than 2-micron fraction was then drawn off in a medicine dropper and placed on a glass slide to dry. Diffractometer patterns were run for each of four oriented films (untreated, glycerol-saturated, heated to 450°C, and heated to 575°C for 30 minutes) for each shale sample studied by X-ray diffraction. Patterns were run at a speed of 1°2θ per minute through 50 degrees total scan. Cu K α radiation was used. About 150 shale samples were so analyzed for clay-mineral content. Criteria used for identification of the various clay minerals are shown in Table 1.

| MINERAL | SLIDE TREATMENT | FIRST ORDER PEAK | HIGHER ORDER REFLECTIONS | NATURE OF PEAKS |
|--------------------|---|---|---|--|
| Illite | Untreated Ethylene glycol saturated 450° C 575° C (30 minutes) | 10A | Integral series | Commonly intense and well-defined to 4th or 5th orders. |
| Illite-mixed layer | Untreated Ethylene glycol saturated 450° C 575° C (30 minutes) | ±10A to ±14A Expansion to 17A Collapse Near loss of identity | Poorly defined | Generally broad and diffuse. |
| ?Vermiculite | Untreated Ethylene glycol saturated 450° C 575° C (30 minutes) | 14A to 14.5A Slight expansion not beyond 14.5A Collapse to ±12A Collapse to 10A, masked by 001 illite peak | Integral series ?Slight expansion Destroyed | Commonly a clear sequence of 4 or 5 basal reflections except in patterns of heated slides. |
| Kaolinite | Untreated Ethylene glycol saturated 450° C 575° C (30 minutes) | 7A (without associated 14A peak) Destroyed | Integral series Destroyed | Relatively well defined 1st and 2nd. order. |
| Chlorite | Untreated Ethylene glycol saturated 450° C 575° C (30 minutes) | 14A Commonly enhanced | Integral series Destroyed | Commonly a clear sequence of 4 or 5 basal reflections except in patterns of heated slides. |
| Montmorillonite | Untreated Ethylene glycol saturated 450° C 575° C (30 minutes) | ±15A 17-18A Collapse to ±9.8A | Generally not present Integral series | Moderately intense except for sharp basal reflection in pattern of ethylene glycol saturated sample. |

Table 1. -- Criteria used for clay-mineral identifications.

Where a double peak is recorded near the 25° scan position, the peak on the low-angle (right-hand) side was identified as the 002 kaolinite peak, that on the high-angle (left-hand) side as the 004 chlorite or the 004 vermiculite peak. Questionable identification of the mineral vermiculite has been made according to criteria reported by Scafe (1963, p. 8). Interested readers are referred also to Grim (1953), Miller and Swineford (1957), Proctor (1959), Brown (1961), and Kahle (1962) for theory pertaining to identification of clay minerals by X-ray diffraction.

Shale samples examined for fossils were broken down and deflocculated; clay particles were decanted, and after the residue was dried on a steam radiator or hot plate it was examined under a binocular microscope. Boiling in water or soaking in kerosene was necessary to break down the most indurated shales.

Subsurface study involved the sequential utilization of drillers logs, electric and radioactivity logs, sample logs of cable tool cuttings prepared by the author, and sample logs prepared by and credited to others (Fig. 1 and appendix). Leroy (1951), Tiratsoo (1952), Uren (1956), and Maher (1959), were used by the author as references to theoretical interpretation of lithology from electric and radioactivity logs. Maher (op. cit.) was used as a guide to logging cuttings.

Not all geologists agree to the merit of drillers logs. Nonetheless, the initial extension of a cross section from the surface to the shallow subsurface in the northern Midcontinent must be made across an area in which drillers logs are the principal type of record available (see Fig. 1), and for which relatively few sets of cable tool cuttings are available for study. If correlation is in error at the outset, all subsequent correlations

are affected. About 1,500 drillers logs^{1/} in an area comprising a part of the outcrop area of Douglas Group rocks and extending as much as 20 miles west of the outcrop area were consulted. Drillers logs obviously in error and those that the author was unable to interpret were disregarded and attempt was made to avoid extension of control for distances in excess of about 6 miles between logs. Where available, areal geologic maps, topographic contour maps, and both published and open-file stratigraphic data were used as guides in interpretation of drillers logs. The author found the use of drillers logs quite valuable within the limits outlined by Leroy (1951, p. 475-478).

Distribution, thickness, and lithofacies maps were constructed. Nine surface to subsurface cross sections and 5 subsurface cross sections were prepared, and 8 are included in the report. Plates 7 and 8 extend as far west as the eastern limits of more comprehensive cross sections by W. L. Adkison (1963, and Subsurface geologic cross section of Paleozoic rocks from Cowley County to Comanche County, Kansas, in preparation).

Previous Work

Many of the outstanding early works, which pertain specifically to study of Douglas Group rocks, and workers (pre-1930) are cited in the general statement of the section on classification and on Plate 1. Further elaboration on this early published material seems unnecessary. Only a small fraction of the basic stratigraphic data (measured sections and areal mapping) collected, was published prior to 1930. D. W. Ohern is to

^{1/} From State Geological Survey of Kansas Oil and Gas Division files; not all drillers logs used are located on Figure 1.

be credited with excellent 1909-1912 work on the Pennsylvanian rocks of northern Oklahoma; much of which remains unpublished (Gould, 1927, p. 14). I have seen field notebooks prepared by J. M. Jewett, R. C. Moore, and N. D. Newell during the late 1920s and early 1930s. Some of these notes are incorporated in measured section descriptions on file with the State Geological Survey of Kansas. The many astute observations made by these men are cited and that part of the data pertaining to Douglas Group rocks credited as basic to subsequent studies.

Of the studies that have been conducted exclusively on Douglas Group rocks, only the works particularly pertinent to this study are cited here. J. M. Patterson (1933) described the Douglas Group in Douglas and Leavenworth Counties, Kansas, found the section to be more fossiliferous than previously suspected, and made pertinent observations on erosion surfaces in Douglas Group rocks. Coal resources of the Douglas Group were comprehensively studied by A. L. Bowsher and J. M. Jewett (1943), and their report includes excellent stratigraphic descriptions as well as valuable insight pertaining to deposition of the coals (p. 37-38). T. W. Lins (1950) studied the depositional environment of the Tonganoxie Sandstone in northeastern Kansas and concluded that the Tonganoxie was a nonmarine fluvial deposit. The only published data on clay mineralogy of any part of Douglas Group rocks is included in a detailed paleoecologic study of the nodulose zone at the top of the Haskell Limestone (Miller and Swineford, 1957). This paper, although local in scope, is the most detailed account of the origin of any of the Douglas Group rocks and, as such, represents a valuable contribution. Winchell (1957) concluded that the "Stalnaker" sandstone of subsurface terminology was correlative to

the Tonganoxie Sandstone of surface terminology and that absence of Lansing Group rocks in south-central Kansas resulted from erosion prior to deposition of the Tonganoxie Sandstone. Sanders (1959), like Lins and Winchell, regards the Tonganoxie Sandstone as a fluvatile deposit and presents useful maps showing net thicknesses of Douglas Group sandstone above and below the Haskell Limestone. Study of cross stratification and ripple marks in the Douglas Group sandstones in Kansas was conducted by Bower (1961) who states (p. 1):

. . . There is no indication of a southern source for the terrigenous materials . . . sources for terrigenous materials of the Douglas Group were located to the northwest, northeast, and east. . . . Most of the clastics in the Douglas Group were deposited in a fluvial environment in northwestern^{1/} Kansas and a tidal flat or shallow marine environment in southeastern Kansas.

Hicks (1962) studied cross-stratification and ripple marks in sandstones of the Vamoosa Formation of Oklahoma and visualized fluvatile deposition of sandstone in the southern part, tidal flat deposition in the central part, and shallow-water marine deposition in the northern part of his area of study (p. 20 and Fig. 7, p. 22).

Widespread, near continuity of a number of thin stratigraphic units, vertical sequences of strata in which rock types are repeated in the same relative order, and dating of the diastrophic movements that formed the Arbuckle Mountains and realization of their effect on northern Midcontinent Late Pennsylvanian sedimentation, are especially noteworthy among the concepts that underlie studies on Pennsylvanian stratigraphy. As pertains to the area and the rocks discussed in this report, the published and

^{1/} Typographical error; northeastern rather than northwestern was intended.

unpublished work of the following geologists has been foremost in development of one or both of the first two concepts mentioned: J. M. Jewett, R. C. Moore, and N. D. Newell of Kansas; F. C. Greene, Henry Hinds, and H. S. McQueen of Missouri; G. E. Condra and E. C. Reed of Nebraska; and M. C. Oakes and D. W. Ohern of Oklahoma. Their publications are referred to in appropriate parts of the report. Any considerable advancement of knowledge and progress in geologic study of any large problem, such as dating the Arbuckle orogenic movements, is the product of the combined labor of many investigators. Table 2 shows a chronologic résumé of dates proposed for important Pennsylvanian uplift of the Arbuckle Mountains region.

| AUTHOR | DATINGS PROPOSED | TIME-STRATIGRAPHIC PLACEMENT IN CURRENT CLASSIFICATION |
|---------------------------------------|--|---|
| TAFF (1904, p. 37-38) | Near beginning of Pennsylvanian or near close of Mississippian At a still later time, before close of Carboniferous | Springeran Post-Springeran Pennsylvanian |
| REEDS (1910, p. 42, 68) | Began at close of Caney epoch | Pennsylvanian |
| MOORE (1921, p. 40) | Post-Glenn formation (post-Holdenville), an epoch in mid-Pennsylvanian | Missourian |
| MC COY (1921, p. 566) | Just prior or during Kansas City-Stanton time of Kansas and pre-Seminole conglomerate | Missourian |
| MORGAN (1924, p. 19-21) | Near close of Atoka time Toward close of Savanna time Before close of Wewoka time Near close of Vamoosa time | Late Atokan Early Desmoinesian Late Desmoinesian Early Virgilian |
| DOTT (1927, p. 22) | After Wapanucka time Upper part of Marmaton time, possibly affected Hunton arch After middle or late Kansas City time | After mid-Morrowan Late Desmoinesian After mid-Missourian |
| POWERS (1928, p. 1053-1055) | Atoka time End of deposition of Savanna sandstone Seminole (mid-Pennsylvanian) time Still more profound folding and faulting recorded in conglomerates of Vamoosa formation | Atokan Early Desmoinesian Early Missourian Early Virgilian |
| TOMLINSON (1929, p. 21, 47) | Early Pennsylvanian shortly before beginning of Dornick Hills time Late Pennsylvanian about at end of Hoxbar epoch | After early Morrowan After mid-Missourian |
| MOORE (1929, p. 900-901) | After Dornick Hills and Wapanucka times After Hoxbar and Belle City times | After mid-Morrowan After mid-Missourian |
| VAN DER GRACHT (1931, p. 1010-1014) | Wichita phase of orogeny, latest Mississippian to early Pennsylvanian Arbuckle phase of orogeny, late Deese time to pre-Pontotoc time | Springeran-Morrowan Late Desmoinesian or early Missourian to early Virgilian |
| MOORE (1933, p. 612) | Post Hoxbar pre-Pontotoc time (Arbuckle orogeny) | After mid-Missourian to before late Virgilian |
| DOTT (1934, p. 584, 587-588, 596-597) | Pre-McAlester and post-Wapanucka with greatest impetus in Atoka time Some uplift during lower and middle Pennsylvanian time Late Pennsylvanian time | Late Morrowan-early Atokan Post-early Atokan-Desmoinesian After mid-Missourian, before late Virgilian |
| HAM (1954, p. 2042-2043) | Early Deese time Post-Hoxbar, post Deese, post-Francis time Late Collings Ranch time Post-Vanoss time | Early Desmoinesian After mid-Missourian Middle Virgilian Late Virgilian |

Table 2. -- Dates proposed for important Pennsylvanian uplift of the Arbuckle Mountains region.

In his excellent paper on overthrusting in the Arbuckle Mountains, Dott (1934) summarized previous work and stated (p. 576):

The foregoing review of previous literature presents the evolution of ideas on Arbuckle structure from that of a single uplift, formed at one period, and modified by normal faulting, to the present conception of two uplifts, formed at different periods, the younger finally overriding the older in a large overthrust, accompanied by extensive thrust faulting.

The author considers Dott's statement misleading in certain respects. Original conception of structural history of the Arbuckle Mountains by Taff (1904) attests explicitly to two periods of uplift. Taff (*ibid.*, p. 37) pointed out that:

Near the beginning of the Pennsylvanian or near the close of the Mississippian, the rocks of the Arbuckle region were folded . . . Faulting on a large scale also occurred. . .

and (p. 38):

At a still later time, before the close of the Carboniferous, the sediments were again folded and elevated into land. This folding affected the recently formed conglomerates as well as all the rocks previously deposited. Faulting occurred also after the deposition of the conglomerate. . .

The deformation of the rocks now exposed in the Arbuckle region commenced near the beginning of upper Carboniferous time and ended before its close.

Reeds (1910) wrote a report, which emphasized physiographic history, mineral resources, and mechanics of structural movements of the Arbuckle Mountains. This report does not stress dating of uplift involved in formation of the Arbuckles. The only mention of dating found was (*op. cit.*, p. 42):

At the close of the Caney epoch, the formations constituting the present Arbuckle Mountains remained no longer in a more or less horizontal position beneath the sea but began to assume their present complex folds.

and (p. 68):

. . . since the prominent uplift of Pennsylvanian time. . .
Two sets of folds have been developed which intersect each
other at almost right angles.

Reeds attempted to date broadly the Arbuckle Mountains uplift as of post-Caney Pennsylvanian age. It is difficult to conceive that either Taff or Reeds regarded the Arbuckle Mountains as a single unit of uplift, formed at one time, in early Pennsylvanian, as was attributed to them by Dott (1934, p. 570). In addition to Reeds, the only authors who mention only one period of uplift, i. e. Moore (1921), McCoy (1921), and Moore (1933), were concerned primarily or exclusively with what has been termed the Arbuckle orogeny (van der Gracht, 1931, p. 1012-1013), a part of the structural history of the Arbuckle Mountains. The Arbuckle orogeny constitutes the younger of two major periods of uplift, that of the Arbuckle anticline (Dott, 1934). The Moore (1929) article, which considers the Arbuckle Mountains in a broader sense rather than in a restricted sense^{1/} and cites two major periods of uplift rather than one, leaves little doubt of this. Most, if not all, of the earlier papers noted in Table 2 do not corroborate Dott's statement quoted above. Multiple usage of the term Arbuckle Mountains in earlier papers and over inclusive application of the term Franks conglomerate prior to Morgan's 1924 paper may have led to Dott's belief.

Dating of the Arbuckle orogeny part of the structural history of the Arbuckle Mountains is particularly pertinent to study of Douglas Group rocks. This orogeny has been correlated with the Missourian-Virgilian

^{1/} See Dott (1934, p. 576-577) for explanation of multiple usage of the term Arbuckle Mountains.

disconformity at the base of the Douglas for more than 30 years (Moore, 1932, p. 88). Major advances toward an understanding of the Arbuckle orogeny as it relates to Pennsylvanian rocks north of the mountains include:

1. Extensive tracing of stratigraphic units by numerous geologists, many of whose publications are mentioned elsewhere in the report; as mentioned above, some of this work was not published.
2. Realization by Moore (1921) and McCoy (1921) that strata called the Franks Conglomerate were much younger than the basal Pennsylvanian placement previously conceived.
3. Recognition by Morgan (1924) of the great stratigraphic range of rocks termed Franks Conglomerate.
4. Publication of geologic maps of Kansas by Haworth (1908) and Moore and Haynes (1917) and of Oklahoma by Miser and others (1926). These maps, based on the actual tracing of beds, showed the approximate equivalency of the Belle City Limestone (mapped northward from northern Pontotoc County, Oklahoma) and the Dewey Limestone (mapped southward from Kansas) and showed that the position of these units was within the Kansas City Group of northern classification rather than the lower part of the Wabaunsee Group as previously believed.
5. Publication of more detailed geologic maps of Kansas (Moore and others, 1937) and Oklahoma (Miser and others, 1954). These

show the map trace of the Lecompton Limestone as far south as the North Canadian River in Okfuskee County, Oklahoma.

6. The comprehensive study of the conglomerates of the Arbuckle Mountains region and recognition of the Collings Ranch Conglomerate as the first, thickest, and coarsest orogenic deposit following culmination of the Arbuckle orogeny (Ham, 1954).

Glossary of Terms

Multiple usage of geologic terms is a source of misinterpretation and ultimate lack of communication. The definitions and explanations given below are those judged to best describe the features observed or the larger features depicted on maps. Sources of the terms are indicated.

Abundant - fossils or other constituents numerous enough to be readily seen in a sample (modified from Hattin, 1957, p. 117).

Bank - a submerged shallow area that extends above the adjacent sea floor and differs from a reef only by being composed of soft material and by being broadly lenticular rather than ridge shaped in cross-sectional profile (modified from Harbaugh, 1959, p. 293).

Basin - a large or small depression, the lowest parts of which receive sediment (modified from Rice, 1955, p. 35).

Bedding dimensions - from McKee, 1957, p. 1706.

Blocky - descriptive term applicable to mudstone that weathers to sub-cubical rock fragments.

Bottom markings - general term applied to structures presumed to be trace fossils of burrowing or crawling invertebrates and for which the possible origin is not further specified; common on upper surfaces of beds or as natural casts on bottom surfaces of beds.

Color - from Rock-Color Chart, a National Research Council publication (Goddard and others, 1948).

Common - fossils or other constituents numerous but not immediately conspicuous in sample (modified from Hattin, 1957, p. 117).

Correlation - to correlate in a stratigraphic sense is to show correspondence in character and in stratigraphic position. Thus an age or time correlation of two units is the demonstration of their correspondence in age and stratigraphic position; an electric log correlation of points in two geographically separated stratigraphic columns is the demonstration of correspondence in electric log character and stratigraphic position; a correlation of two fossil beds is the demonstration of correspondence in their fossil content and stratigraphic position; and a lithologic correlation is a demonstration of correspondence in lithologic character and stratigraphic position (from International Subcommittee on Stratigraphic Terminology, Stratigraphic Classification and Terminology, 1960, p. 19).

Crystalline carbonate - rock in which the depositional texture is not recognizable (from Dunham, in Ham and others, 1962, p. 117).

Grains - particles 20 microns or larger in size (from Dunham, in Ham and others, 1962, p. 113).

Grainstone - carbonate rock that contains less than 1 percent mud and is grain-supported (from Dunham, in Ham and others, 1962, p. 117).

Grain-supported - texture in which grains are so abundant as to support one another (from Dunham, in Ham and others, 1962, p. 117).

Lime mudstone - carbonate rock containing less than 10 percent mud-supported grains (from Dunham, in Ham and others, 1962, p. 117).

Lithiclast - a sedimented, aggregated fragment, which has been reworked and redeposited as new sediment from Folk (1959, p. 4) term intra-clast, but is a descriptive term and does not necessarily imply the genesis visualized by Folk .

Lithofacies - either general or detailed lithologic aspect of a selected stratigraphic unit (modified from Krumbein and Sloss, 1953, p. 268; the writer regards fossils a part of the lithologic aspect).

Lithofacies map - map showing areal variation of lithofacies (from Krumbein and Sloss, 1953, p. 268).

Mud - particles smaller than 20 microns in size (from Dunham, in Ham and others, 1962, p. 113).

Mudstone - noncarbonate rock that is composed of clay-size particles and lacks fissility (from Dunbar and Rogers, 1957, p. 166).

Mud-supported - texture in which grains are not so abundant as to support one another (from Dunham, in Ham and others, 1962, p. 113).

Northern Midcontinent - the northern and western flanks of the Ozark Mountains, including parts of Missouri, Iowa, Nebraska, and Kansas (from Moore, 1933, p. 600).

- Oöolith (or oöid) - a rounded particle less than 2.0 mm in diameter which displays a series of concentric layers, radial rays, or both (from Kahle, 1962, p. 17).
- Osagite - limestone texture in which skeletal debris coated with an algal-foraminiferal intergrowth is abundant or profuse. Coated nuclei are commonly sand to rarely small pebble size and are invariably of a rounded lozenge or bean shape.
- Packstone - carbonate rock that contains 1 percent or more mud and is grain-supported (from Dunham, in Ham and others, 1962, p. 117).
- Pellet - spheroidal to ellipsoidal particles of microcrystalline calcite that are of oolith size but display no internal structure (from Kahle, 1962, p. 18).
- Profuse or prolific - fossils or other constituents so abundant as to form rock framework.
- Shape and rounding - visual estimation chart (from Williams, Turner, and Gilbert, 1954, p. 282).
- Shelf - zone in the ocean between low-tide limit and the depth (usually about 65 fathoms) where there is a marked descent toward the great depths (from American Geological Institute, Glossary of Geology, 1957, p. 263).
- Size - from Wentworth's particle size classification (see Krumbein and Sloss, 1953, p. 71).
- Skeletal - refers to fossils of organisms that secrete hard material around or within organic tissue (from Leighton and Pendexter, in Ham and others, 1962, p. 60).
- Spar (or sparry) - clear, transparent or translucent, crystalline particles 20 microns or larger and generally forming an interlocking mosaic (modified from Leighton and Pendexter, in Ham and others, 1962, p. 60).
- Sparse - fossils or other constituents so few in number as to be a negligible part of sample (modified from Hattin, 1957, p. 118).
- Terrigenous detritus (or terrigenous clastics) - clay, silt, and sand the ultimate source of which was continental.
- Wackestone - carbonate rock that contains more than 10 percent mud-supported grains (from Dunham, in Ham and others, 1962, p. 117).

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Carol Ann Roper and Lila M. Watkins typed the report. Beth Clark Thomason drafted Plates 2 to 9. Sally S. Liggett drafted 6 of the Figures.

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Work of others that is utilized is so indicated in appropriate parts of the report.

CLASSIFICATION

Introduction
(with reference to relevant literature)

Plate 1 is designed to be used while reading this section of the paper. Throughout the section on classification references are numbered in accordance with the numbered list (Pl. 1).

Stratigraphic classification must be changed as knowledge progresses. Often a lack of understanding, which results from failure to acquaint themselves with the rocks, causes people to complain about classification changes. Each geologist or group of geologists that proposes a revision is obligated to present a classification in harmony with the facts as known at the time of presentation. Of course differences of opinion exist, of course not all changes result in better classification, and of course any classification is arbitrary. All of the geologists cited on Plate 1 (and a number of those cited in the Selected References) are to be credited with contributing to classification of northern Midcontinent and Oklahoma Pennsylvanian rocks. Only those works particularly pertinent to this study are cited specially.

Hinds and Greene (45) published the first report containing an abundance of detailed and accurate information on Douglas Group rocks. The group term Missouri was adopted for "Upper Coal Measures" as used in a number of pre-1917 Kansas reports. This report is regional in scope and of outstanding quality.

Condra (13) contributed an outstanding report on the Pennsylvanian stratigraphy of southeastern Nebraska. Many new stratigraphic names were proposed and interstate correlations attempted. Douglas Group and older

Pennsylvanian rocks, best exposed in Nebraska along the lower Platte River Valley in Cass and Sarpy Counties, are widely separated from the main area of outcrop in Oklahoma, Kansas and Missouri. Disconnected outcrops here and there along major drainage in southeastern Nebraska, southwestern Iowa, and northwestern Missouri; divide areas more or less thickly mantled by glacial drift; the then poorly known structural relationships; and general lack of shallow subsurface control were reason enough for some erroneous correlations proposed by Condra. This is no discredit to Condra who is to be cited as one of the first to realize the surprising persistence and uniformity of thin stratigraphic units in this part of the world. Condra and associates (especially Reed) were quick to revise their reports (e. g. 17).

A number of United States Geological Survey reports (5, 12, 24, 25, 27, 28, 42, 43, 96, 100) contributed a vast amount to the detailed knowledge of Pennsylvanian stratigraphy of Osage County, Oklahoma. Structural mapping rather than classification was the prime objective of this work. Individual geologists or two- and three-man teams established nomenclature applicable to their respective areas. In many cases, classification used in one area was not coordinated with that of an adjacent area. Many stratigraphic names were proposed; continuous tracing across Osage County was not attempted. Beckwith (3) attempted to utilize previous work and develop a classification applicable to all of Osage County, Oklahoma. In so doing Beckwith realized the multiplicity, lenticularity and complexity of the named stratigraphic units; his map (3, map XXII, eastern part of county) and text descriptions emphasize this.

Beckwith's map depicts a number of dashed, dotted, and "hanging" line contacts. This report represents an outstanding contribution.

Moore (58) published the results of a monumental classificatory and nomenclatorial study of the Kansas Pennsylvanian section. The scope of this work is indicated by the fact that the synonymies, which accompany every stratigraphic name, alone represent a sizable contribution. Even though the purpose of the report was not to describe individual stratigraphic units in detail, a wealth of accurate stratigraphic data is included. A number of erroneous correlations were corrected. Also, a number of interstate correlations, which proved correct, were suggested, long before actual establishment.

Moore and others (68) proposed divisions of Missouri rocks of southern Kansas and northern Oklahoma into two groups, the Skiatook and the Ochelata, bounded by disconformities. This classification has since been applied essentially in its original sense. The only major change has been extension stratigraphically upward of the Missouri-Virgil boundary in northeast Oklahoma from base of the Bigheart sandstone to base of the Cheshewalla sandstone (Oakes, 76).

McQueen and Greene (52) published an excellent paper treating the geology of northwestern Missouri. The Pedee Group was accepted in accordance with Kansas classification, but pre-1931 usage of the term Douglas was retained in Missouri classification. The Haskell Limestone was considered a formation rather than a member as in Kansas. The Westphalia Limestone, Robbins Shale, and Ireland Sandstone members of Kansas classification were not recognized in Missouri.

In May, 1947, representatives of the State Geological Surveys of Iowa, Kansas, Missouri, and Nebraska met at Lawrence, Kansas, to discuss classification of Pennsylvanian rocks in the several states. The practice of interstate conferences has been perpetuated to the present and has acted as a singular force toward coordination of interstate nomenclature and elimination of stateline "faults". The results of the 1947 conference were published by Moore (60). Twelve leading geologists from the afore-mentioned states and Oklahoma reached essential agreement on all major and many minor features of Pennsylvanian classification. Greene and Searight (33) redefined the Douglas Group for Missouri in accordance with the 1947 conference definition.

No major classification changes have been proposed for rocks of the Pedee and Douglas Groups since 1951. Important contributions to the knowledge of these rocks and minor classification changes are shown on Plate 1 and referred to elsewhere in the text.

Oakes (72-78) has studied extensively the Pennsylvanian rocks of northeastern Oklahoma and has made many and valuable contributions to the detailed knowledge of these rocks. As pertains to the section considered in this report, one of Oakes' major objectives was to develop a relatively uniform mappable classification for Oklahoma. In so doing he proposed the following classification changes: restriction and redefinition of the Wann Formation (73); redefinition of the Missouri-Virgil boundary in Oklahoma (76); and two new formations, the Barnsdall and the Tallant (77)^{1/}.

^{1/}The author assumes that Oakes considered the Ochelata Group redefined in this paper although it is not mentioned. Apparently the same assumption was made by Ries (85) who considered the Tallant as the topmost formation in the Ochelata Group.

Oakes' Tallant Formation comprises strata formerly considered as the lower part of the Nelagoney Formation (see Pl. 1), a name apparently abandoned without mention by Oakes.

Basis for Time-Stratigraphic Classification

In 1899 Keyes (51) attempted to establish firmly the term Missourian Series, which included as a small part the rocks considered in this paper. Previous workers had applied the names Missouri terrane, Missouri Formation, Missouri Stage, Missourian Formation, and Missourian Series with imprecise delimitation. Boundaries of Keyes' Missourian were placed at the base of the Hertha limestone (basal part of limestone called Bethany by Keyes) below and the top of the Cottonwood limestone above (see 58, p. 68). Paleontologic character (51, p. 302), referred to by Keyes as biologic definition, was suggested as one of the bases of classification, but was not discussed in any detail whatsoever. Other criteria mentioned are those generally considered definitive of rock-stratigraphic units and of secondary importance relative to time-stratigraphic units. Whether he attempted to make clear cut distinction between time- and rock-stratigraphic units, is indefinite. Keyes states (*ibid.*, p. 299-302):

A similar consideration of the Missourian series, or the third of the four major numbers of the Carboniferous, is herewith given. . . In all of the six principal features of geographic distribution, topographic expression, lithologic nature, stratigraphic delimitation, biologic definition, and economic content, which go to characterize and contrast geological formations, the Missourian series is clearly set off from all associated strata.

The Missouri Group of Hinds and Greene (46) extended from the base of the Hertha Limestone to the top of the Pennsylvanian in northwestern Missouri. Although the upper boundary was not definitely stated in the

publication, it may be assumed that then current Kansas University Geological Survey policy was adopted (see p. 15, p. 186). The Kansas classification (39) placed the top of the Pennsylvanian at the base of the Wreford Limestone and the top of the Wabaunsee Stage at the base of the Cottonwood Limestone. It is probable that Hinds and Greene considered the latter as the top of the Missouri Group. Girty (46, p. 281-282) recognized a well-defined faunal difference between the Des Moines and Missouri Groups. An unconformity within the Pleasanton Formation (p. 77) in the north-central part of the outcrop area was observed. Another unconformity, within the Missouri Group at the base of the Lawrence shale (p. 171) in southern Platte and Clay Counties, was noted. Although prominent only locally, Hinds and Greene thought these unconformities could be regional in aspect and state (p. 214):

. . . there is evidence that the sea may have withdrawn from all or part of Missouri in both Pleasanton and Lawrence time while long and rather deep channels were formed by sub-aerial erosion.

Girty did not find either break in sedimentation to have any noteworthy expression faunally (p. 274, p. 292-295).

Moore and Haynes (67) were the first to adopt the Des Moines and Missouri Groups in Kansas classification. The base of the Hertha Limestone was considered the common boundary and the top of the Missouri Group placed at the base of the Cottonwood Limestone. Marked faunal differences and at least locally an unconformity (p. 94) served as the principal basis for recognition of these groups.

Prior to 1932 numerous authors mentioned faunal break, lithologic change, and erosional unconformity as bases for recognition of their

combined time- and rock-stratigraphic classifications. Little further discussion was devoted to principles and objectives underlying time-stratigraphic categories subordinate to system. The first serious consideration of the principles and objectives of time-stratigraphic classification as it pertains to the strata and area discussed herein was published by Moore (55), who (p. 83-84) stated:

. . . existence of widespread unconformities may be very important in differentiating major stratigraphic units. Deformation of the earth crust, involving folding or warping of previously deposited strata, is commonly accompanied by the recession of seas and the occurrence of erosion on lands. . . . Either because of accelerated biologic changes at times of diastrophism or because of considerable lapse of time during which no sedimentary formations are laid down in a given region, unconformities of the type described commonly coincide with major changes in the paleontologic record. This combined diastrophic and paleontologic evidence furnish punctuation points in the geologic record that provide the basis for definition of geologic systems as now recognized, and within the system, similar punctuation points of lesser magnitude define series.

The classification forwarded in this paper (55) was refined and published in 1936 (58). At this time, the Pennsylvanian rocks in Kansas were subdivided into three series, in ascending order, the Des Moines, the Missouri, and the Virgil, each bounded above and below by disconformity. The Missouri-Virgil disconformity relative to rock-stratigraphic units was the base of the Douglas Group, Stranger Formation, and Tonganoxie Sandstone Member.

McQueen and Greene (52) redefined the boundaries of the Missouri series in Missouri, classing its base in accordance with State Geological Survey of Kansas policy and top coincident with the top of the Virgil series of Kansas classification. A major unconformity and faunal break were recognized at the base of the Missouri series.

As a result of the interstate conference held in Lawrence in May, 1947, northern Midcontinent states and Oklahoma generally accepted the Pennsylvanian classification as proposed by Moore (58). That part of interstate classification relevant to this discussion is shown in Figure 2A. Placement of time-stratigraphic and coincident rock-stratigraphic boundaries are indicated. No formal commitment on matters of rank assignable to, capitalization of, or use of adjectival names for the accepted time-stratigraphic divisions was made by the conference.

Moore and Thompson (69) analyzed the physical characters and paleontological features of North American Pennsylvanian rocks and concluded that stratigraphic cleavage of two positions within the system had paramount significance. The Morrowan-Atokan boundary and the Desmoinesian-Missourian boundary were judged to be the best marked (both paleontologically and on the basis of physical evidence) lines of stratigraphic partition within the Pennsylvanian System. Accordingly the northern Midcontinent time-stratigraphic classification shown as Figure 2B was proposed.

This classification was used in essentially this form by Moore (62) and Jewett (48). The only change involved substitution of Lower, Middle, and Upper Pennsylvanian as Series terms for Ardian, Oklan, and Kawvian, respectively.

Rank of time-stratigraphic unit categories subordinate to System is a matter of value judgment and must change with the status of knowledge. The purpose of change is to work continually for a classification more

| SYSTEM | SERIES | Group | |
|---------------|------------|-----------------------|----------|
| | | Northern Midcontinent | Oklahoma |
| PENNSYLVANIAN | VIRGILIAN | | |
| | | Douglas | |
| | MISSOURIAN | Pedee | Ochelata |
| | | | |

A

| SYS. | SERIES | STAGE | Rock units adjacent to time-stratigraphic unit boundaries |
|---------------|---------|---------------------|---|
| PENNSYLVANIAN | KAWVIAN | VIRGILIAN | Wabaunsee gr. |
| | | | Douglas gr. |
| | | MISSOURIAN | Pedee gr. |
| | | | Pleasanton gr. |
| | OKLAN | DESMOINESIAN | Marmaton gr. |
| | | | Cherokee gr. |
| | | ATOKAN (or DERRYAN) | Atoka fm. (subsurface only) |
| | ARDIAN | MORROWAN | Kearny fm. (subsurface only) |
| | | SPRINGERAN | |
| | | | |

B

FIGURE 2.-- Time-stratigraphic classifications. A, Report of interstate stratigraphic conference held at Lawrence, Kansas in May, 1947 (see Moore, 60). B, Proposal by Moore and Thompson (69).

meaningful in terms of historical geology. Time-stratigraphic nomenclature of Upper Pennsylvanian rocks as proposed by Moore (62) and followed by Jewett (48) has been the official policy of the State Geological Survey of Kansas since 1959. It is followed in this report.

Basis for Rock-Stratigraphic Classification

Lithology, continuity, and topographic expression have been considered collectively as guide to selection of group and formation boundaries. Moore (55, p. 86) stated:

. . . the only practical basis for differentiation of beds such as those of the Kansas Pennsylvanian, that are to be named and mapped, is on a lithologic basis.

Application of this practice by many geologists has shown that bases and tops of escarpment-forming limestones are optimum for classificatory purposes. Although tops of limestone formations are neither as readily nor as precisely mappable as their bases, they are necessarily utilized to define lithic units. This mapping procedure has been outlined clearly by Moore (58, p. 20-21) and, as applied to the rocks discussed herein, is illustrated by the accompanying diagram (Fig. 3). Key or marker units used include the South Bend, Haskell, and Toronto Limestones and their correlatives.

It has also been a common practice in the Midcontinent region to attempt mapping bases of sandstones or sandstone-shale complexes on a regional basis.

Sandstone within the Stranger and Lawrence Formations comprises a large number of lenses and tongues of larger lenses, many of which overlap geographically or merge stratigraphically or both. Two formal stratigraphic

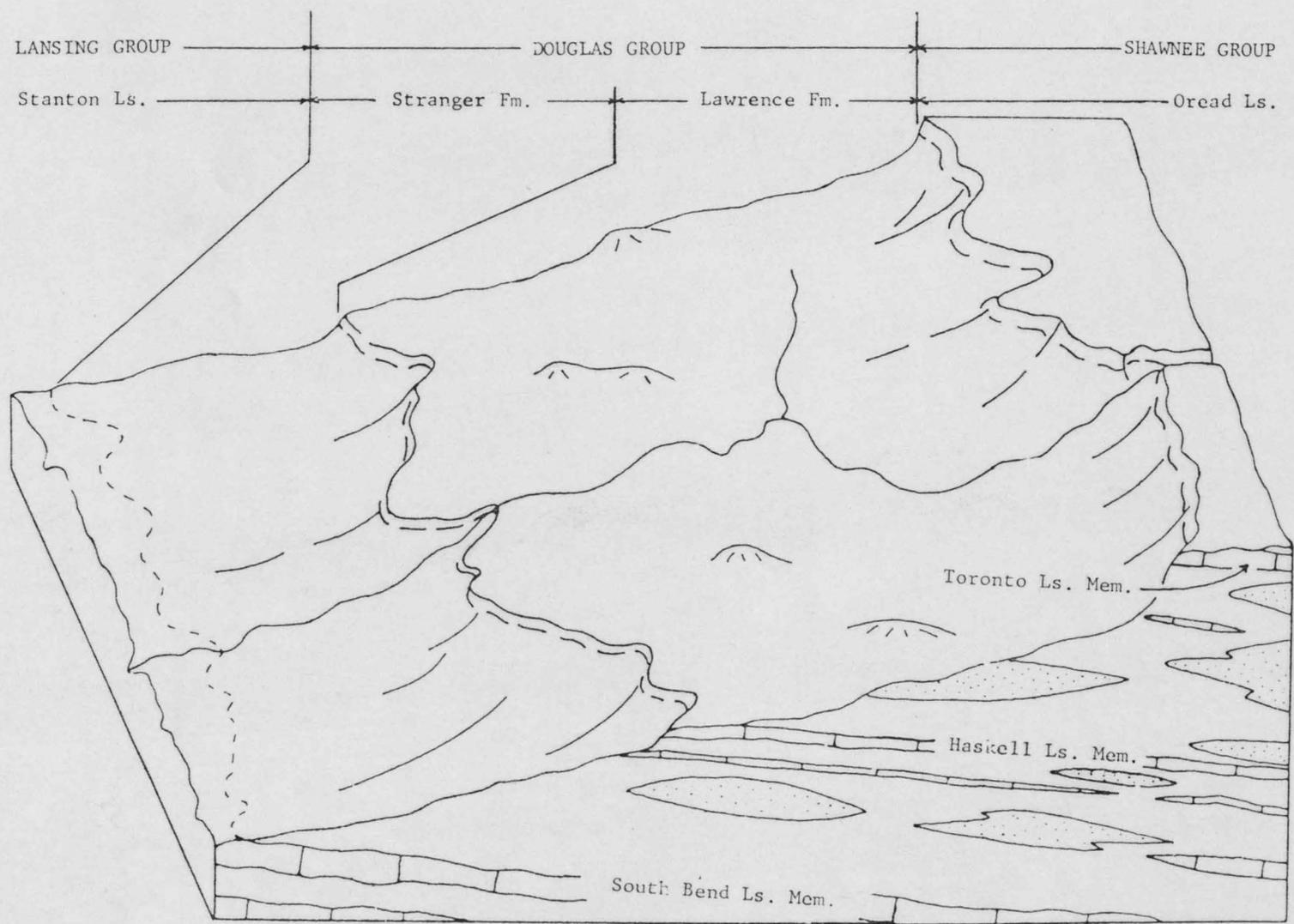


FIGURE 3.-- Diagram showing marker units utilized in classification and mapping of Douglas and adjacent rocks.

names, Tonganoxie and Ireland, have been proposed for sandstone-shale complexes in the Douglas Group part of the Kansas section. At least 16 formal names (see Pl. 1), 13 of which are used currently, have been proposed for sandstones within that part of the Osage County, Oklahoma section approximately correlative^{1/} to the Douglas Group.

I do not believe that any sandstone-shale interface within the Douglas Group of the northern Midcontinent can be traced accurately for a linear distance in excess of 30 miles. No lithologic interface whatsoever in this part of the section can be traced accurately and continuously across even Osage County in Oklahoma. In attempting to map regionally the types of sandstones or sandstone-shale complexes developed in this part of the section, the mapper inevitably records a disconformable map contact, which is the result of mapping technique rather than stratigraphic disconformity. Others, working both in local areas and on a more or less regional basis, have come to similar conclusions.

Beckwith (3, p. 226-228) grouped the massive sandstones and intervening shales that form collectively all the section between the shale next below the Middle Oread (Leavenworth of northern Midcontinent classification) and the shale next above the Labadie^{2/} Limestone Members. The five named sandstones in this interval, i. e. Bowhan, Jonesburg, Fourmile, Cochahee, and Wynona were considered as beds by Beckwith and grouped as

^{1/} This correlation is as precise as possible. Douglas Group top has been recognized in only one Oklahoma exposure. Base of the Leavenworth Limestone Member (Oread Formation, Shawnee Group) is the next younger stratigraphic datum traceable across the Kansas-Oklahoma line.

^{2/} Correlative with the Haskell Limestone Member (Lawrence Formation, Douglas Group) of northern Midcontinent classification.

the Wynona sandstone member. Beckwith states (p. 226):

The group as a whole extends from Arkansas River to the Kansas line, but it cannot be traced continuously except by adjacent distinctive beds. The sandstone beds have few distinguishing characteristics, and individual beds cannot be traced more than a few miles. They thin very rapidly, and as one lens pinches out, another usually comes in a short distance below or above.

Tracing of the Weston-Stranger boundary (of former classification) across Montgomery and Chautauqua Counties, Kansas was accomplished by selecting a new datum for mapping with the loss of an old one (N. D. Newell, written communication with H. G. O'Connor, Nov., 1960).

In his discussion of the Okesa sandstone member of the Barnsdall Formation Oakes (78, p. 90) notes that neither top nor base of this member is a stratigraphic horizon, except locally. Study of Figure 11 (78, p. 90) shows that to map the "base" of the Okesa, Oakes was forced to select several mapping contacts. The "base" of the Okesa as shown on the areal geologic map of Tulsa County is a solid continuous contact extending across adjacent parts of Osage, Pawnee, and Creek Counties.

The name Birch Creek has been applied to a number of lenticular limestones in Osage and Washington Counties, Oklahoma. Most geologists who have worked in areas where this part of the section crops out have realized the multiple application of the name Birch Creek. Quotations from a single reference are cited here to summarize current usage of the term Birch Creek. Tanner (93, p. 30) stated:

All of the lenses are not in precisely the same stratigraphic position. . . . In general the Birch Creek occurs at more than one horizon and represents more than one environment.

Nevertheless the "base" of the Birch Creek is shown on Tanner's geologic

map (93, in pocket) as a solid line contact continuous^{1/} entirely across a part of Osage County, Oklahoma. The map contact distance in this case is approximately 50 miles.

Greig (34, p. 22-30), in an excellent report on Pawnee County, describes clearly the practice utilized to extend so-called bases of some of the named sandstones of Osage County, Oklahoma into adjacent counties:

. . . the lenticular nature of upper Missouri sandstones makes it doubtful that the 'Revard' of one locality is the exact equivalent of the 'Revard' of an adjacent locality. . . . The base of the first mappable sandstone above the Revard was arbitrarily chosen as the top of the Tallant formation. Since it is not certain which of the lower Virgil sandstones is thus developed, it is uncertain that the contact shown on Plate 1 is the true base of the Virgil. In any case, the questionable stratigraphic interval is relatively short, and the contact on Plate 1 should be a close approximation of the actual contact. . . . The Cheshewalla sandstone of this report corresponds to Carl's Kiheki sandstone. According to Carl's correlation the Missouri-Virgil boundary in Pawnee County would be at the base of the Revard sandstone of Plate 1, or approximately 70 feet lower stratigraphically than shown in Figure 3 . . . of the several members of the Vamoosa formation shown in Table 2 only the Kanwaka shale and Wynona sandstone can be positively identified . . . In Pawnee County the Labadie limestone is absent. The first sandstone above the Revard is probably the Cheshewalla . . . In mapping the Cheshewalla as the base of the Virgil series an attempt was made to follow what appears on the aerial photographs to be a single escarpment, but it is probable that the contact shown on Plate 1 'jumps up and down in section' somewhat with the lateral variation of sandstone development. A vertical error of more than 50 feet is unlikely between any two points on the contact, however, because the total thickness of the section between the Revard and the Wynona sandstones is only about 150 feet.

The Carl referred to by Greig mapped an adjacent area in Osage County (Pl. 1 reference 9). Mapping a supposed contact some distance in a series of sandstone lenses is such that the base of the Cheshewalla on Carl's map could easily vary 50 feet stratigraphically relative to the base of type Cheshewalla (100, p. 61). If this hypothetical variation happened to be

^{1/}Except where overlapped by alluvium along major drainage and in one small area where the member is thought to be faulted out.

upward stratigraphically from north to south in Carl's area, then there could be points on Greig's Cheshewalla "base" contact as much as 170 feet higher stratigraphically than points on Carl's Cheshewalla "base" contact (probable maximum of 120 feet indicated by Greig for his map added to highly probable maximum of 50 feet for Carl's map). Although both authors indicate existence of an unconformity at the base of the Virgilian (base of Cheshewalla sandstone), Carl within his text and Greig on his map, both also note lack of evidence for this disconformity. Greig (34, p. 23) stated that the Missouri-Virgil unconformity is not evident from lithology or other outcrop features in Pawnee County and (p. 29) that the Cheshewalla shows no evidence of disconformity nor any increase in grain size downward. Carl (9, p. 48) stated that no physical evidence of an unconformity was observed.

The practice of extending map contacts by selection of a new mapping datum stratigraphically close above or below the loss of an old one has become habit as applied to sandstone-shale parts of the Midcontinent Upper Pennsylvanian section. This mapping technique has led to much confusion. Moore (1929, p. 886) stated:

It should be noticed, however, that overlap, especially in a series of sandy and shaly beds where recognition of such overlap is difficult, may lead to very erroneous conclusions regarding correlation.

Error in correlation involved in the first step up or down is minor but, in terms of Douglas Group strata considered regionally, can and has been cumulative and sizable, especially in southernmost Kansas and Oklahoma. Application of this method does not in reality extend the trace of a stratigraphic boundary, does not establish a regional correlation and does not justify portrayal of the results as solid continuous contacts

on areal geologic maps. Designation of sandstone-shale interfaces in Douglas Groups rocks of the northern Midcontinent and Osage County, Oklahoma as group or formation boundaries should be avoided. Consideration of lenticular sandstones as informally named beds or designation of loosely defined sandstone-shale complexes as formally named members is desirable for economic purposes.

Classification Recommended for Northern Midcontinent

A principal objective of stratigraphic classification is the grouping of strata of unlike lithology to serve directly as a basis for areal mapping and indirectly for economic development. Any standardization of names for as large an area as possible has the obvious advantage of precision in thought and expression. If map-unit boundary correlations are correct and the boundaries utilitarian, regional geologic history is more easily comprehensible.

Classification discussed below pertains to rocks formerly included in the Pedee and the Douglas Groups, which collectively are bounded by Lansing Group top below and Shawnee Group base above. Classification is not better than correlations upon which it is based. Detailed regional correlations are discussed in appropriate parts of the section on Stratigraphy. Proposal of a classification judged to be applicable throughout the northern Midcontinent was submitted to the Stratigraphic Names Committee of the State Geological Survey of Kansas. A part of the minutes of the July 2, 1962, meeting is quoted as follows:

The Stratigraphic Names Committee met Monday, July 2, 1962 with the following present: H. G. O'Connor, chairman, J. M. Jewett, R. C. Moore, F. C. Foley, and S. M. Ball. D. F. Merriam was not present but had agreed to vote with Moore on the Ball proposal.

Chairman O'Connor called the meeting to order and asked Ball to discuss proposed changes in Pedee-Douglas nomenclature and to answer any questions. The proposals are as follows:

- (1) It is proposed that the term Douglas Group be amended or redefined to include the Iatan Limestone and the Weston Shale in addition to stratigraphic units now included within the group.
- (2) It is proposed that the Douglas Group comprise two formations, Stranger Formation below and Lawrence Formation above.
- (3) It is proposed that the base of the Haskell Limestone Member be regarded as the base of the Lawrence Formation.
- (4) It is proposed that the Stranger Formation include the Weston Shale, Iatan Limestone, Tonganoxie Sandstone, Westphalia Limestone, and Vinland Shale Members; and that the Lawrence Formation include the Haskell Limestone, Robbins Shale, Ireland Sandstone, Amazonia Limestone, and Wathena Shale (new name) Members.
- (5) It is proposed that, if the redefinition of the Douglas Group is adopted, the Missourian-Virgilian boundary be placed at the base of the newly defined Douglas Group of rocks.

Following a discussion period, Jewett moved that Ball's proposals be adopted as a unit and as proposed. The motion was seconded by Moore and carried by unanimous affirmative vote.

Figure 4 shows the revised classification of the Douglas Group, and for comparison, its relation to former usage.

The bounding surfaces of the Douglas Group, the top of the South Bend Limestone below and the base of the Toronto (Weeping Water) Limestone above, are two of the more easily recognized and nearly continuous lines of stratigraphic partition in the northern Midcontinent. Both boundaries comply with all requirements of group and formation boundaries. Excepting local absence in southern Platte and Clay Counties Missouri and in Wyandotte

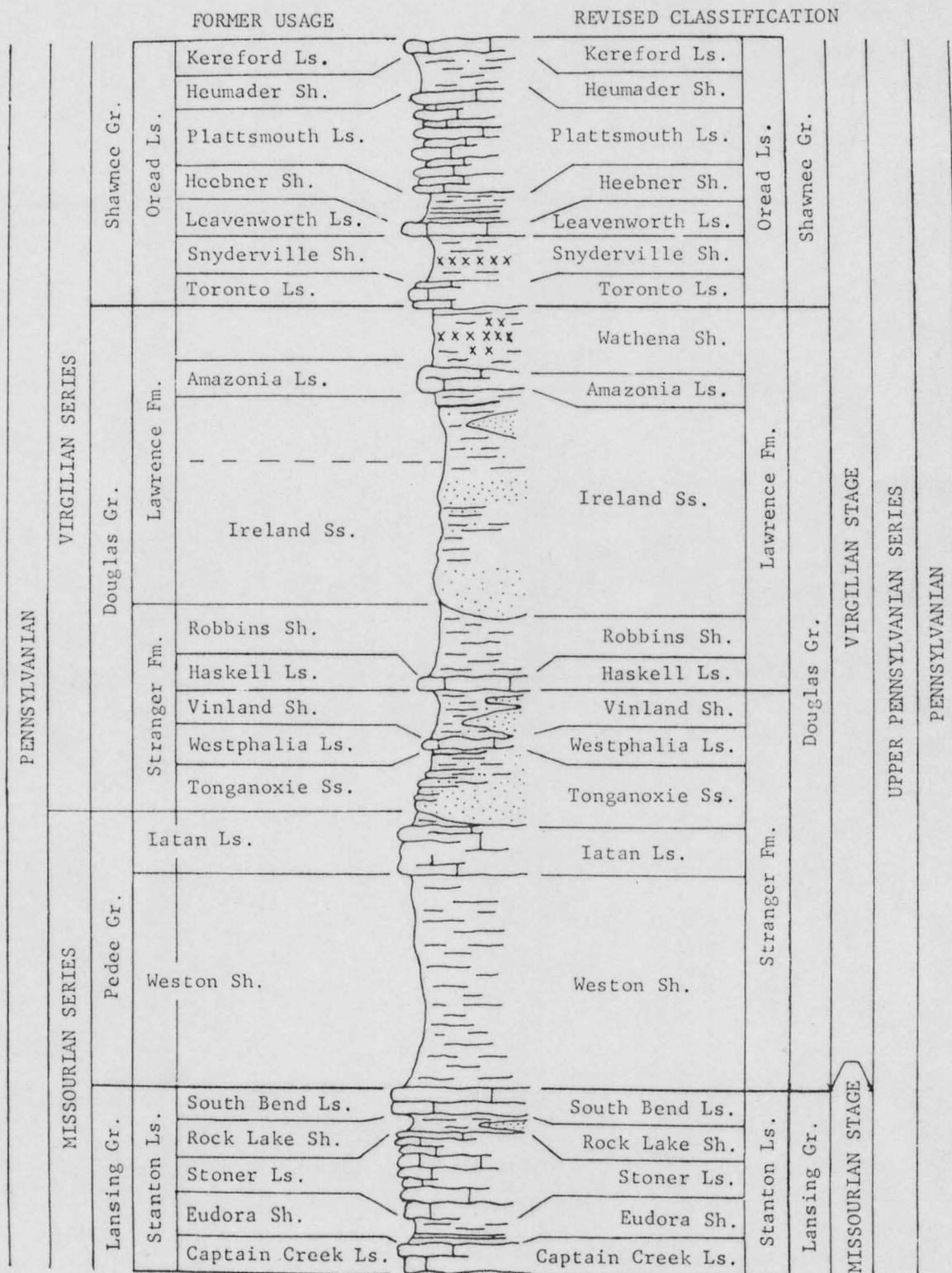


FIGURE 4 .-- Classification of Douglas Group rocks. Previous usage is shown on the left, adopted nomenclature on the right.

and Leavenworth Counties, Kansas, the top of the South Bend Limestone is traceable precisely and nearly continuously from southern Buchanan County, Missouri (T. 56 N., R. 34 W.) to southern Montgomery County, Kansas (T. 34 S., R. 14 E.). This stratigraphic horizon is readily identifiable throughout most of the area of shallow subsurface considered in this study (Fig. 1). The base of the Toronto Limestone, except where absent locally, can be recognized readily from southern Gentry County, Missouri (T. 62 N., R. 32 W.) to southern Elk County, Kansas (T. 31 S., R. 12 E.). The Haskell Limestone Member extends as more or less connected outcrop from southern Buchanan County, Missouri (T. 56 N., R. 34 W.) to east-central Chautauqua County, Kansas (T. 33 S., R. 13 E.). Excepting local absence in Leavenworth, Douglas, and Franklin Counties, Kansas, the Haskell Limestone is the best stratigraphic marker within the Douglas Group outcrop area and its utility relative to shallow subsurface study is indicated on Plates 2 to 9. It is clearly the best stratigraphic horizon for mapping purposes within Douglas Group rocks. It is not inferred that these three members retain with great fidelity the facies of their type sections throughout the areal extent indicated. Their recognition and mappability is based on exceptional continuity and position in sequence and only secondarily upon lithologic characters.

A standard practice of name application has been used throughout the paper. A single binomial or trinomial designation is used throughout areas in which named units are known to be essentially continuous^{1/} regardless of lateral facies variation. Stratigraphic names are not extended

^{1/} Excepting distances less than 2 miles where discontinuity results from surficial alluvial, colluvial, or drift cover.

across areas between disconnected outcrops which cannot be correlated definitely or are radically different lithologically. In areas where a particular stratigraphic unit is not identifiable for any of a variety of reasons, adjacent unit names are compounded by hyphenation^{1/}. Where a hyphen is used, the name preceeding it is that of the older stratigraphic unit. Use of hyphenation in a regional stratigraphic study precludes introduction of innumerable additional names and identifies precisely the stratigraphic span to which the compound name is applied. Other aspects of name application conform to my interpretation of the Code of Stratigraphic Nomenclature issued by the American Commission on Stratigraphic Nomenclature in 1961.

Disconformities within and paleontologic character of the Douglas Group were given particular attention as regards time-stratigraphic classification of these rocks.

Numerous definite or apparent disconformities are recognized within Douglas and adjacent rocks. Disconformities that can be shown^{2/} to truncate or to have truncated^{3/} older strata are referred to as definite; those as or more logically explained by facies changes are referred to as apparent. The accompanying illustration (Fig. 5) indicates the stratigraphic position and known geographic extent of these disconformities.

^{1/}This practice is outlined clearly by Moore (58, p. 40).

^{2/}Cases in which irregular contact can be walked across truncated edges of older strata; with or without development of associated conglomerate.

^{3/}Cases in which perspective is limited such that truncation cannot be observed but basal conglomerate or other evidence leaves no reasonable doubt that truncation exists.

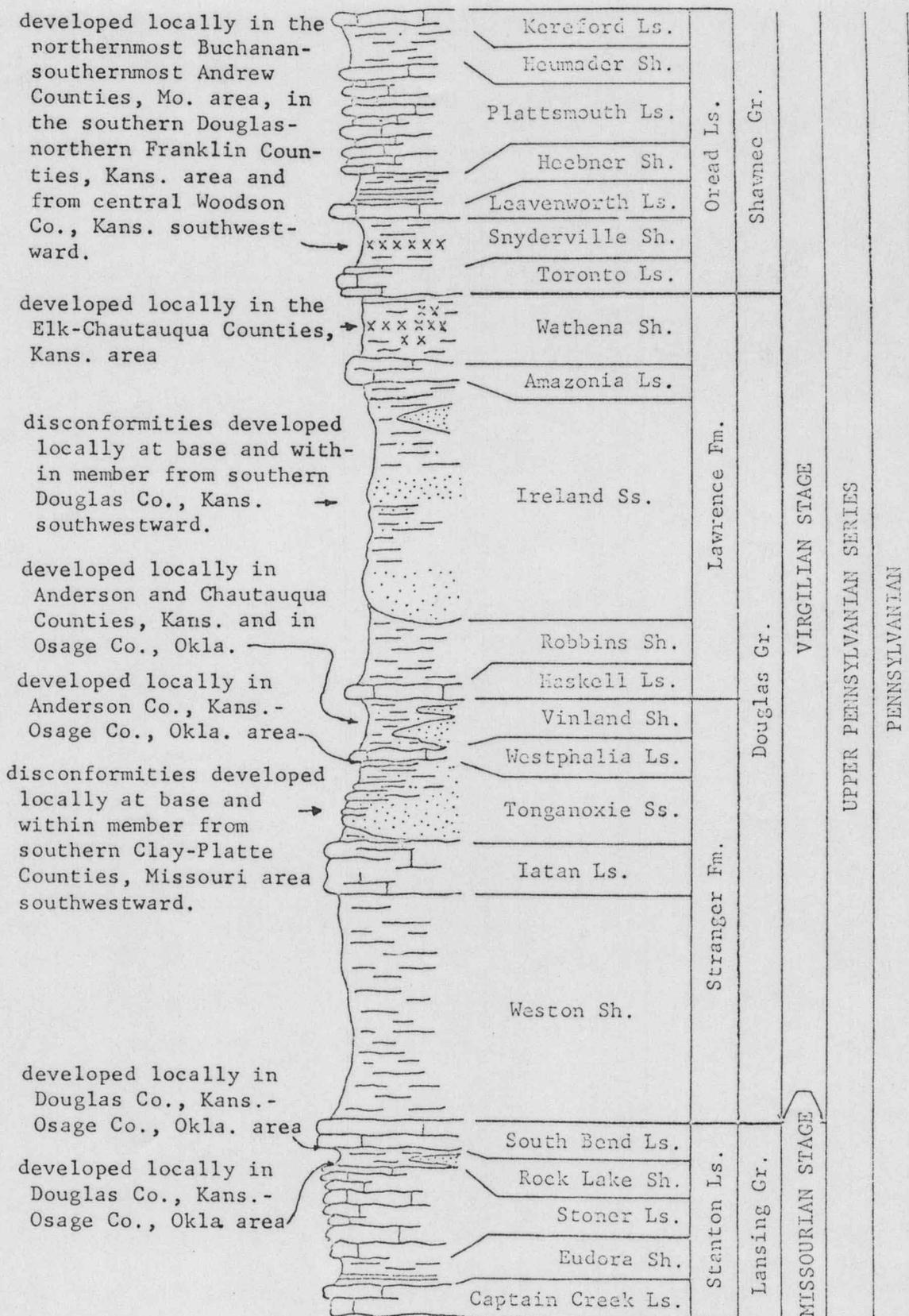


FIGURE 5.-- Distribution of disconformities within Douglas and adjacent rocks. Arrows indicate stratigraphic position of disconformities. Erosion surfaces within the Wathena Sh. Mbr. of the Lawrence Fm. and within the Snyderville Sh. Mbr. of the Oread Fm. are commonly developed at the bases of sandstone or conglomerate lenses.

None of these disconformities is regionally developed and no single disconformity is necessarily of more significance than any other one. Selection of one of these local disconformities as the Missourian-Virgilian boundary was not attempted.

Little mention has ever been made of a faunal or floral break within Douglas Group strata. Girty (in 46, p. 289-295) published a study of the fauna of the Douglas Group, which included the Oread Limestone in addition to the Douglas Group as defined herein. Girty stressed the faunal difference of the Oread relative to the other members of the group and stated (p. 290):

The most important fact in this connection is that a new fauna comes in with the Oread Limestone, or perhaps it would be better to say that a facies different from that of the three other members appears there.

Girty's lists indicate that 27 species were found among Douglas rocks only in the Oread, but 22 of these were recorded in Lansing or Kansas City rocks and many of the same species were found in rocks younger than the Oread. About 75 percent of the 73 species found in Douglas rocks confined to members older than the Oread ranged across the Missourian-Virgilian boundary of previous classification.

Moore (58) made a pertinent observation relative to a published suggestion of a major (long time interval) hiatus within Douglas Group rocks. He stated (p. 156):

The evolutionary change in invertebrates between the Stanton and Oread Formations is not pronounced and there is scarcely any faunal break whatsoever in this part of the stratigraphic column. Apparently the time involved in the pre-Stranger hiatus plus that of the pre-Lawrence hiatus is negligible compared with the general rate of evolution in the Pennsylvanian faunas.

Knowledge of Upper Pennsylvanian fusulinids had, in 1949, progressed to the point that the following statement seemed warranted (69, p. 299):

The most pronounced evolutionary break among the Kawvian Triticites of Kansas is at the unconformity between the Missourian and Virgilian Stages. This paleontological break can be recognized in most parts of America where this part of the Kawvian Series contains fusulinid-bearing marine deposits.

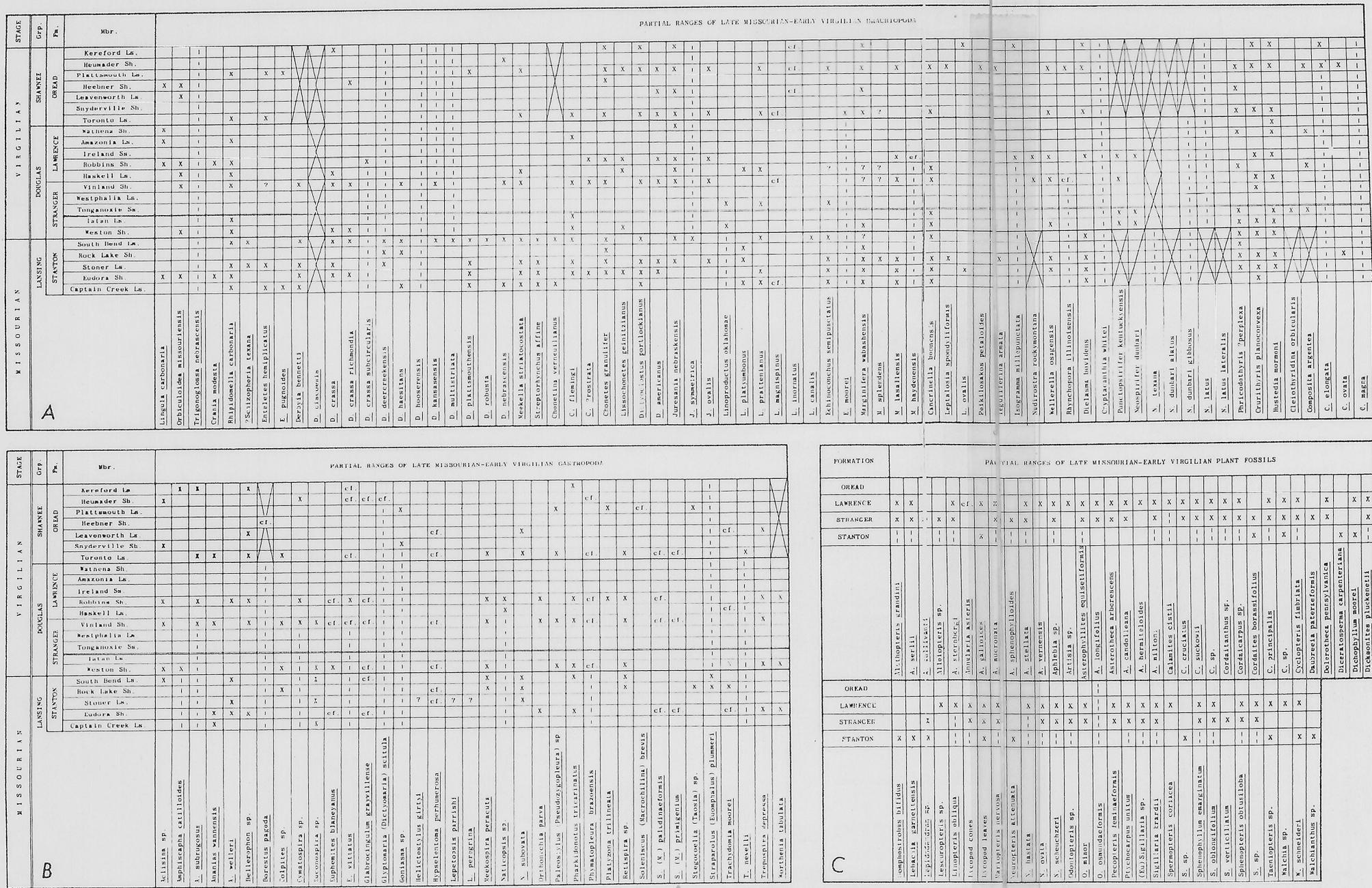
Added knowledge obliterated this suggested faunal break. In a comprehensive 1957 paper on Missourian fusulinids, Thompson stated (p. 290):

The subgenus Kansanella (Kansonella) is also represented by exceedingly abundant undescribed specimens in lower Virgilian rocks up to the Leocompton limestone. There does not seem to be any pronounced and distinct change within this genus across the Missourian and Virgilian boundary . . . Species of Triticites in upper Missourian rocks gradually attain thicker walls and relatively thicker and larger shells and resemble closely lower Virgilian species of the genus.

The stratigraphic distribution of brachiopods, gastropods, and land plants within Douglas and adjacent rocks is shown as Figure 6.

At the present time, neither regional hiatus nor paleontologic break within the Douglas Group, can be recognized, if at all existent.

Time-stratigraphic classification serves the purpose of providing a systematic indication of the relative position and age of its subdivisions as regards geologic history. Ideally boundaries of time-stratigraphic units represent the same horizon in time throughout their extent. Since time lines cannot be identified regionally, bounding surfaces of time-stratigraphic units are generally placed coincident to boundaries of some other type of stratigraphic unit. A regional hiatus or paleontologic break is a logical choice of a time-stratigraphic unit boundary. If neither widespread disconformity nor paleontologic break can be recognized, but retention of a time-stratigraphic unit is judged



desirable, its boundaries may be placed arbitrarily to correspond with some objective reference. Within certain limits^{1/} Douglas Group rocks can be correlated with the Arbuckle Orogeny and therefore may be considered a significant bounding unit in time-stratigraphic classification. The boundary between the Missourian and Virgilian Stages should be placed arbitrarily at the base of the newly defined Douglas Group.

Areal limits of application of the revised classification include the outcrop area of these rocks throughout the northern Midcontinent. Practical utility of the classification in Missouri, Nebraska, and Iowa involves only the use of hyphenation where minor named units cannot be identified; one hyphenation for Missouri, two for Nebraska, and three for Iowa (see Pl. 1). The minimum extent of subsurface utilization is indicated (Fig. 1).

^{1/}Limits specified in discussion of Historical Geology.

STRATIGRAPHY

Missourian Stage

Lansing Group

Study of any stratigraphic unit properly involves consideration of adjacent units. For this reason, attempt was made to gain a regional perspective of rocks of the Lansing Group, which underlies the Douglas Group. The Lansing Group comprises three formations of which the lower and upper, Plattsburg and Stanton respectively, are predominantly limestone whereas the middle formation, the Vilas Shale, is predominantly shale. A thickness map of Lansing Group rocks was not prepared for the purpose of this study but enough records are available to make the following discussion of general thickness variation meaningful. Within the area designated the limestone-shale facies (Fig. 7), the Lansing Group ranges from approximately 50 feet to approximately 100 feet thick and is thinnest to the north and northwest and thickest to the south and southeast. Condra and Reed (1959, p. 50-51) report about 51 feet of Lansing rocks exposed in Cass and Sarpy Counties, Nebraska and (ibid.) about 61 to 65 feet for Lansing thickness in the subsurface of southeasternmost Nebraska. Howe and Koenig (1961, p. 104-106) record an approximate 53- to 80-foot thickness range and 60-foot average thickness for the Lansing Group in northwestern Missouri. In the Kansas part of the area of limestone-shale facies (Fig. 7), Lansing rocks range from approximately 40 to approximately 115 feet in thickness. Lower parts of this thickness range generally characterize the north and northwest parts of this area

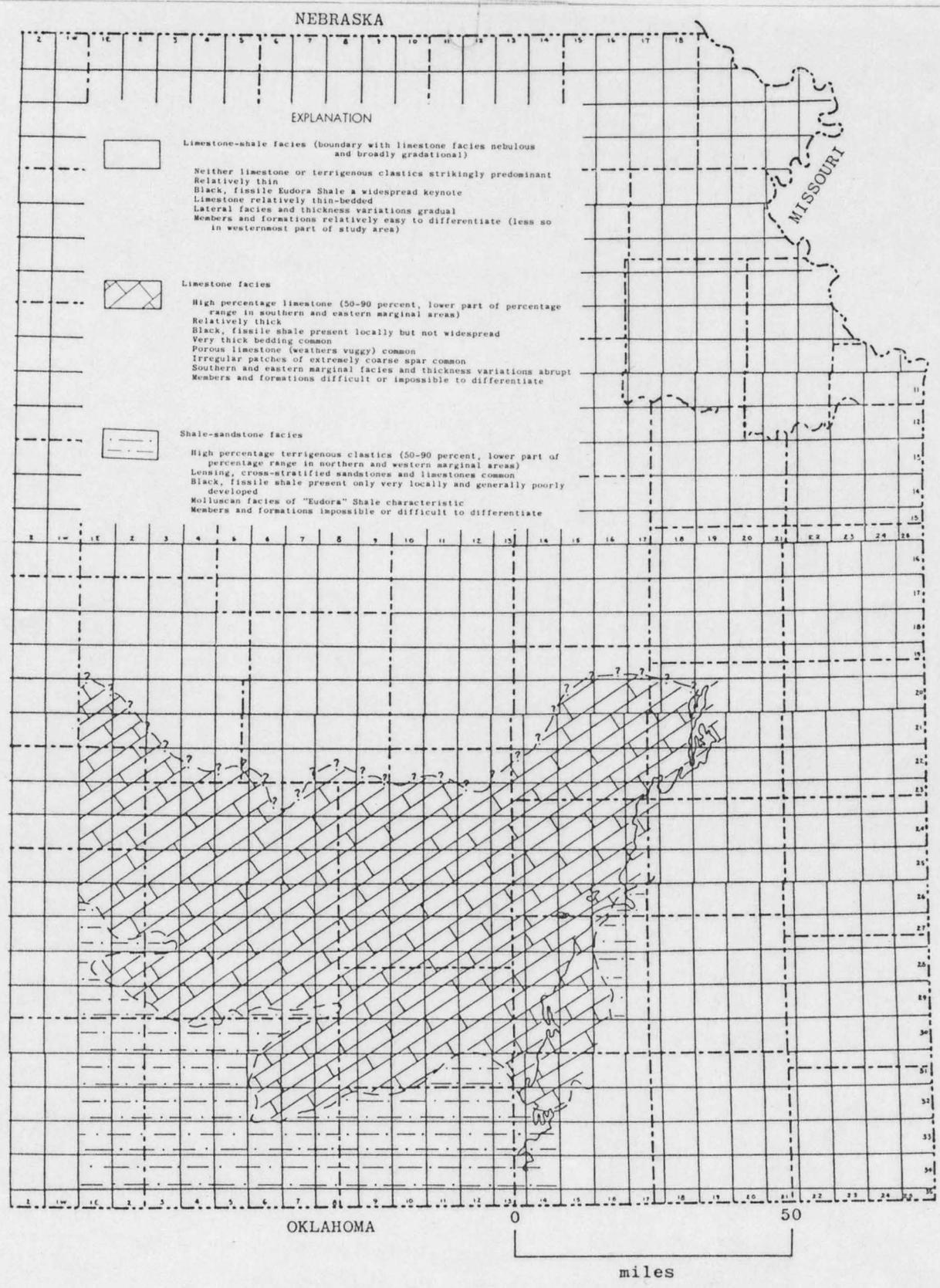


FIG. 7 --Lansing Group lithofacies. Limestone-shale facies extends into Missouri, Nebraska, and Iowa; shale-sandstone facies extends into Osage and Washington Counties, Oklahoma. Approximate outcrop trace of Lansing Group top generalized from new State Geologic Map of Kansas (in press) is shown from northern Anderson County, Kansas to southernmost Kansas where it becomes discontinuous.

whereas the higher thicknesses occur in the south and southeast parts of this area (see Merriam, 1959, fig. 3A, p. 135^{1/}).

The Lansing Group ranges from approximately 100 feet to at least as much as 175 feet in thickness within the area designated as limestone facies (Fig. 7). I did not attempt to identify the base of the Lansing Group throughout this area and would not until preparation of a regional distribution map of the Wyandotte Limestone (the uppermost limestone formation of the underlying Kansas Group) in the east ranges of Kansas was attempted. Such a map of the Wyandotte would negate or verify either its local or widespread presence at the base of the thick predominantly limestone section, most of which is unquestionably Lansing. Approximately 200-foot thicknesses (Wagner, 1962, p. 139-141 and O'Connor, 1962, p. 153-155) of Lansing rocks are not uncommon in Wilson and Montgomery Counties, Kansas outcrops within the area of limestone facies (Fig. 7).

Within the area of shale-sandstone facies (Fig. 7), the Lansing Group, where both its base and top can be identified, is approximately 200 feet thick. Wagner (op. cit.) and O'Connor (op. cit.) report thicknesses of this general magnitude for outcrop areas in northeastern Wilson and west-central Montgomery Counties respectively. South of Table Mound (sec. 9, T. 32 S., R. 15 E., Montgomery Co., Kans.) the Plattsburg Limestone (lowermost of Lansing Group formations) is not definitely recognized in Kansas exposures (O'Connor, op. cit., p. 154). No correlatives of the

^{1/}I am not aware of any record of less than about a 35- to 40-foot thickness of Lansing rocks in this area. I do not agree that within large parts of Clay and Washington Counties the Lansing Group is in excess of 75 feet thick. See the correlations part of the section on Historical Geology for further discussion.

Plattsburg have been definitely recognized in Washington and Osage Counties, Oklahoma. The limestone development shown in the lower and middle parts of the Wann Formation of Oakes (1940, p. 76, fig. 8) could be in part correlative to the Plattsburg Limestone. However, I regard most of these limestones equivalent to some part of the Stanton Limestone for reasons outlined in the correlations part of the section on Historical Geology. No Plattsburg Limestone was identified within the subsurface part of the shale-sandstone facies area except questionably on the extreme northern margin of the area (see Fig. 7). In the southernmost Kansas part of the outcrop area (T. 34 S. and T. 35 S.), the Stoner Limestone Member of the Stanton Formation is not recognized and adjacent shale members are classed as the Eudora-Rock Lake Shale. Sandstone at least 40 feet thick is present locally in the Eudora-Rock Lake in this area (O'Connor, *op. cit.*, p. 154). Sandstone is present within the Lansing in an apparently similar stratigraphic position (Pl. 8, in pocket). The Torpedo Sandstone (for discussion of this unit, see Oakes, 1940, p. 81-86) of Oklahoma terminology is developed in this part of the section farther south.

Broadly described, the Lansing Group is a shale-sandstone wedge, which grades to the north and west into a thick limestone development. The shape of Lansing rocks in this area of predominantly limestone is complex and as yet poorly known. Parts of this complex area of limestone facies (Fig. 7) are apparently broadly lenticular in cross section and have been termed marine banks (Harbaugh, 1959, 1960). Whether most of the area of limestone facies is a marine bank complex will not be known until much additional study is completed. The limestone facies is broadly gradational

to the north into the more or less tabular limestone - shale facies, which is exemplary of what Moore (1936, p. 29) has termed megacyclothems.

Pertinent characteristics of Lansing Group lithofacies are summarized in the explanation accompanying Figure 7. The Stanton Limestone is better developed, that is, thicker and definable, throughout a larger area than the Plattsburg. The Stanton is approximately twice as thick as the Plattsburg in northern Kansas, northwestern Missouri, and eastern Nebraska; although discontinuous it extends about 40 miles farther south than does the Plattsburg. Only the uppermost member of the Stanton Limestone, the South Bend Limestone, which bounds the Douglas Group below, was described in detail for the purpose of this study. The South Bend Limestone is the most widespread unit within the Lansing Group.

Stanton Limestone

South Bend Limestone Member

Condra and Bengston (1915, p. 7, 23) proposed the name South Bend for one of the ledges cropping out in the Platte River bluffs of Cass County, Nebraska. A section along the railroad one half mile east of Pawnee Creek mouth was described. It is impossible to be sure as to exactly which section the description applies but the type locality from approximately 1 to 2 miles northwest of the town of South Bend, is definite. Condra (1927, p. 158) described the South Bend quarry section. This section, more commonly referred to in later years as the Burlington quarry section, includes what has been considered as type South Bend Limestone. The section exposed at the bottom of the access road to the old Burlington quarries (near cen. south line SW $\frac{1}{4}$ sec. 10, T. 12 N., R. 10 E.; now owned by Mr. Kerford) is used by the author as a reference standard.

Description of standard reference section. -- Five units are differentiated on the basis of outcrop, hand sample, thin section, and acetate peel study (Pl. 10). Unit 1 comprises the basal 0.7 foot thick, light gray bed devoid of shale breaks or partings. The rock is a brachiopod lime wackestone. Valve and spine cross sections of productid brachiopods are the characteristic fossil. Other skeletal grains include gastropod, pelecypod, crinoid, echinoid, and bryozoan debris. Fossil fragments, especially those of brachiopods, show bryozoan encrustation. Matrix material is predominantly 10-20 micron lime mud the continuity of which is interrupted by patchy blebs of sparry calcite. Partial or complete obliteration of skeletal grain structure by recrystallization to coarse spar is common.

A greenish gray calcareous shale parting forms unit 2. This unit is 0.1-0.2 foot thick and contains sparse Neospirifer and productids.

Unit 3 comprises two limestones separated by a shale break and aggregates about 5.5 feet in thickness. The lower limestone is about 2.2 feet thick and grades upward from greenish gray to light olive gray. The basal 0.5 foot is crinoid lime wackestone that grades upward into coated-grain lime packstone. In addition to crinoid ossicles, productid brachiopod, bryozoan, and foraminiferal debris are present in the wackestone. Long axes of the larger lath-shaped skeletal grains parallel the stratification in most cases. The small amount of spar present is concentrated in irregular patches in association with closely packed skeletal fragments, which show sutured and concavo-convex contacts.

The packstone part of the lower limestone of unit 3 is about 2 feet thick and light greenish gray. Indistinct very thin bedding is poorly

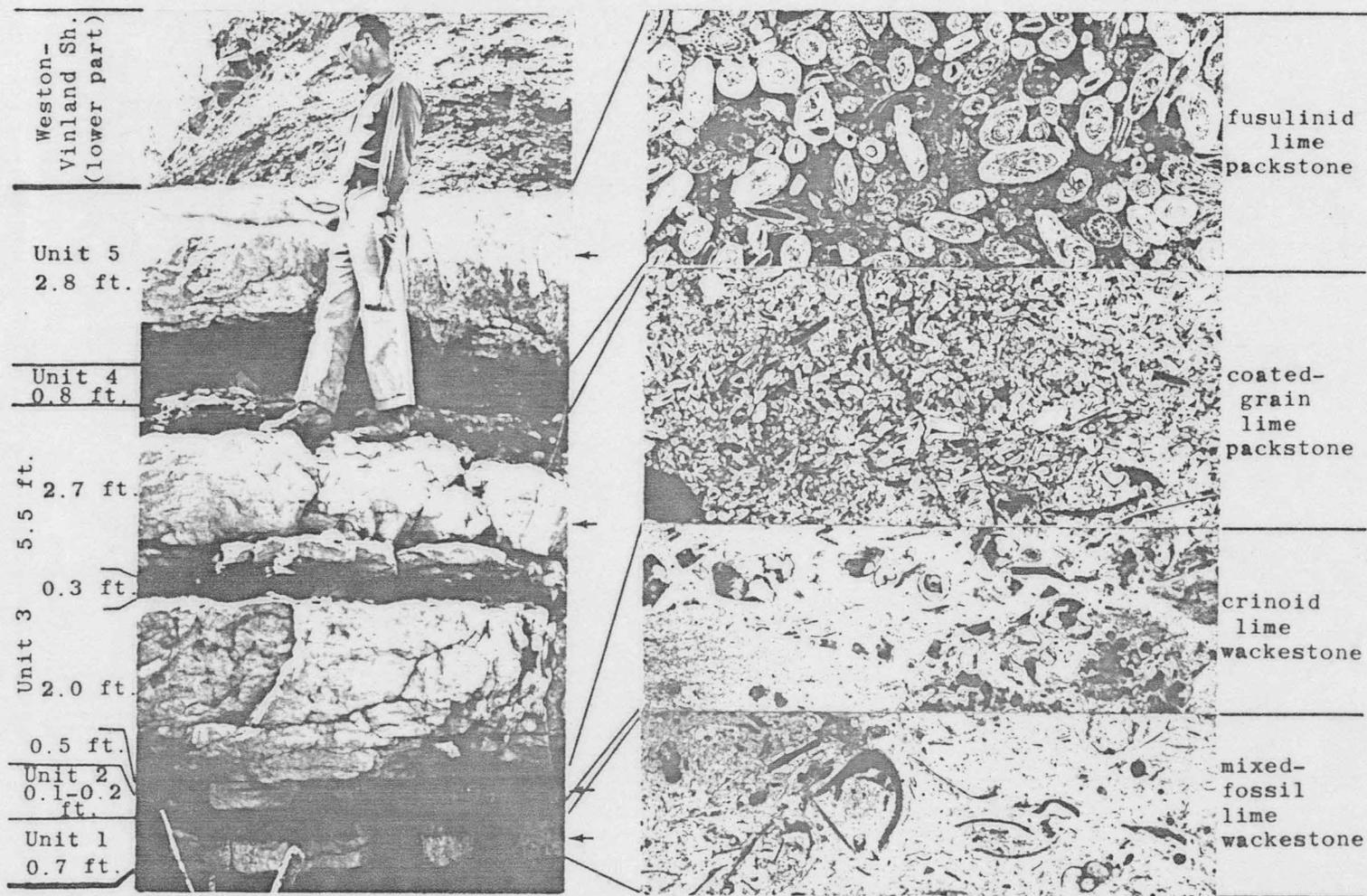


PLATE 10.-- Standard reference section of South Bend Limestone. Quarry exposure near center south line SW $\frac{1}{4}$ sec. 10, T. 12 N., R. 10 E., Cass County, Nebraska. Negative prints of thin sections (X3) on right. Arrows show exact positions of samples chosen as representative of the footages indicated and described in text. Vertical surfaces, orientation as shown.

developed in the lower part. Crinoids are the characteristic fossils. Other skeletal material comprises echinoid, brachiopod, gastropod, bryozoan and foraminifer, including extremely sparse fusulinid, remains. Most of the grains are coated and their long axes randomly oriented relative to stratification. Lime mud and sparry calcite exhibit patchy distribution. Some of the interstitial spar mosaics show a druse of calcite rimming fossils. In other cases sparry calcite stringers transect skeletal material.

The shale break of unit 3 consists of 0.2 to 0.4 foot of greenish gray clayey shale which contains Neospirifer. Ellipsoidal, light greenish gray, fossiliferous limestone stringers are distributed throughout the shale. This weathering break could be considered shaly limestone as well as limy shale and probably would not be apparent in fresh exposures or in cores.

Coated-grain lime packstone forms the upper limestone of unit 3. This part of the unit is light greenish gray and about 2.7 feet thick. Relative to the lower limestone an increase in sparry calcite/lime mud ratio; an introduction of sparse ooliths; better developed (that is, thicker) grain coatings, many but not all of which can be identified as Osagia; and increase in number of fusulinids from sparse to common in the uppermost 0.5 foot are the only lithologic differences noted.

Unit 4 is a greenish gray mudstone, locally mottled grayish red, and about 0.8 foot thick. The mudstone is calcareous throughout. No fossils were observed.

One of the best key beds in lower Platte River Valley section forms the topmost unit of the South Bend Limestone. This unit is a single bed

about 2.8 feet thick devoid of shale partings or breaks, very light olive gray, and fractures conchoidally. Vertical jointing is prominent and characteristic. A zone of fossiliferous chert nodules ranging through about 0.5 foot of section, from approximately 1 foot to 1.5 feet below the top of the unit, is a distinctive characteristic. Most of the chert nodules are irregularly ellipsoid and some are as much as 0.8 foot long by 0.3 foot thick; smaller ellipsoidal nodules are of a proportional size. Other nodules range from extremely irregular to nearly equant in shape. This chert nodule zone is present in all but one of the Platte River Valley exposures of the South Bend known to me and maintains a consistent stratigraphic position. Texturally the rock is a fusulinid lime packstone. Profuse fusulinids are the striking faunal constituent. Other skeletal grains include brachiopod, bryozoan, crinoid, and echinoid debris. Most of the grains are obviously abraded and many also coated with Osagia. Sparry calcite is the dominant interstitial material except in the basal 0.5 foot of the unit where lime mud is present in about equal proportion. Lime mud is patchily distributed and grains are randomly oriented. Some recrystallization is evidenced by spar stringers transecting allochems and by effects of pressure solution along contiguous grain boundaries.

Unit contacts within the South Bend Limestone and bounding contacts of the member are gradational. Increase in the shale/limestone ratio of the South Bend as seen in other Platte Valley exposures of the member is noteworthy. The reason for an increase in shale proportion is a partial shale out of the upper limestone of unit 3 of the standard reference section as it is traced laterally.

Geographic, thickness, and facies range. -- A distribution map of the South Bend Limestone is shown as Figure 8. Except for local absence in southern Platte and Clay Counties, Missouri and in Wyandotte and Leavenworth Counties, Kansas, the South Bend Limestone is essentially continuous and precisely traceable from southern Buchanan County, Missouri (T. 56 N., R. 34 W.) to southern Montgomery County, Kansas (T. 34 S., R. 14 E.). Southward to southern Osage County, Oklahoma (T. 23 N.) discontinuous limestone lenses occupy the stratigraphic position of the South Bend Limestone. These lenses are collectively referred to the Birch Creek Limestone in Oklahoma terminology (Oakes, 1940, p. 86-91) and, at least in part, are correlative to the South Bend. Northeastward from southern Buchanan County, Missouri, the South Bend crops out in disconnected exposures in DeKalb, Gentry, and Worth Counties, Missouri (Hinds and Greene, 1915, p. 155-169). Glacial drift seriously hampers tracing of beds in this area and I was unable to locate enough sections to be sure of correlations. I was unable to identify the South Bend Limestone definitely in Iowa exposures (see selected section 7 in appendix and discussion in correlations part of section on Historical Geology).

Other areas of South Bend Limestone exposure are located in Cass and Sarpy Counties, Nebraska and are separated from the main line of outcrop by about a 100-mile wide area of younger rocks. There the South Bend is best exposed along the Platte River and along Weeping Water Creek Valley.

It seems probable that the South Bend is essentially continuous throughout the subsurface part of both the area of limestone-shale facies and the area of limestone facies (Fig. 7). Southward the South Bend is

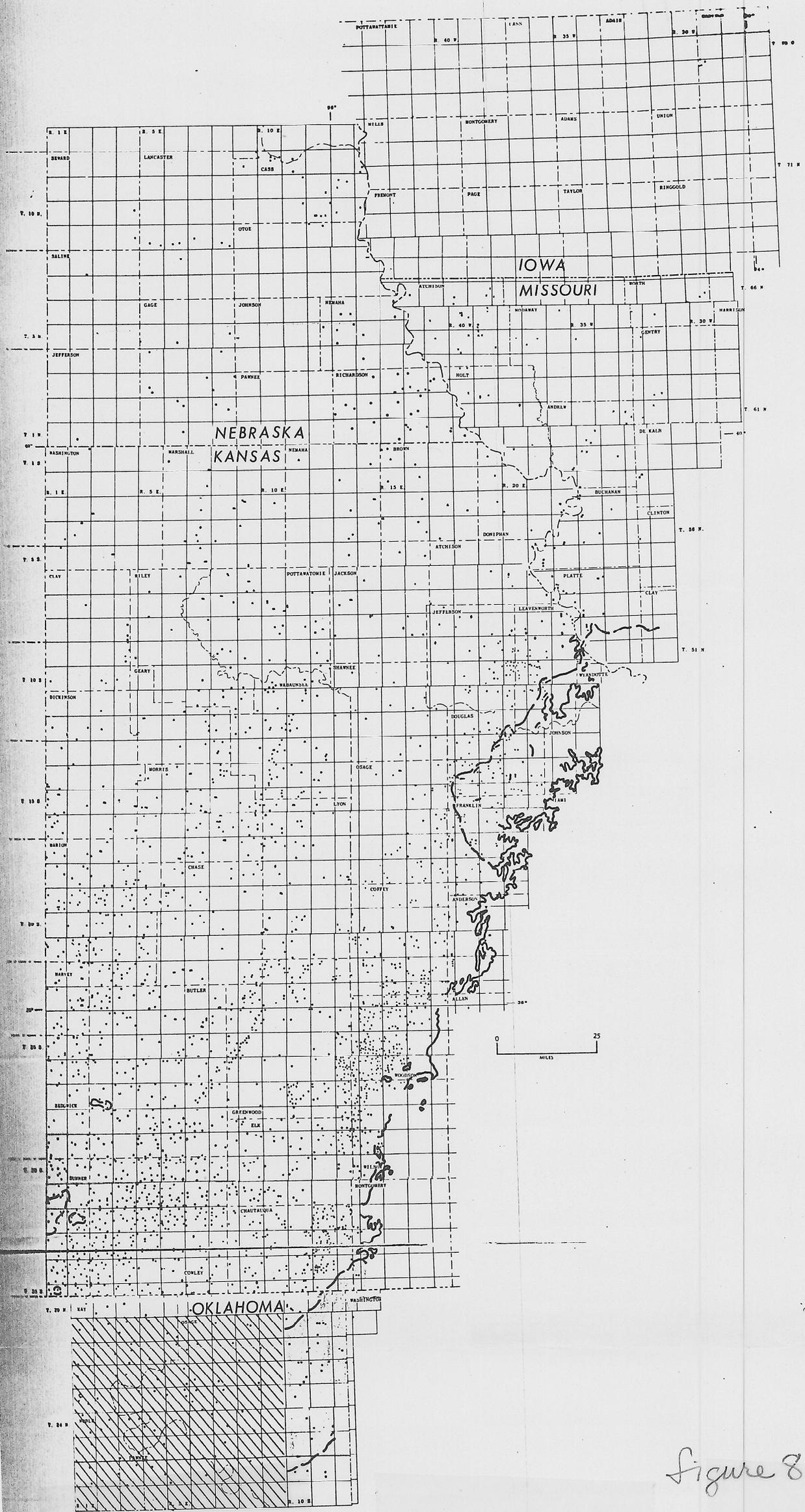


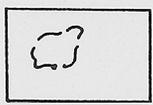
Figure 8



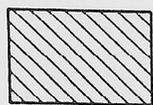
Area of general continuity.



Area of discontinuity.



Area in which not identified and believed to be absent.



Correlation not established.



Approximate surface trace of South Bend Limestone top. Broken where breached by major drainage or covered by relatively thick Pleistocene deposits.

widespread within the Kansas part of the shale-sandstone facies area (see Fig. 7 and Plates 8 and 9, in pocket) but is absent locally in the southwest part of the east ranges in Kansas. No Lansing limestone whatsoever was identified on about a dozen logs (Fig. 8) and the South Bend was identified questionably on a number of additional logs. Not enough control was studied for the subsurface part of the shale-sandstone facies area in Oklahoma to warrant extending the distribution map of the South Bend southward. Surface study of the Birch Creek (South Bend) Limestone and study of the electric logs shown in northern Oklahoma (Fig. 1) indicate that the member is probably discontinuous in the northern part of the Osage County, Oklahoma subsurface and absent in the southern part.

In its type area, the lower Platte River Valley of Nebraska, the member ranges from about 7.5 to about 10 feet in thickness on the outcrop (see selected sections 1 and 2 in appendix). About 15 to about 20 miles southeast in the areas northwest and southwest of Nehawka, the South Bend Limestone is 5 to 6 feet thick. According to my correlations, units 5(3) to 5(6) of Condra's section (1927, p. 173) record an aggregate thickness of about 6 feet for the South Bend. A log of rotary cuttings described by Ray Burchett^{1/} and made available to this study records a 5-foot thickness for the South Bend at a depth of 284 to 289 feet in section 28, Township 10 North, Range 12 East. The log of cable tool cuttings of the well located in northeast Nemaha County, Nebraska (Fig. 1 and log 42 in appendix) shows 13 feet of South Bend. The control shown for the Nebraska part of the study area indicates a thickness range of approximately

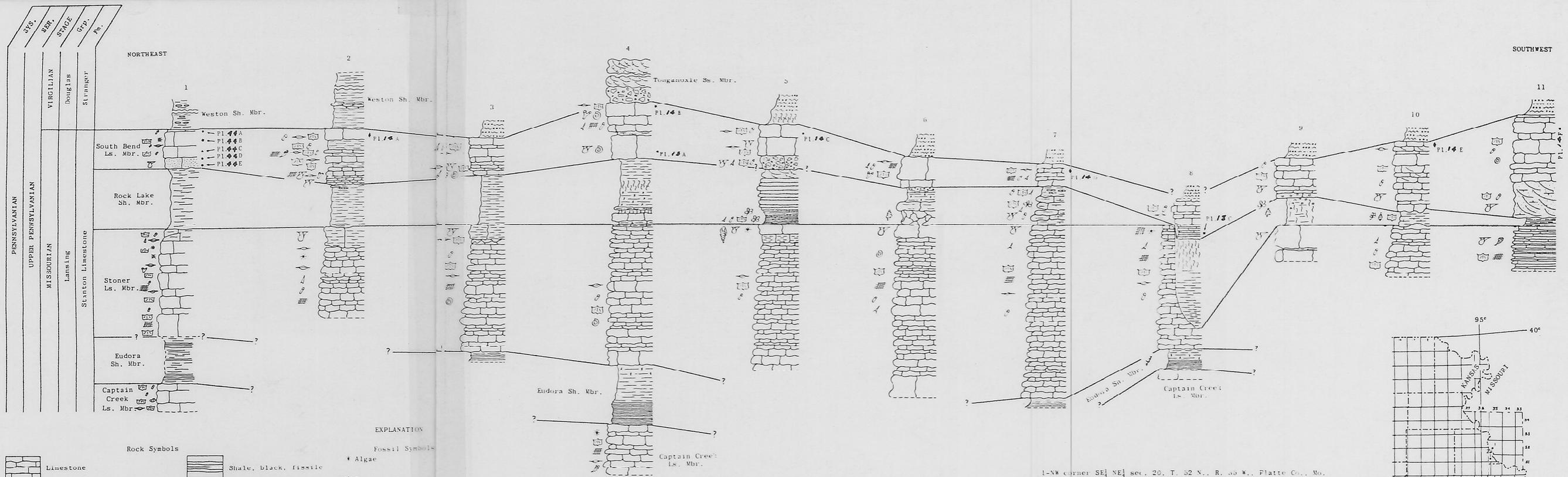
^{1/} Geologist, Nebraska Geological Survey.

5 to approximately 13 feet for the South Bend Limestone. Thickness of the member in Missouri ranges from about 2.5 feet to as much as 10 feet.

From Platte County, Missouri to Anderson County, Kansas, thickness of South Bend Limestone outcrops ranges from about 2.5 to approximately 12 feet and is commonly from 6 to 7 feet (Fig. 9). Thickness varies with the amount of terrigenous clastics in the member. Clayey or silty shale breaks or partings are commonly well developed in the South Bend in Nebraska, Missouri, and northernmost Kansas. Quartz silt and sand is a prominent characteristic of the lower part of the South Bend throughout the principal outcrop area of Missouri and Kansas.

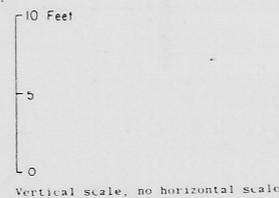
Within the area of limestone-shale facies (Fig. 7), thickness of the South Bend Limestone ranges from approximately 2 to 3 feet to approximately 13 feet. This thickness range is regarded no more than generally representative. Considering the amount of control, the small thickness range, and the local variability in thickness, it is obvious that control was insufficient to establish any geographic thickness trend in this area.

Southward across central Anderson County to southeastern Woodson County the South Bend ranges from about 3 to about 12 feet in thickness. Commonly thicknesses are within the 4- to 6-foot range. The thickest section of the member measured in this area was about 12 feet in southwesternmost Anderson County (selected section 34 in appendix). From southeastern Woodson County to southern Wilson County, the South Bend ranges from about 2 to about 8 feet in thickness in an area of both limestone facies and shale-sandstone facies (Fig. 7). The maximum development of the member occurs in southern Wilson and northern Montgomery Counties where 8- to 27-foot thicknesses are known (see Wagner and Harris, 1953;



| Rock Symbols | | Fossil Symbols | |
|--------------|-----------------------------------|----------------|-------------------------|
| | Limestone | | Algae |
| | Limestone, argillaceous | | Brachiopods |
| | Limestone, arenaceous | | Bryozoans, fenestrate |
| | Limestone, brecciated | | Bryozoans, ramose |
| | Limestone conglomerate | | Crinoids |
| | Limestone, cross-stratified | | Echinoids |
| | Sandstone | | Fusulinids |
| | Sandstone, cross-stratified | | Gastropods, spiraled |
| | Shale | | Gastropods, planispiral |
| | Mudstone | | Myalimid pelecypods |
| | Mudstone, greenish-gray | | Other pelecypods |
| | Shale, black, fissile | | Conodonts |
| | Shale, limestone nodules | | Land plants |
| | Shale, clay-ironstone concretions | | Trilobites |
| | Shale, calcareous | | Coral |
| | Shale, silty | | |
| | Siltstone | | |
| | "Soil" | | |
| | Limestone gravel | | |
| | Strata omitted | | |
| | Strata concealed | | |

* (thin sections) and • (acetate peels) denote stratigraphic placement of samples illustrated.



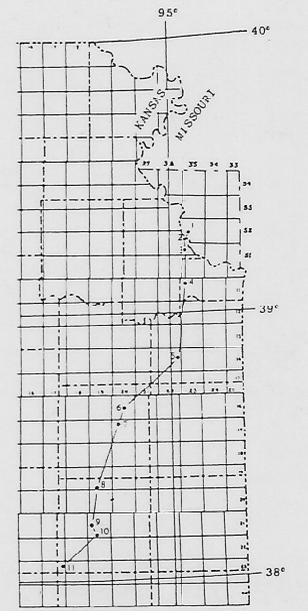
? Contact not exposed in adjacent section.

In section 8, pre-Rock Lake erosion removed most of the Stoner. Base of the South Bend Limestone is topographically lower than Stoner Limestone top at this locality, which is widely known for vertebrate fossils and the land plant fossil, *Walchia*, from the Rock Lake Shale.

With the exception of section 8, all sections showing "soil" immediately atop the South Bend are quarry face exposures. The "soil" is material pulverized during stripping of overburden and is not weathered South Bend.

Shales were not washed for microfossils.

- 1-NW corner SE 1/4 NE 1/4 sec. 20, T. 32 N., R. 30 W., Platte Co., Mo.
- 2-SW 1/4 NE 1/4 sec. 7, T. 9 S., R. 20 E., Leavenworth Co., Kans.
- 3-Center south line SW 1/4 sec. 30, T. 9 S., R. 23 E., Leavenworth Co., Kans.
- 4-Center west line NW 1/4 sec. 8, T. 11 S., R. 23 E., Wyandotte Co., Kans.
- 5-Center south line NW 1/4 sec. 15, T. 14 S., R. 22 E., Johnson Co., Kans.
- 6-NW corner sec. 22, T. 10 S., R. 20 E., Franklin Co., Kans.
- 7-NE 1/4 SW 1/4 sec. 5, T. 17 S., R. 20 E., Franklin Co., Kans.
- 8-Center south line sec. 32, T. 19 S., R. 19 E., Anderson Co., Kans.
- 9-NE corner sec. 19, T. 21 S., R. 19 E., Anderson Co., Kans.
- 10-NW corner SW 1/4 sec. 33, T. 21 S., R. 19 E., Anderson Co., Kans.
- 11-SE corner sec. 12, T. 23 S., R. 17 E., Anderson Co., Kans.



Index map showing line of cross section (1-11). Public land descriptions are given to the left.

FIGURE 9.--Stratigraphic cross section of the South Bend Limestone and adjacent rocks from Platte County, Missouri to Anderson County, Kansas. Section descriptions are included in the appendix.

Wilson, 1957; and O'Connor, 1962, p. 154). The thicker sections of the member occur in southwesternmost Anderson County and from Fredonia, southern Wilson County, to Elk City, northern Montgomery County. General, but not perfectly progressive thinning to the south, southeast, and northeast from these areas is noteworthy.

South of the north-south center line of Township 32 South and within the southern Kansas part of the shale-sandstone facies area (Fig. 7), the South Bend ranges from about 12 feet thick (O'Connor, op. cit., p. 155) to a featheredge in parts of Townships 34 and 35 South. The member is locally discontinuous in southernmost Kansas. If all the sandstone (8-foot maximum thickness, O'Connor, *ibid.*) that commonly underlies the limestone upper part of the member in this area is classed with the South Bend, the member is more nearly continuous and can be mapped with greater utility.

In Nebraska outcrops of the South Bend Limestone, a lower mixed-fossil lime wackestone facies and an upper coated-grain lime packstone facies persist (Pl. 11). Interbedded shale is characteristic. Comparison to the standard reference section shows that thinning of the member corresponds approximately to thinning of the packstone facies although local (e. g. Pl. 11) increase in shale percentage partially counterbalances such thinning.

The distinctive zone of nodular chert in the uppermost bed of the member along Platte River was not observed in exposures northwest of Nehawka. Previous workers have reported absence of the cherty zone at the top of the South Bend (Condra and Scherer, 1939, p. 4) and of the entire member locally (Condra and Reed, 1943, p. 51; Condra and Reed,

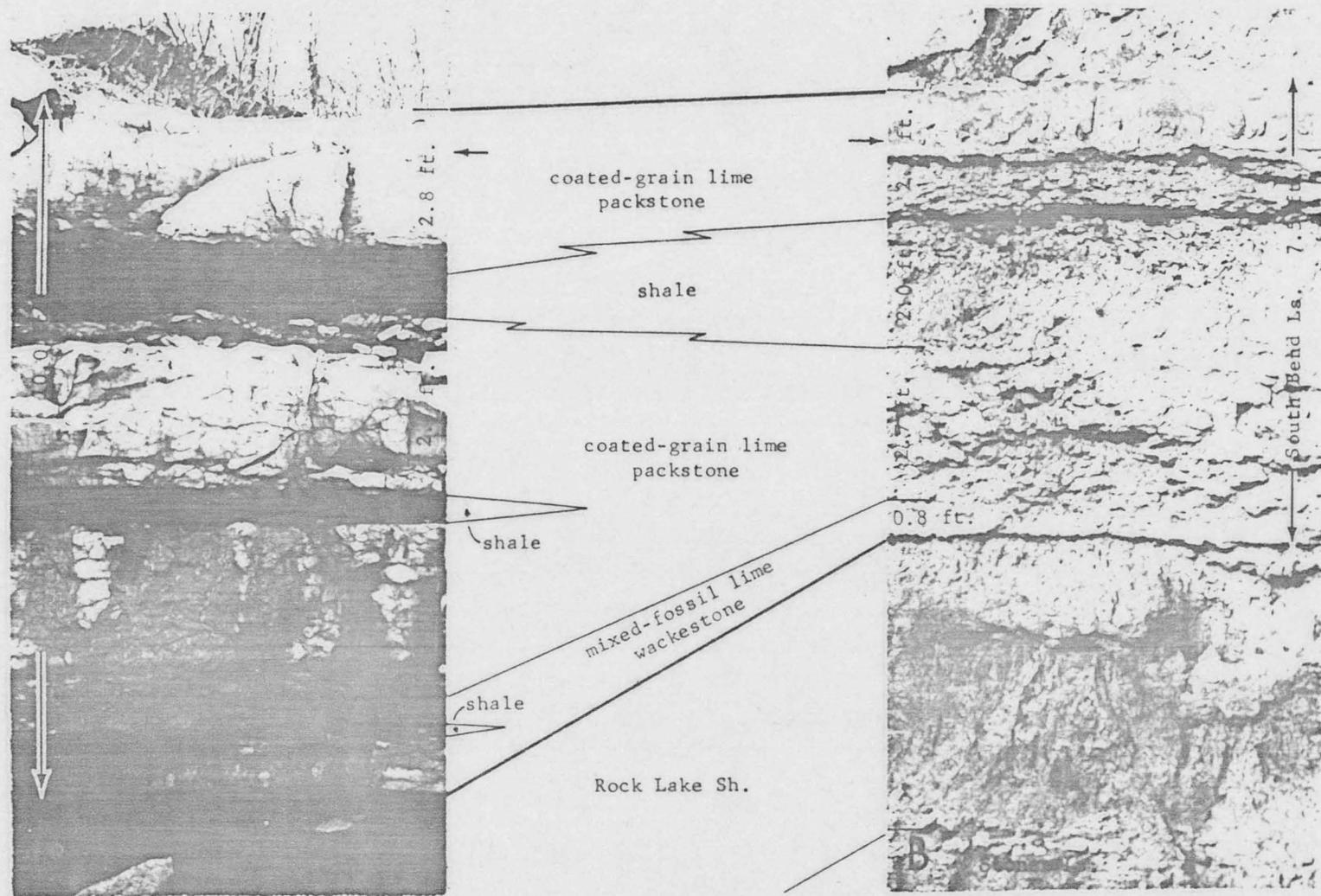


PLATE 11.-- Facies variation in South Bend Limestone from south side (A) to north side (B) of Platte River. A, Standard reference section, see Pl. 10 . B, Quarry face in NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 16, T. 12 N., R. 11 E., Sarpy County, Nebraska. Horizontal arrows show position of distinctive zone of nodular chert in uppermost bed, which contains profuse fusulinids and classes also as a fusulinid lime packstone.

1959, p. 51) in the vicinity of Nehawka and have attributed these conditions to Pennsylvanian erosion. During the course of this study, no indication of such disconformity was observed near Nehawka and possibly not enough exposures were studied there. Lithology of the uppermost 0.5 foot of the South Bend is nearly identical in the exposures studied (Pl. 12, selected sections 1, 2, and 3 in appendix; several sections between Stone Products quarry and Gretna Fish Hatchery along the north side of Platte River; and sections along the creek in W $\frac{1}{2}$ sec. 6, T. 10 N., R. 13 E.).

From northwestern Missouri to southern Woodson County, Kansas the South Bend Limestone generally comprises a lower quartzose molluscan lime wackestone (Pl. 13) or calcareous quartzose sandstone facies, an upper mixed-fossil lime wackestone facies (Pl. 14) and interbedded shales, which are prominent in the Missouri and northernmost Kansas parts of the outcrop area. The lower part of the member displays marked variability in thickness, terrigenous detritus content and bedding (Fig. 9). Quartz particles are an especially abundant constituent in southern Leavenworth, Douglas, Johnson, and Anderson Counties, Kansas exposures of the South Bend. Oolith or pellet lime packstone (rarely grainstone) or limestone-clay pebble conglomerate are developed locally in the lower part of the South Bend in Johnson, Franklin, Anderson, Woodson, and Wilson Counties, Kansas. Cross stratification is locally associated with the conglomerate or the quartzose sandstone deposits.

The upper mixed-fossil lime wackestone facies of the South Bend is extremely persistent throughout this area. A fauna of brachiopods, bryozoans, crinoids, and fusulinids; even bedding; and vertical jointing characterize this facies.

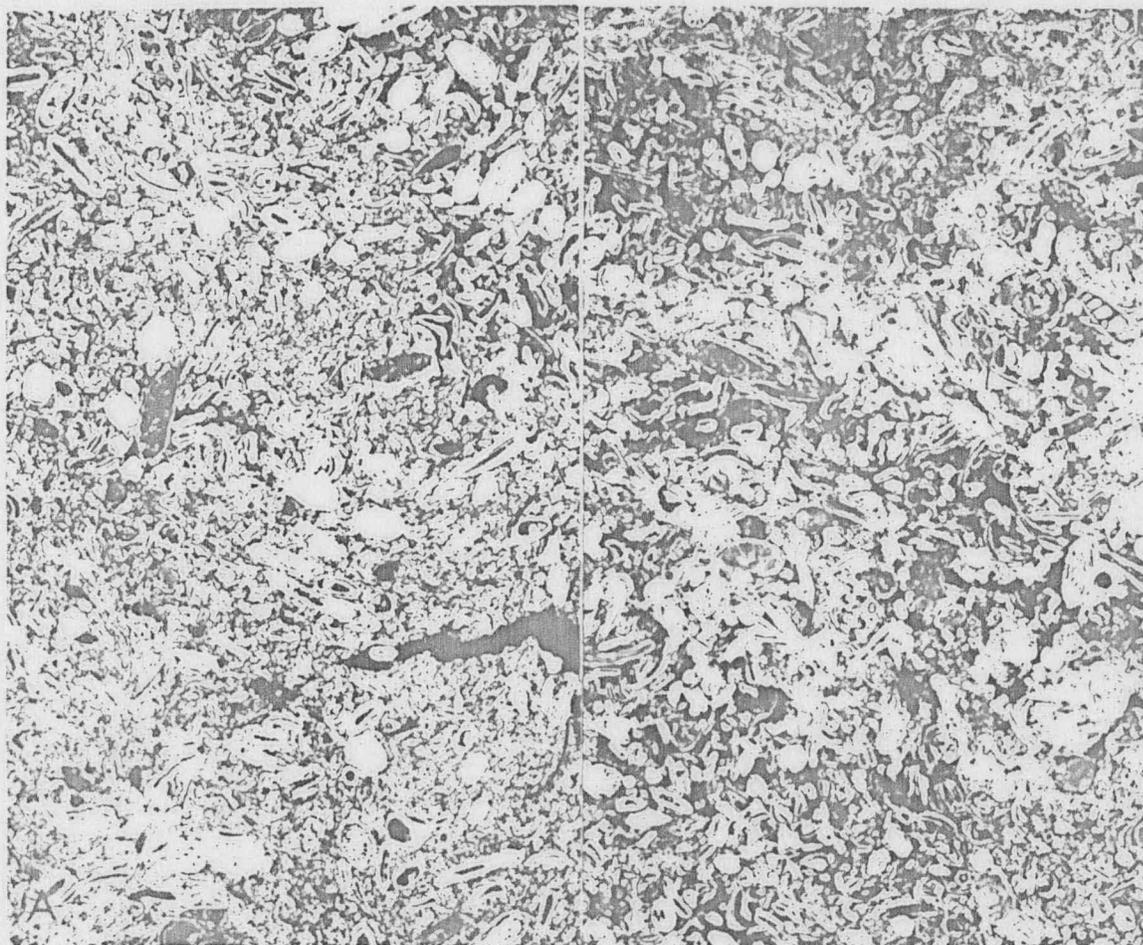


PLATE 12.-- Topmost 0.5 foot of South Bend Limestone as developed along the Platte River (A) and along Weeping Water Creek valley (B). A, Sample from Stone Products quarry face in NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 16, T. 12 N., R. 11 E., Sarpy County, Nebraska. See selected section 2 in appendix. B, Sample taken just east of bridge near center north line NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 12, T. 10 N., R. 12 E., Cass County, Nebraska. See selected section 3 in appendix.



PLATE 13.-- Quartzose molluscan lime wackestone facies of the South Bend Limestone.
 A, Sample from road cut exposure near center west line NW $\frac{1}{4}$ sec. 8, T. 11 S., R. 23 E., Wyandotte County, Kansas. B, Sample from quarry exposure in NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 15 S., R. 22 E., Johnson County, Kansas. C, Sample taken near center south line sec. 32, T. 19 S., R. 19 E., Anderson County, Kansas. D, Sample from road cut exposure near quarry entrance at SW corner sec. 31, T. 21 S., R. 19 E., Anderson County, Kansas. E, Sample taken at NE corner sec. 26, T. 34 S., R. 13 E., Montgomery County, Kansas. A-D (X2) are negative peel prints. E (X2) is a negative print of a thin section. Vertical surfaces, orientation as shown. See also Plate 44 E and Figure 9.

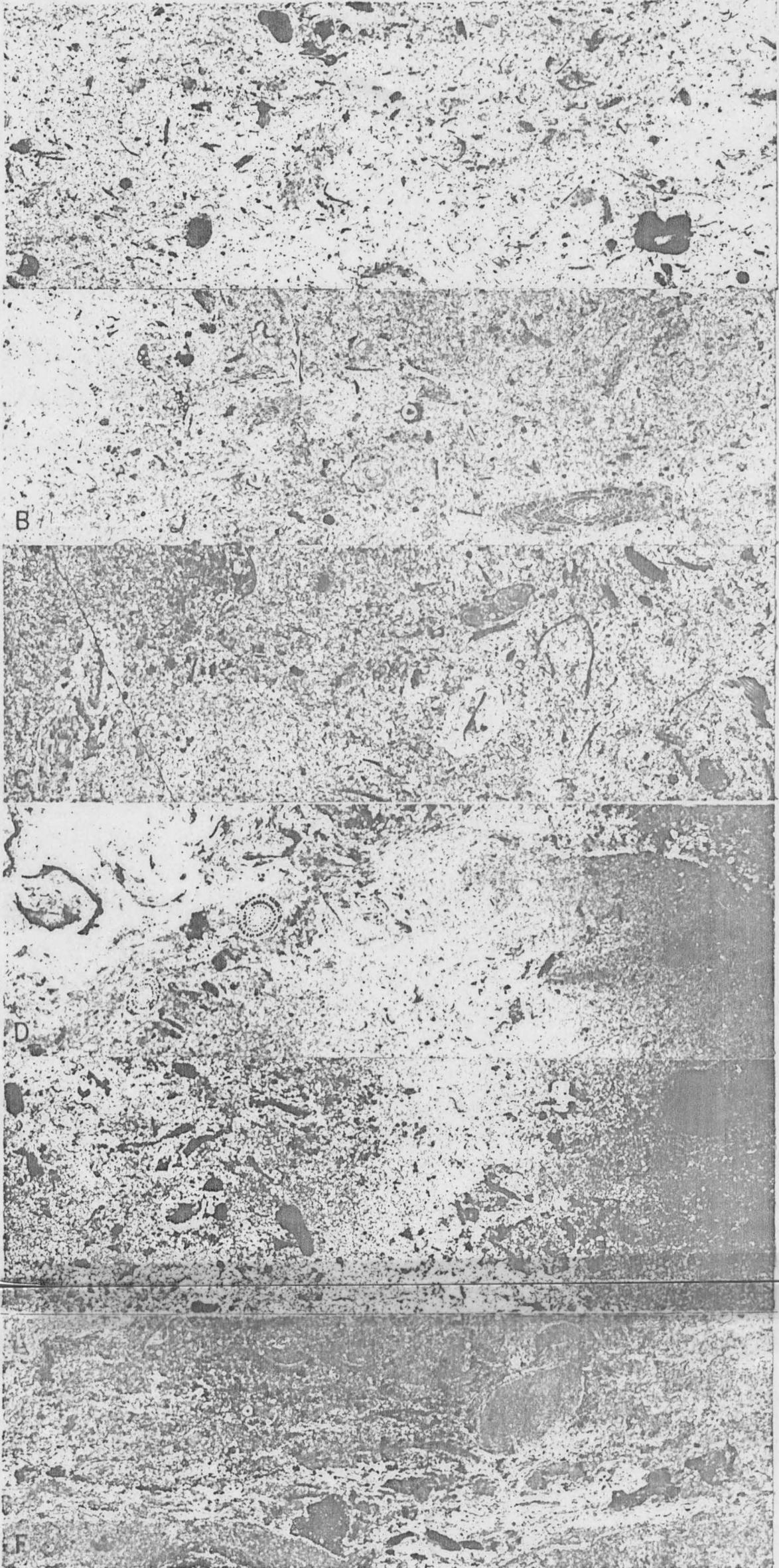


PLATE 14.-- Mixed-fossil lime wackestone facies of the South Bend Limestone. A, Sample from railroad cutbank exposure in SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 9 S., R. 23 E., Leavenworth County. B, Sample from roadcut exposure at center west line NW $\frac{1}{4}$ sec. 8, T. 11 S., R. 23 E., Wyandotte County. C, Sample from quarry face at center south line NW $\frac{1}{4}$ sec. 13, T. 14 S., R. 22 E., Johnson County. D, Sample from quarry face in NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5, T. 17 S., R. 20 E., Franklin County. E, Sample from abandoned quarry face at NW corner SW $\frac{1}{4}$ sec. 33, T. 21 S., R. 19 E., Anderson County. F, Sample from abandoned quarry face at SE corner sec. 12, T. 23 S., R. 17 E., Anderson County. Negative prints (X4) of thin sections (A, D, and E) and peels (B, C, and F). Kansas samples. Vertical surfaces, orientation as shown. See also Plate 44 and Figure 9.

From southern Woodson to southern Wilson Counties, Kansas, lower and upper facies of the South Bend lack consistent identity and the member is best described as a sandy oolith or pellet lime packstone or grainstone-calcareous sandstone association in which contacts between the limestone and sandstone parts of the member are neither characteristically sharp nor characteristically gradational. The South Bend within this area is quite adequately described by Wagner and Harris (1953), Wagner (1954), and Wagner (1961). These authors discuss the locally developed conglomerate and disconformable relationships in the lower part of the member as well as the common presence of cross-stratification throughout the member, which are salient characteristics of the South Bend in the southern Woodson to southern Wilson Counties, Kansas area.

In northern Montgomery County, Kansas, the South Bend Limestone attains its maximum known development, a thickness of about 27 feet in exposures along the Elk River south of Elk City. There the member is a mixed-fossil lime mudstone to wackestone that contains fossil crinoids, bryozoans, fusulinids, productid brachiopods, and questionably linear algae. The lime mud matrix is interrupted by linear stringers and irregular blebs of sparry calcite. Oolith lime grainstone is present in the basal part of the member. Fossils are especially prominent in the lower 6 to 7 feet of the member; Meekella striatocostata and large crinoid columnals as much as three-fourths inch in diameter are present in abundance. The central 12 to 15 feet of the South Bend is massive, questionably algal lime mudstone that contains sparse crinoids and brachiopods and a few fusulinids. Exfoliation parallel to the exposure face in layers 2 inches or less thick characterizes this part of the member (see Wilson,

1957, p. 432, Fig. 2 and 3). The upper 6 to 7 feet of the member weather into slabby beds which are moderately fossiliferous and include locally developed oolith lime grainstone beds. This facies is well exposed both to the west and east of the bridge over Elk River in the south half NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 18, T. 32 S., R. 14 E. (Pl. 15). The absence of either quartzose sandstone or conglomerate is a distinctive characteristic of this facies in marked contrast to South Bend exposures both to the north and to the south.

In central and southern Montgomery County, Kansas south of the north-south center line of Township 32 South, the South Bend Limestone comprises generally a lower fossiliferous quartzose sandstone-oolith lime grainstone-conglomerate facies and an upper mixed-fossil lime wackestone to mudstone facies, which is locally a molluscan lime wackestone facies in southernmost Montgomery County (e. g., near SE corner sec. 7, T. 35 S., R. 14 E. and near center east line sec. 18, T. 35 S., R. 14 E.). The sandstone, grainstone, and conglomerate are known to occur singly, in any combination of two, or all three (e. g. at NE corner sec. 26, T. 34 S., R. 13 E., Pl. 8, section 1) in the lower part of the South Bend. Contacts between these rock types and with the overlying wackestone to mudstone facies are gradational and locally interfingering as shown in exposures along the south line SE $\frac{1}{4}$ section 28, Township 32 South, Range 14 East.

The South Bend Limestone of Nebraska comprises a significantly different association of rock types than the South Bend Limestone in Missouri and Kansas outcrops. The large volume of quartz, which is a characteristic constituent of the member in the latter area, is absent from the former

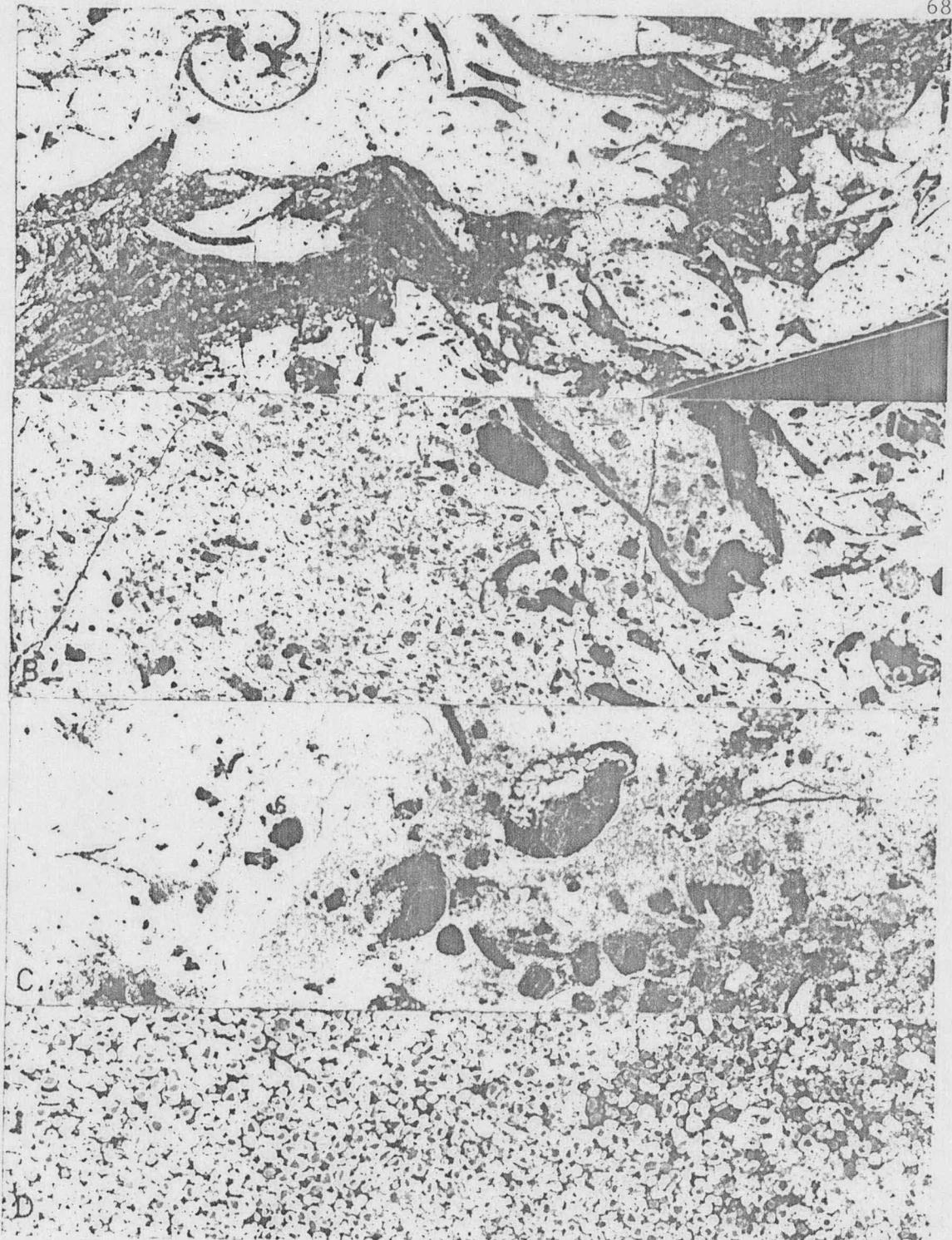


PLATE 15.-- Mixed-fossil lime mudstone to wackestone facies of the South Bend Limestone in northern Montgomery County, Kansas. Samples taken near bridge over Elk River in south half NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 18, T. 32 S., R. 14 E. A, Mixed-fossil lime wackestone. Note ?algal crusts in lower left-hand corner and abundant sparry calcite. This rock type is characteristically associated with so-called marine banks (see Harbaugh, 1959, Pl. 8). B and C, Mixed-fossil lime mudstone. Note partially recrystallized fusulinid at right margin of B. Much of the spar in these samples represents recrystallized fossils. D, Coated-pellet lime packstone locally developed in lower part of South Bend at this exposure. Negative peel prints (X4). Vertical surfaces, orientation as shown.

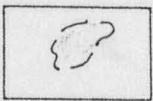
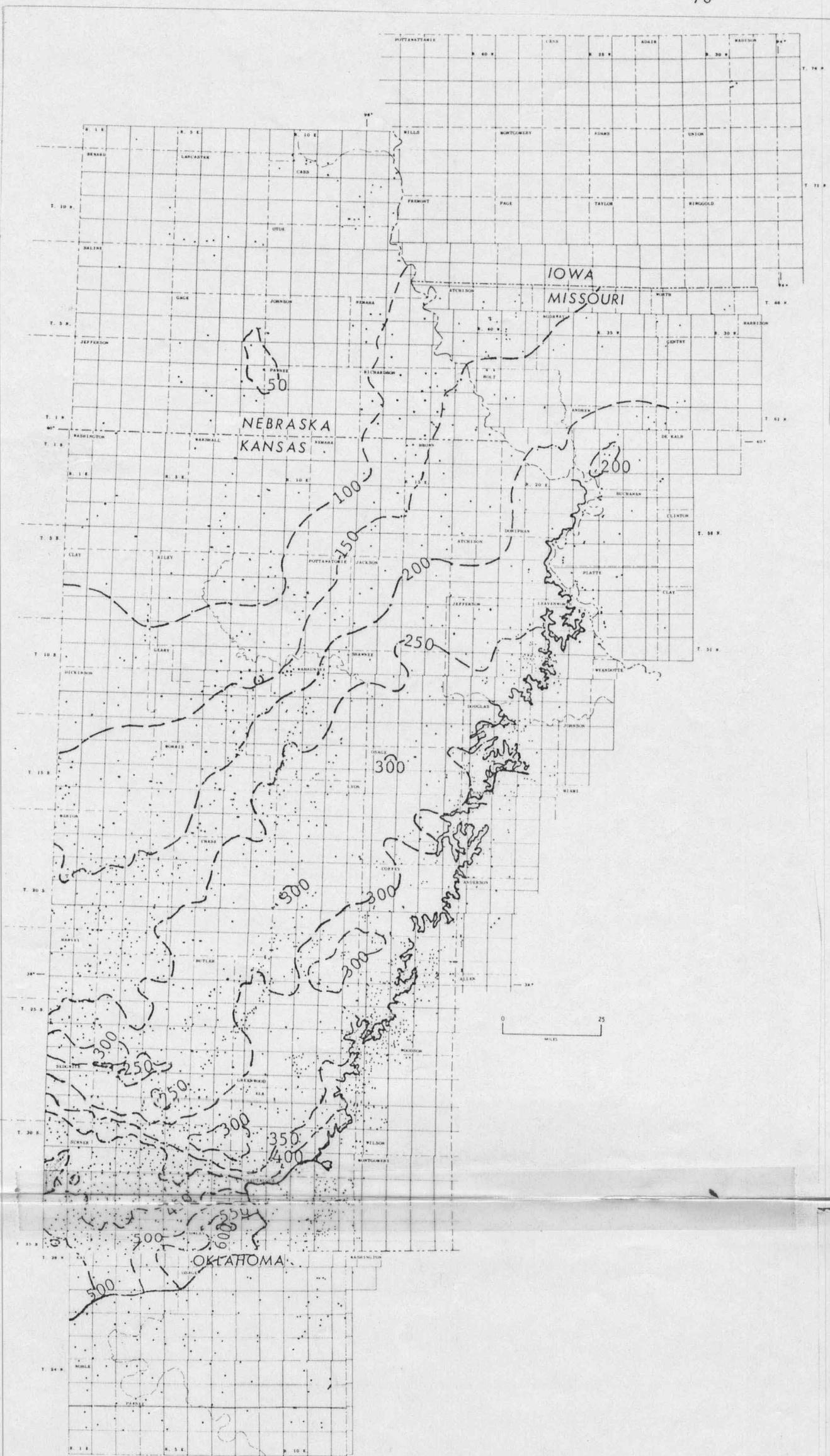
area. Interbedded shales are common only in Nebraska and less so in Missouri and are noticeably lacking farther south. Coated-grain lime packstone, the predominant rock type in Nebraska exposures of the South Bend, has not been recorded in Missouri or Kansas exposures of the member.

Virgilian Stage

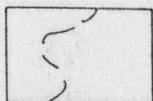
Douglas Group

The Douglas Group is the lowermost part of the Virgilian Stage and extends from the top of the Lansing Group below to the base of the Shawnee Group above. As thus defined, the Douglas comprises a unit of rocks that ranges from about 600 feet thick in the south and southeast to about 50 feet thick in the north and northwest part of the study area (Fig. 10). The thickest surface section was studied in southernmost Kansas (T. 35 S., Rs. 11 to 13 E.) and the thinnest surface section was measured in Cass County, Nebraska (selected section 1 in appendix). Thickness variation and general lithologic aspects of Douglas rocks are shown by a diagrammatic cross section along the main line of outcrop from Oklahoma to Iowa (Fig. 11). Average thicknesses at the different latitudes were used in construction of this figure. Other areas of Douglas Group exposure are inliers located in Sarpy and Cass Counties, Nebraska. The group comprises about 60 to 65 feet of section along Weeping Water Creek (Cass Co., Nebr.) and about 50 to 55 feet of section along the Platte River (Cass and Sarpy Cos., Nebr.).

Areal distribution of shale-limestone and shale-sandstone facies (Fig. 12) shows that the northwest part of the study area is characterized by relatively high limestone percentage (greater than 33) of Douglas rocks.



Areas in which Douglas Group base was not identified.



Limit of areas in which Douglas Group top was either not identified or was extremely discontinuous.



Approximate surface trace of Toronto Limestone (bounds Douglas Group above). Broken where breached by major drainage.

FIGURE 10.--Douglas Group thickness (in feet) map. See Figure 1 for qualification of control points.

EXPLANATION

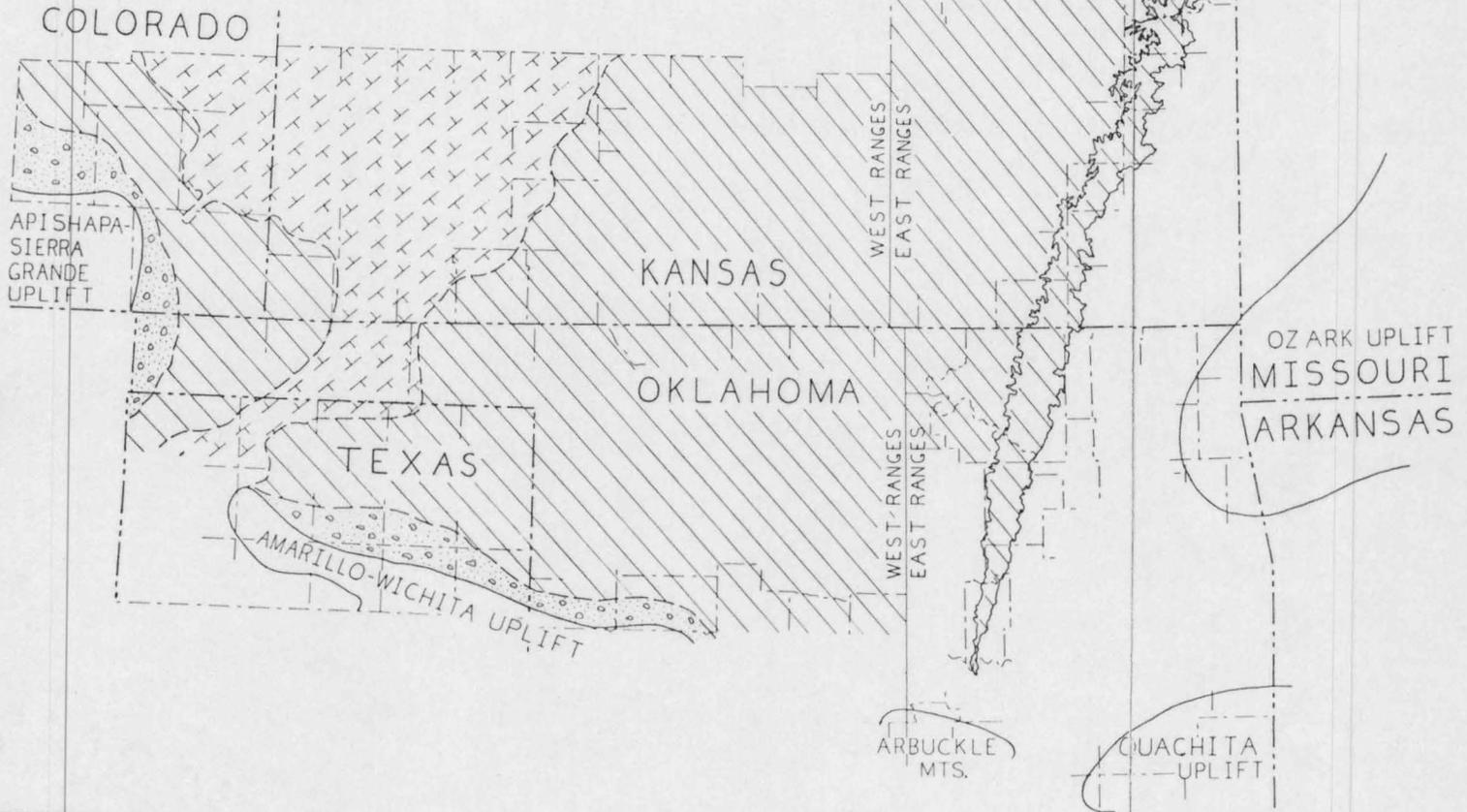
 shale-limestone facies, > 1/3 ls.

 shale-sandstone facies, < 1/3 ls.

 > 1/4 arkosic clastics

0 25 50 75 100 Miles


 approximate limits of outcrop



RE 12.--Douglas Group lithofacies. Area west of boundary between east and west range from Rascoe (1962, p. 1363) is shown for comparison. Approximate outcrop trace of Douglas Group top (on west) and base (on east) modified from 1937 State Geologic Map of Kansas (Moore and Landes). The approximate composite outcrop trace (Miser and others, 1954) shown for Oklahoma represents a more inclusive sequence, that is from the Lecompton Limestone above to the base of the Barnsdall Formation below, in northern Oklahoma. Southward the approximate outcrop trace both above and below represents successively younger beds insofar as correlations can be established (see correlations part of section on Historical Geology for discussion of strike overlap in Oklahoma). Approximate outcrop trace of Douglas Group top and base in Missouri from the State Geologic Map of Missouri (McCracken and others, 1961). In the Kansas and Missouri parts of the figure, the outcrop trace of Douglas Group base has been adjusted to current classification.

Limestone percentage within the group along the main line of outcrop ranges from 5 or less throughout most of the area to as much as 15 in northernmost exposures in Missouri (Fig. 11).

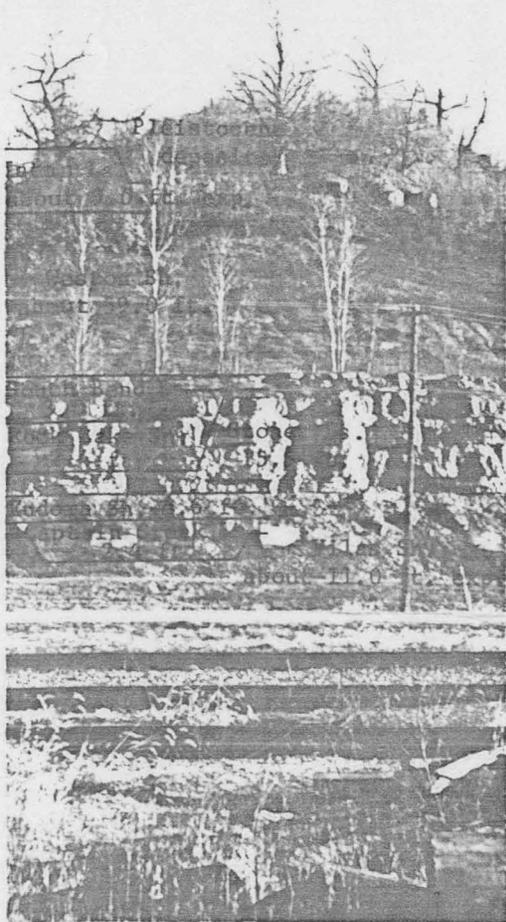
Broadly described, the Douglas Group is a shale-sandstone wedge thickest to the south and southeast, thinnest to the north and northwest, and becoming a shale-limestone sheet in the northwesternmost part of the study area. The word sheet is used in this context on the basis of Plate 3 (in pocket), which extends an airline distance of about 75 miles and shows Douglas thicknesses within an approximately 50- to 62-foot range. Striking characteristics of Douglas Group rocks within the principal area of outcrop include: predominance of shale and sandstone; numerous facies changes and local disconformities; and the exceptional persistence of the relatively thin (generally 1.5 to 2.5 feet thick) Haskell Limestone.

Stranger Formation

Weston Shale Member

The term Weston Shale was first used by Keyes (1899, p. 300) for the shale section in the lower part of the Missouri River bluffs near Weston, Platte County, Missouri. The rock span to which the name Weston has been applied remains unchanged. An exposure (SW $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 31, T. 53 N., R. 35 W.; Pl. 16) is proposed as the type section.

Description of type section . -- The Weston aggregates about 59 feet of surprisingly uniform light bluish gray to medium bluish gray with greenish gray overtones, clayey, slightly silty shale. Ironstone nodules and concretions occur in the upper half of the member.



| Footage above base | Fossils | Clay minerals |
|--------------------|---|---|
| 55-59 | Brachiopods(P), same genera recorded as in preceding footage, also <u>Cancrinella</u> ; crinoid columnals and plates(A); gastropods(C); trilobites(C), genal spines, free cheeks, pygidia; ramose bryozoans(C); horn corals(S) | illite, kaolinite, illite-mixed layer clay, montmorillonite |
| 50-55 | Brachiopods(P), <u>Rhipidomella</u> , <u>Hustedia</u> , <u>Composita</u> , <u>Punctospirifer</u> , <u>Chonetes</u> , <u>Derbyia</u> , <u>Crurithyris</u> , productid spines and valve fragments; crinoid columnals and plates(A); gastropods(A); pelecypods(A); echinoid spines and plates(C); ramose bryozoans(C); trilobite fragments(S); fish teeth(S) | illite, kaolinite, illite-mixed layer clay, ?vermiculite |
| 45-50 | Brachiopod shell fragments and spines(P), <u>Crurithyris</u> ; crinoid columnals and plates(A); gastropods(C); pelecypods(S); ostracodes(C), <u>Bardia</u> ; bryozoans(C); echinoid spines(C) | |
| 35-45 | Gastropods(S) | |
| 10-35 | No fossils recorded from washings | |
| 5-10 | Arenaceous foraminifers(S), <u>Ammobaculites</u> , <u>Ammodiscus</u> ; ostracodes(S); pelecypods(S); gastropods(S) | |
| 0-5 | Arenaceous foraminifers(C), <u>Ammobaculites</u> , <u>Ammovertella</u> , <u>Ammodiscus</u> , ? <u>Bathysiphon</u> ; ostracodes(C); crinoid columnal and plate fragments(C); brachiopod valve fragments and productid spines(C) | |

PLATE 16. -- Type section of Weston Shale. Road cut exposure in SW $\frac{1}{2}$ SE $\frac{1}{2}$ NE $\frac{1}{4}$ sec. 31, T. 53 N., R. 35 W., Platte County, Missouri. (P), (A), (C), and (S) represent profuse, abundant, common, and sparse respectively and are notations of apparent relative abundance as visually estimated from binocular microscope study. Fossil identifications by R. R. West, geologist for Humble Oil and Refining Company and formerly at the University of Kansas.

Vertical distribution of fossils and clay minerals is shown (Pl. 16). Arenaceous foraminifers, ostracodes, fragmented crinoid columnals and plates, brachiopod valve fragments and productid spines are common in the lower 5 feet of the Weston. Arenaceous foraminifers, sparse ostracodes, sparse gastropods, and sparse pelecypods occur from 5 to 10 feet above the base of the member. The fauna from 10 to 45 feet above the base is negligible; only extremely sparse low-spired gastropods were recorded. Remains of brachiopods are profuse, those of crinoids and mollusks abundant, and those of bryozoans, echinoids, trilobites, and ostracodes common in the upper 14 feet of the Weston.

Clay mineralogy of the Weston is remarkably uniform vertically and comprises illite, kaolinite, illite-mixed layer clay, and ?vermiculite except in the upper 4 feet, which contains montmorillonite rather than ?vermiculite. There is no indication that the clay minerals differ relative to fossiliferous and apparently nonfossiliferous parts of the member.

The basal contact of the Weston is relatively sharp and the upper contact gradational.

Geographic, thickness, and facies range. -- With the exception of the area (see Fig. 8) in which the underlying South Bend Limestone is absent locally, the Weston Shale is essentially continuous throughout the study area. In the area in which the overlying Iatan Limestone is not identified (see Fig. 13), Weston top cannot be accurately traced and, where arbitrarily placed, represents more than one stratigraphic horizon. The procedure for classing the Weston where the Iatan is not recognized is shown on Pl. 2C (Ball and others, 1963) and comprises

either placement of its top at base of a massive sandstone or a coal, whichever is lowermost in local exposures, or combination of the term Weston- with the name of the next younger member whose top can be recognized. Where both the top of the underlying South Bend Limestone and the base of the overlying Iatan Limestone are identifiable, the Weston Shale ranges from a maximum known thickness of about 100 feet in northernmost Platte (see selected section 22 in appendix) and Buchanan (Howe and Koenig, 1961, p. 106) Counties, Missouri to a minimum of about 1 foot in southern Cass County, Nebraska (see selected section 3 in appendix). Howe and Koenig (ibid.) noted:

. . . the Weston . . . thickens from 60 feet in central Platte County to nearly 100 feet in Buchanan County and thence thins rapidly northward and westward to a thickness of only a few feet.

General but not perfectly progressive thinning to the north and to the west is a striking characteristic of the Weston. The member is a shale wedge generally thicker to the south and southeast and thinner to the north and northwest (see Plates 2 and 4, in pocket^{1/}). On Plate 3 (in pocket), the Weston is nowhere in excess of 6 feet thick and is generally less, a condition similar to that which obtains in the northwesternmost parts of Plates 2 and 4.

South of approximately the latitude of Leavenworth, Kansas the overlying Iatan Limestone is not recognized in outcrops. Within this area strata classed as Weston range from a featheredge to about 140 feet in thickness (see Wagner and Harris, 1953). Featheredge thicknesses

^{1/}In the interest of showing logs at the standard vertical scale of 1 inch equals 100 feet, only names of principal reference units are shown on Plates 2 to 9. The Weston Shale comprises the section between the South Bend and Iatan Limestones.

locally in southern Platte and Clay Counties, Missouri and Wyandotte, Leavenworth, Douglas, and Franklin Counties, Kansas result from erosional disconformity beneath the overlying Tonganoxie Sandstone. As noted above, the classificatory boundary between the Weston and the Tonganoxie does not define a single stratigraphic horizon across Kansas and into northern Osage County, Oklahoma. Local disconformity at the base of, and the lenticular and multiple character of sandstone parts of the Tonganoxie Sandstone preclude meaningful statement concerning thickness variation of the Weston within this part of the outcrop area. Where bounded by the Westphalia Limestone above, the shale-sandstone complex that includes the Weston below and the Tonganoxie above thickens from approximately 70 feet in central Leavenworth County, Kansas to approximately 210 feet in northern Osage County, Oklahoma (see diagrammatic illustration of section between the base of the Douglas Group and that of the Westphalia Limestone in Figure 11).

The Weston Shale displays a remarkable uniform facies along the principal outcrop area in Missouri, Kansas, and northern Osage County, Oklahoma. Shades of greenish gray, olive gray, and less commonly bluish gray, clayey shale form the Weston. Fissility is well developed throughout; mudstone was not observed. Discontinuous stringers of clay-ironstone concretions are common and are locally developed in all parts of the member. As at the type section the member is apparently more fossiliferous in its lower and upper parts at least locally. However, considering all available records, the Weston is known to be fossiliferous in all its parts in one place or another (see selected sections 3, 11, 12, 39 and 40 in appendix; Girty, in Hinds and Greene, 1915; Moore, 1922; Dunbar and

Condra, 1932; Newell, 1933; Patterson, 1933; Wagner and Harris, 1953; O'Connor, 1960; Ball and others, 1963; and numerous reconnaissance measured sections in files of the State Geological Survey of Kansas). Laborious cracking of clay-ironstone concretions yields extremely sparse pelecypod, brachiopod, and crinoid remains, which apparently represent the only marine megafossils known from the Weston locally. Large-volume washing and subsequent picking of fossils was not attempted in this study and until such painstaking study is done, concise and comprehensive statement of Weston Shale faunas cannot be made. Study of the small number of Weston samples washed during Patterson's 1933 study and during this study and observation of the cable tool cuttings described in the appendix indicates that the member will ultimately be known to contain abundant ostracodes and areanaceous foraminifers. Preliminary clay-mineralogical study of the Weston (selected sections 11, 39, and 40 in appendix) shows the consistent presence of illite, kaolinite, illite-mixed layer clay, and ?vermiculite.

Iatan Limestone Member

Keyes (1899, p. 300) applied the name Iatan to limestone cropping out at the foot of the Missouri River bluffs near Iatan, Platte County, Missouri. Until 1936 (Moore, p. 137) when its stratigraphic rank was elevated to that of formation, the Iatan was classed as a member. Since 1936 usage of the name has remained unchanged. A type section for the Iatan has never been designated. For this reason, the exposure (NW cor. NE $\frac{1}{2}$ SW $\frac{1}{2}$ sec. 19, T. 54 N., R. 36 E.) in the railroad cut at Iatan is proposed as a standard of reference.

Description of standard reference section. -- Two units are differentiated on the basis of outcrop, hand sample, and thin section study. Unit 1 (Pl. 17) consists of 8-9 feet of very thin- to thin- and irregularly-bedded mixed-fossil lime wackestone and mixed-fossil lime mudstone. Fresh and weathered surfaces are light gray mottled with light brownish gray. Long thin irregular veinlets and irregularly-shaped patches of clear calcite are differentially etched and so numerous that weathered surfaces are an identifying characteristic. Some of the veinlets are brachiopod valves, seen in section, but the vast majority are a laminar corraline alga, Archaeolithophyllum (identification by W. B. Howe). Fossil remains are not abundant. Productids, other brachiopods, corals, bryozoans, crinoid stem fragments, and minute gastropods are sparse to common throughout the rock and numerous fusulinids are concentrated on bedding surfaces in the upper half foot. Composita, Phricidothyris, Cancrinella, Derbyoides, Punctospirifer, marginiferids, and Naticopsis were identified.

It can be seen petrographically that this unit consists of medium to coarsely crystalline sparry calcite fossils in a matrix of finely crystalline to aphanocrystalline calcite. Fossils amount to about 10-15 percent of the rock. Extremely sparse clay minerals and quartz silt particles form a negligible percent of the rock.

The upper unit (2, Pl. 17) comprises 2-3 feet of light olive gray, mixed fossil lime wackestone, which weathers light gray, and is a single thick bed. Texture of the upper unit contrasts to that of the lower unit by lacking numerous algal veinlets and relatively large unbroken shell fragments. Medium sand to granule-size fossil debris and sparse

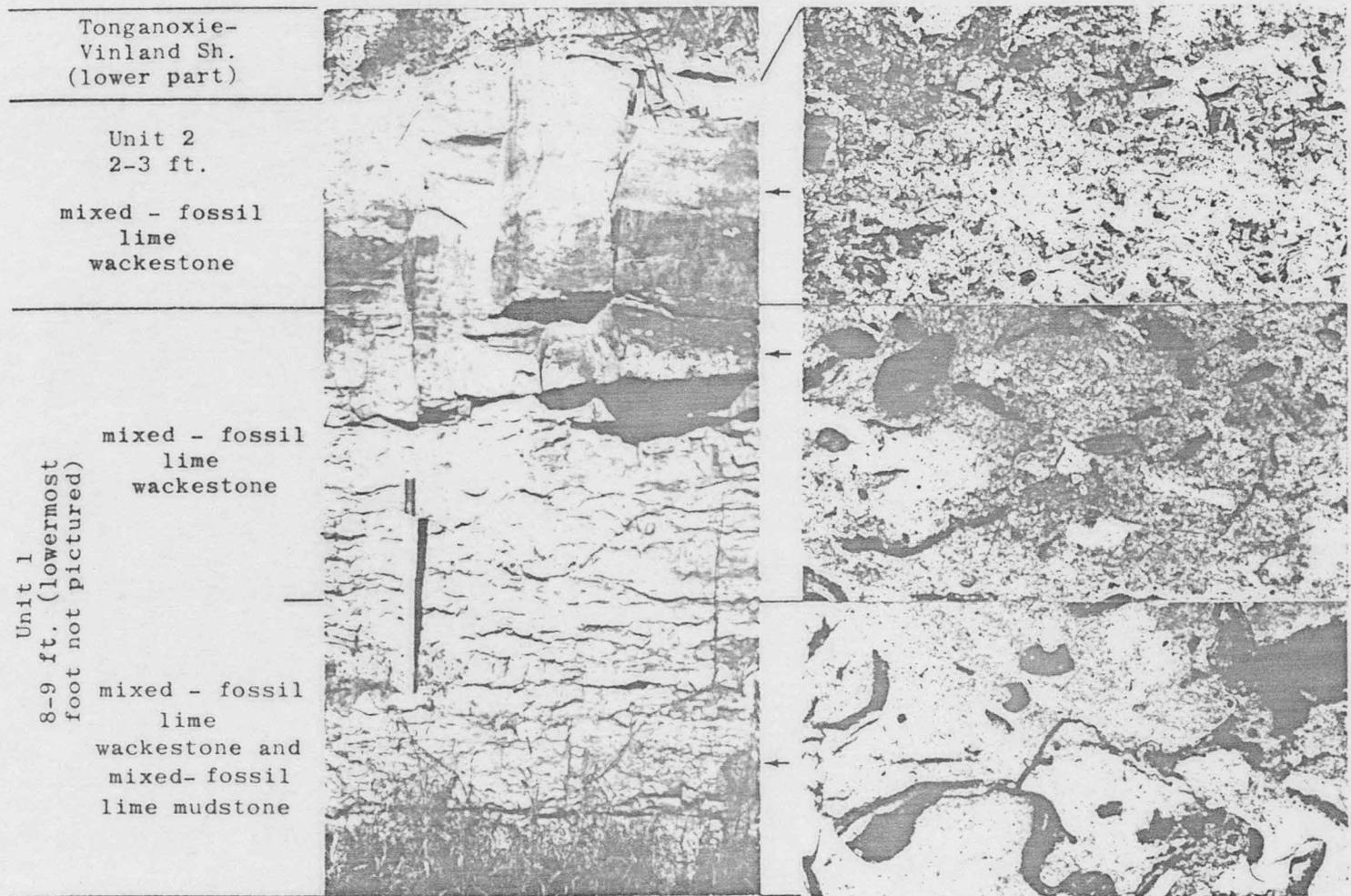


PLATE 17.-- Standard reference section of Iatan Limestone. Railroad cutbank exposure at NW corner NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 54 N., R. 36 W., Platte County, Missouri. Negative prints of thin sections (X3) on right. Arrows show exact positions of samples chosen as representative of the footages indicated and described in text. Vertical surfaces, orientation as shown.

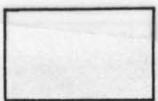
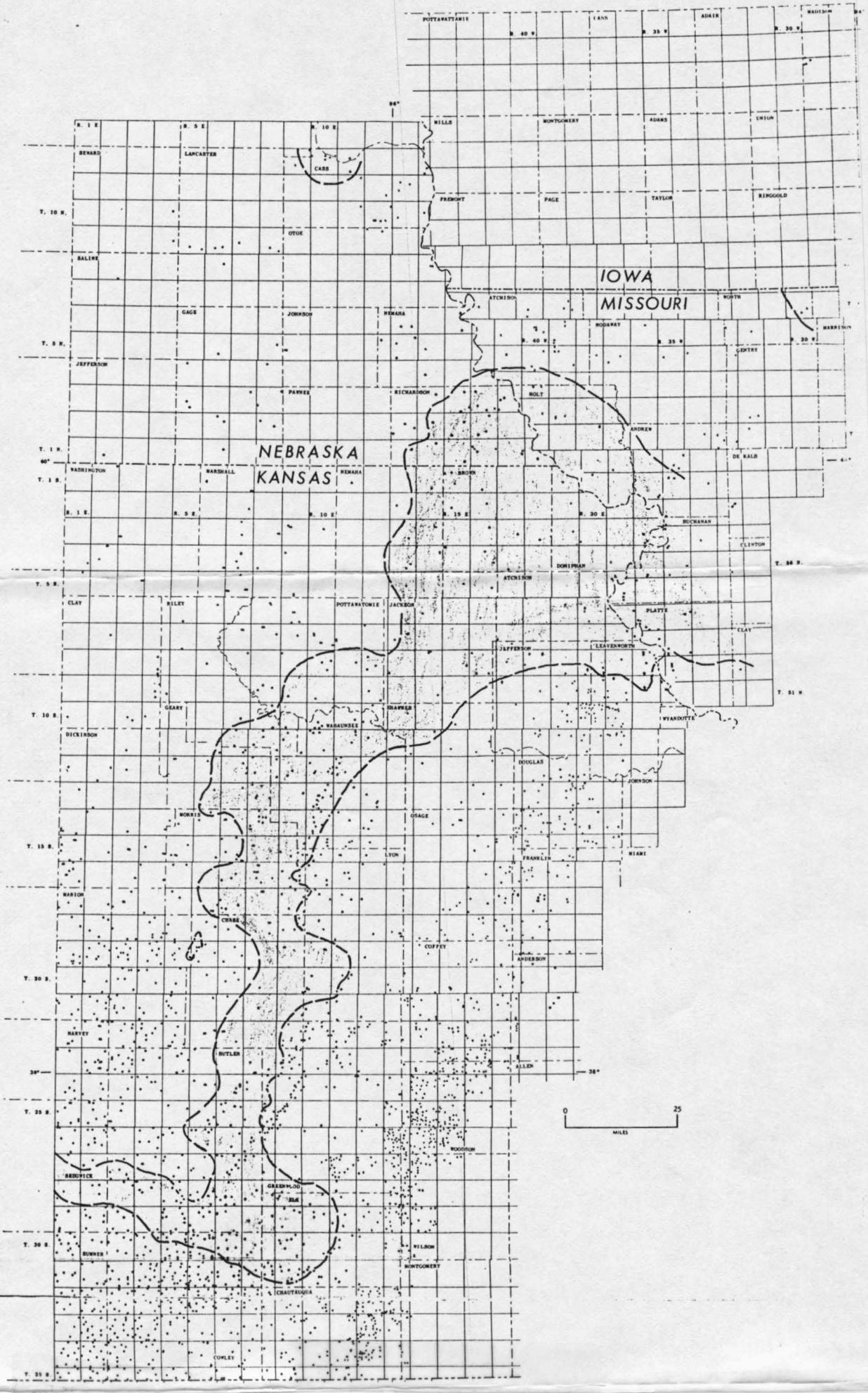
fusulinids are embedded in a dense matrix. Crinoid, algal, brachiopod, fusulinid, and bryozoan remains, in order of relative abundance, were noted.

In thin section, it can be seen that about 10-15 percent of the rock is composed of fossils and extremely sparse coarse silt- to fine sand-size quartz particles. The matrix is made up of lime mud and ferruginous material.

This exposure is not an ideal standard of reference because the basal part of the formation is not exposed. However, in the vicinity of Iatan there are no known exposures in which both base and top of the formation as well as overlying and underlying strata can be studied. By comparison of sections composited near Iatan, total thickness of the Iatan is estimated at 13 to 14 feet. Therefore approximately the basal 2 feet are not included in the standard reference section.

Geographic, thickness, and facies range. -- A distribution map of the Iatan Limestone is shown as Figure 13. The Iatan is not recognized in the southeastern part of the study area but is essentially continuous in the northwestern part of the area. In broad areas of the subsurface the underlying Weston Shale is relatively thin (see the northwestern part of Plates 2 and 4, Pl. 3, and the westernmost parts of Plates 5 and 6). Where this condition prevails, it has been the common practice of several geologists to class the limestone unit herein referred to the Iatan with Lansing rocks.

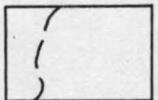
South of approximately the latitude of Leavenworth, Kansas, approximately $39^{\circ}18'N$, the Iatan Limestone is not recognized in surface outcrops. Along Missouri River the member is well exposed locally from Leavenworth,



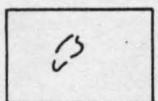
Area of general continuity.



Area of discontinuity.



Limit of areas in which not identified and believed to be absent.



Area in which not identified and believed to be absent.

FIGURE 13.-- Distribution map of the Iatan (Nehawka) Limestone. The sub-surface of southwestern Iowa was not studied. See Figure 1 for qualification of control points. Outcrops of the Iatan have not been definitely identified south of Township 8 South in Kansas.

Kansas to approximately 0.5 mile north of Iatan, Missouri. The excellent geologic map published in the Leavenworth-Smithville folio (Hinds and Greene, 1917) is reproduced as Figure 14 because it accurately portrays areal distribution of the Iatan Limestone in the area of its best exposures. The heavy black solid-line contact is the map trace of Iatan base. Top of the Iatan passes beneath Missouri River alluvium in southeasternmost Atchison County about one-third mile farther northwest than its base (near center NE $\frac{1}{4}$ sec. 19, T. 7 S., R. 22 E.) and is not exposed farther north in Kansas. Thus, the Kansas part of the map trace represents virtually the entire extent of outcrop in that state. Farther north in Missouri to at least west-central DeKalb County the Iatan is exposed in disconnected outcrops between areas in which the member is covered by glacial drift.

Best Nebraska exposures of the Iatan (Nehawka) Limestone are located in a small area northwest of Nehawka in south-central Cass County (e.g., W $\frac{1}{2}$ sec. 6, T. 10 N., R. 13 E., and NE $\frac{1}{4}$ sec. 12, T. 10 N., R. 12 E.). The member is generally present in this area but was observed farther north only along the north side Platte River (Pl. 18D in pocket and selected section 2 in appendix) in Sarpy County.

The Iatan Limestone was not definitely recognized in Iowa exposures.

According to Howe and Koenig (1961, p. 108) maximum thickness of the Iatan is more than 15 feet in west-central Platte County, Missouri. Twelve exposures in Missouri, 4 exposures in Kansas, and 6 exposures of the member in Nebraska were studied. Thickness of the Iatan ranges from about 17.5 feet (Pl. 18A) to about 4.5 feet in the exposure north of Clarksdale in DeKalb County, Missouri (Pl. 18B). Thicknesses of the

Leavenworth Quadrangle
Kansas-Missouri



Smithville Quadrangle
Missouri



FIGURE 14.-- Surface distribution of the Iatan Limestone within its type area and area of best exposures. Iatan trace shown by heavy black lines. Areal geologic map from Hinds and Greene (1917).

member within the subsurface generally are in this range with the exception of the southernmost part of Iatan extent, that is, especially southern Sedgwick, southern Butler, northeasternmost Cowley, and west-central Elk Counties, Kansas, where thicknesses of approximately 30 feet are commonly developed (Pl. 7). Because of thinness of intervening shales, it is extremely difficult locally to differentiate Iatan from both the next younger limestone, the Westphalia, and the next older limestone, the South Bend. Winchell (1957, p. 136) recorded a 40-foot thickness for what he called the Westphalia. I am not aware of any record, either surface or subsurface, of more than 10 feet of Westphalia Limestone. It is probable that the 40-foot thickness of Westphalia recorded by Winchell includes the Iatan and may include also the Haskell for Winchell (*ibid.*) wrote:

For purposes of correlation in this report, the Westphalia is combined with the Haskell to form a unit collectively called the Haskell.

Other geologists (e. g., Adkison, 1963, cross section 28, logs 14 to 19) have grouped the unit which I regard as the Iatan with Lansing rocks in this area.

Facies as developed in four areas are described and considered representative of Iatan outcrops. Rock types present in the standard reference section of the Iatan are generally representative of Platte and southern Buchanan Counties, Missouri and Kansas exposures. The only marked variation is in the topmost bed, which locally is a fusulinid lime packstone containing abundant coated grains (Pl. 18A, in pocket). Some of the coatings are Osagia but are thinner and not as striking as are the Osagia-coated grains in the Iatan farther north (Pl. 18B).

From central Buchanan County to west-central DeKalb County, Missouri (Pl. 18B, in pocket), prominence of coated grains, lack of irregular bedding, thinness, and presence of interbedded calcareous shale or shaly limestone are noteworthy facies changes (compare Plates 17 and 18).

The brachiopod lime mudstone facies of the Iatan (Nehawka) Limestone (Pl. 18C) developed in the vicinity of Nehawka, Cass County, Nebraska, weathers into irregularly elongate pieces of limestone that impart a false aspect of brecciation to weathered surfaces. This weathering characteristic has been noted by others (e.g., Condra and Reed, 1943, p. 50 and Howe and Koenig, 1961, p. 108), is moderately developed in unit 1 of the standard reference section (Pl. 17), and is well developed in exposures along Missouri River bluffs for about 0.5 mile south from the type section of Weston Shale (Pl. 16). Extremely sparse productid brachiopods were the only fossils observed in the upper 4 feet of the Iatan northwest of Nehawka. The basal 1 foot of the member there is slightly more fossiliferous and contains sparse crinoids and pelecypods.

The Iatan Limestone was not recognized in bluff exposures along the south side of Platte River, but shows the stratigraphic relationships illustrated as Plate 18D (in pocket) along the north side of the Platte River in Sarpy County, Nebraska.

Tonganoxie Sandstone Member

The Tonganoxie Sandstone (Moore and others, 1934; see Moore, 1936, p. 147) was named for quartzose sandstone outcrops east of Tonganoxie in Leavenworth County, Kansas. Neither a type nor a standard reference section has ever been designated for the member and neither is designated

in this report. Rather, the Tonganoxie in its type area, southern Leavenworth County, Kansas, is described and sections showing aspects of the member elsewhere are either described or referred to.

Within the type area, a complete section of the Tonganoxie Sandstone was not observed at a single locality. Because of general absence of the overlying Westphalia Limestone and local absence of the topmost bed, the Upper Sibley coal, of the Tonganoxie, top of the member is commonly indeterminable in the northern half of T. 11 S., R. 21 E. Where such stratigraphic relationships obtain, strata between Tonganoxie Sandstone and Haskell Limestone bases are classed as the Tonganoxie-Vinland Member. In T. 11 S., R. 21 E., the basal contact of the Tonganoxie Sandstone is generally disconformable and overlies either lower parts of the Weston Shale or some part of the South Bend Limestone. A geological plan and profile^{1/} prepared by geologists of the Kansas State Highway Commission infers that through an east-west distance of 6 miles (from near SE corner sec. 1, T. 11 S., R. 21 E., Leavenworth County, Kansas to the SE corner sec. 1, T. 11 S., R. 22 E.) the base of the Tonganoxie is in contact with some part of the South Bend Limestone. For an additional distance of 2 to 3 miles eastward, the same stratigraphic relationship is confirmed in numerous exposures. Thus, in an 8- to 9-mile distance, base of the Tonganoxie ranges through about 7 feet of section. This is, of course, an extreme case of the planar character of the locally disconformable

^{1/}Project 24-52. Commonly these profiles represent geologic data that cannot be duplicated by the field geologist unless drilling is available, which is rarely the case. Hence, the profiles are an extremely useful type of data. In some cases, stratigraphic names used on the profiles do not agree with those applied by the stratigrapher who is necessarily more concerned with such matters. The limestone shown along the south line of sec. 3, T. 11 S., R. 21 E., of this profile and called Amazonia is the Haskell Limestone.

contact at the base of the Tonganoxie Sandstone. Nonetheless, it should be stressed that, in southern Leavenworth County, no more than a possible maximum of 50 feet of relief in a 4- to 5-mile distance can be demonstrated for the disconformable basal contact of the Tonganoxie.

The section illustrated as Figure 15 was prepared from measured sections and the Highway Commission profile (mentioned above) along U. S. Highway 24-40 east of Tonganoxie. The Tonganoxie-Vinland Member is approximately 150 feet thick (allowance made for an average 10 feet per mile west component of dip), forms the entire Stranger Formation, and is predominantly quartzose sandstone and siltstone. Size of quartz particles ranges from predominantly fine- to very fine-grained sand to silt upward. In each sample, 95 or more percent of the quartz grains represent only 2 grades of Wentworth's particle-size classification and in each case the size grade given first in descriptions (Fig. 15) is strikingly predominant. The quartz particles are subangular to subrounded, elongate to equant, commonly contain impurities, and some grains show quartz overgrowths. Most grains exhibit uniform extinction under crossed nicols but some show a mosaic pattern and may be metaquartzite. Mica flakes form from about 3 to about 10 percent of the thin sections from this locality; higher parts of this percentage range characterize the younger, finer-grained parts of the member. Trace amounts to about 3 percent feldspars and trace amounts of unidentified heavy minerals are the other grains present. Silica is the main cementing material, but ferruginous material is present both as a cement and as a stain on quartz grains. The sandstones and siltstones are micaceous subgraywacke. According to Folk's (1951, p. 127-128) concept of textural maturity stages

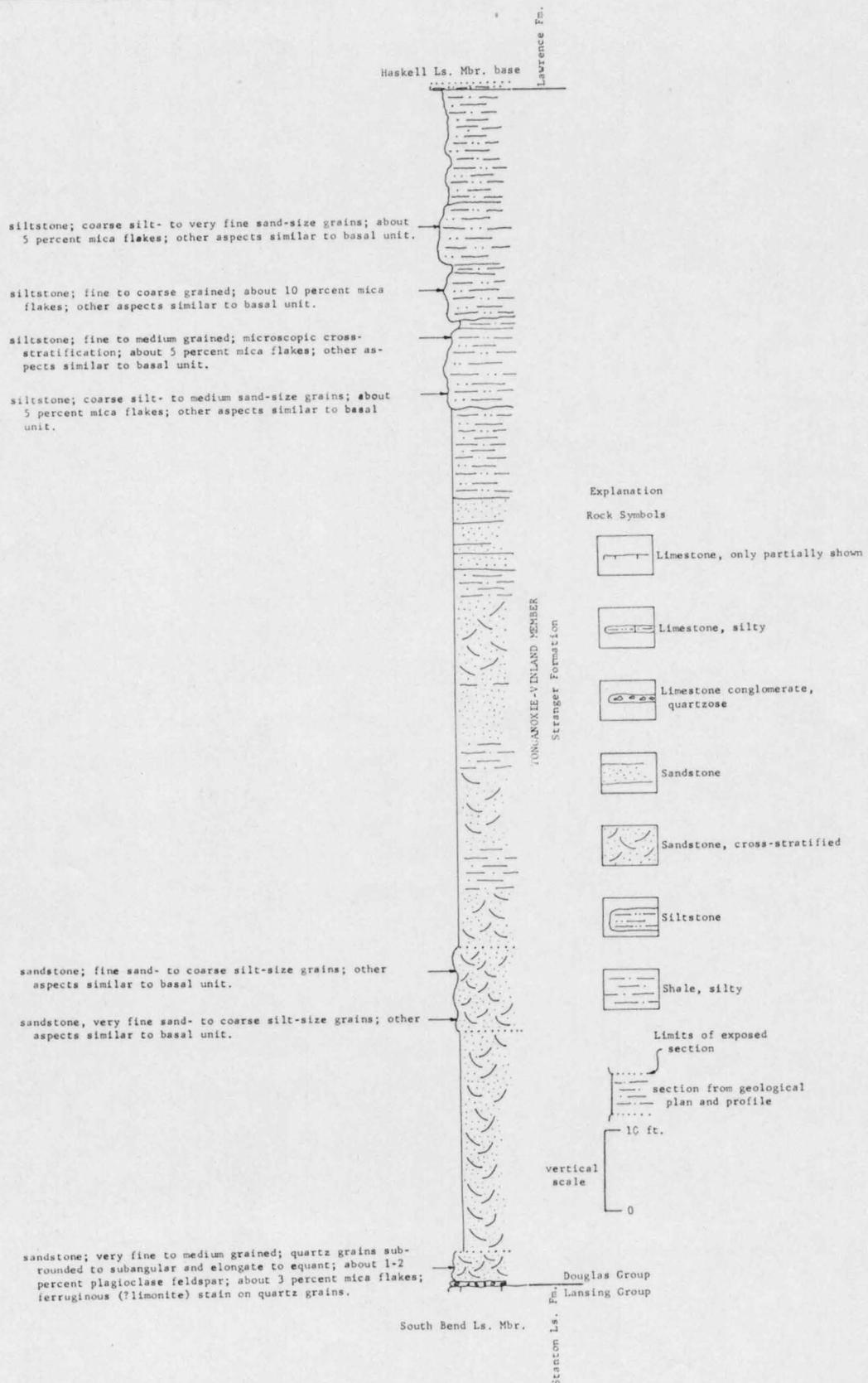


FIGURE 15.-- Generalized stratigraphic section of the Tonganoxie Sandstone in its type area. Section composed from a geological plan and profile (Kansas State Highway Commission, Project 24-52) and exposures along U. S. Highway 24-40 between south line SE $\frac{1}{4}$ sec. 3, T. 11 S., R. 21 E. and south line SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 1, T. 11 S., R. 22 E., Leavenworth County, Kansas. Arrows indicate stratigraphic position of samples thin sectioned.

these samples class as mature. Sparse poorly preserved plant fossils were noted in some hand samples but did not appear to be characteristic of any part of the member. Invertebrate fossils were observed only in the basal conglomerate.

Elsewhere in Leavenworth County the upper part of the Tonganoxie Sandstone is commonly shale and the member is bounded above by the top of the Upper Sibley coal. This coal, although locally absent, is an important stratigraphic marker from southernmost Buchanan County, Missouri to northernmost Franklin County, Kansas. It is easily located and identified by stratigraphic position immediately below the Westphalia Limestone or, where this limestone is absent, by position relative to either the zone of septarian limestone nodules or the molluscan zone in the overlying Vinland Shale or to the Haskell Limestone (Fig. 16).

Among the sedimentary structures developed in the Tonganoxie only bounding contacts and contacts between the different lithologies within the member were studied in a detailed manner. Contact relationships are discussed in the Historical Geology part of the report. General aspects of sedimentary structures of the Tonganoxie include: trough-type cross stratification or massive splitting in sandstone parts of the member; regularly very thin- to thin-bedded sandstones; regularly laminated to very thin-bedded siltstones; asymmetrically ripple-marked sandstones and siltstones; and microscopic lamination and cross lamination in both sandstones and siltstones. From central Woodson County, Kansas to northern Osage County, Oklahoma^{1/}, such structures as contorted bedding, flow casts,

^{1/}To southern extent (sec. 4, T. 27 N., R. 11 E.) of overlying Westphalia Limestone. South of the area of distribution of the Westphalia application of the name Tonganoxie is not desirable.

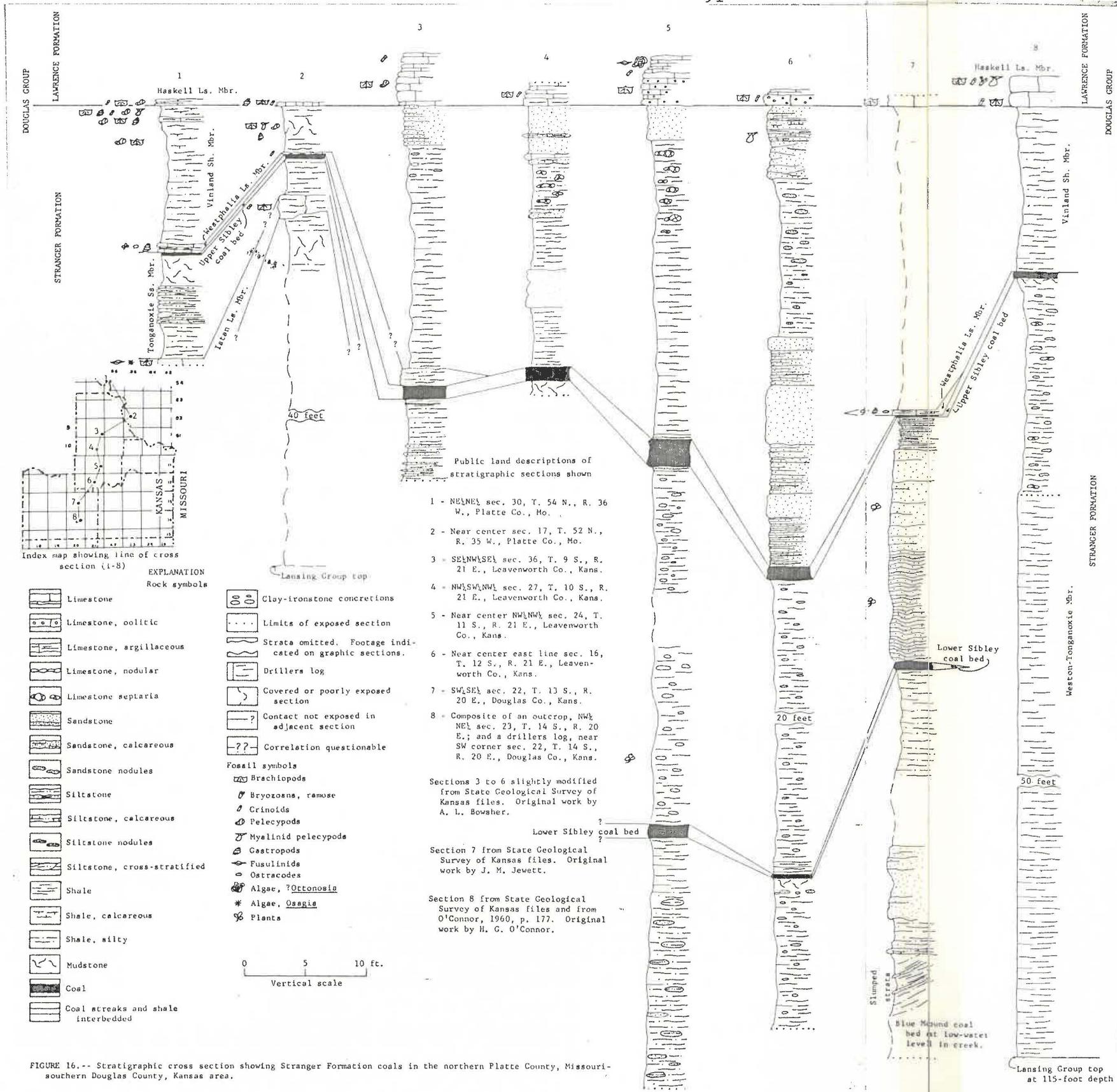


FIGURE 16.-- Stratigraphic cross section showing Stranger Formation coals in the northern Platte County, Missouri-southern Douglas County, Kansas area.

tadpole nests (interference ripples), and bottom markings were observed in various parts of the Tonganoxie. Descriptions of sedimentary structures were given by Lins (1950, p. 122-123), Bower (1959, p. 10-12), and Tanner (1956) in his description of the Bigheart, Revard, Possum, Mission, and Cheshewalla sandstones.

As far north as an east-west "line" defined approximately by Leavenworth, Kansas and East Leavenworth, Nashua, and Linkville, Missouri; and as far south as T. 14 S., Douglas County, Kansas, surface stratigraphy and facies of the Tonganoxie are similar to the section (Fig. 15) described above. Thus, the southern Platte and Clay Counties, Missouri, Leavenworth and northern Douglas Counties, Kansas area is predominantly one of sandstone-siltstone development with lesser amounts of shale, conglomerate, and coal.

Northward in Missouri and Kansas exposures, shale is the principal rock type, siltstone is minor and sandstone is negligible in the Tonganoxie or the Tonganoxie-Vinland parts of the section. I did not observe sandstone, siltstone, or coal within the Stranger Formation in Nebraska or Iowa.

From T. 14 S., R. 20 E., Douglas County to T. 17 S., R. 19 E., Franklin County, only minor amounts of sandstone are present in the Tonganoxie.

Stratigraphy of the Tonganoxie from T. 17 S., R. 19 E., Franklin County to T. 20 S., R. 18 E., Anderson County is generally similar to the type area. However, notable differences include: (1) a generally gradational, rather than sharp basal contact; (2) an approximate maximum 35- to 40-foot sandstone thickness, rather than an aggregate 70- to 75-foot sandstone thickness; and (3) virtual absence of the Upper Sibley coal bed. For detailed description of rock types that form the Tonganoxie Sandstone in

the southern Franklin County-northernmost Anderson County area, the reader is referred to Ball and others (1963, p. 23-25 and Lineback, 1961, p. 38-39).

Except locally in southernmost Anderson County, sandstone is an inconspicuous part of the Tonganoxie Member from T. 20 S., R. 18 E., Anderson County to T. 26 S., Rs. 15 E. and 16 E., Woodson County. The member is predominantly a silty shale-siltstone facies in this area. Because of the paucity of sandstone and its restriction to the uppermost part of the Weston-Tonganoxie sequence, the main escarpment is that formed by the sandstone and the Westphalia Limestone, which is commonly but not ubiquitously in immediate contact above. This escarpment is not topographically prominent because combined thickness of the sandstone upper part of the Tonganoxie and the Westphalia does not exceed 20 feet and is commonly about 10 to 12 feet. At some localities (e.g., exposures in sec. 19, T. 20 S., R. 18 E., near center sec. 12, T. 21 S., R. 17 E. and log 15 in appendix), sandstone in the Tonganoxie is negligible. Because of remarkably subdued topography developed on the dominantly shale and silty shale section between top of South Bend and base of Westphalia Limestones, only the upper 10 to 30 feet of this part of the Stranger Formation is well-exposed, and this part only locally, in the Anderson-northern Woodson Counties area. Gradation from clayey shale of the Weston upward through silty shale, then interbedded silty shale and siltstone to sandstone of the Tonganoxie characterizes this area. Gross lithology of the sandstone and siltstone parts of the member are not noticeably different than corresponding rock types farther north or farther south (see Wagner and Harris, 1953; Wagner, 1954; and Wagner, 1961). Prevalence of

very thin and thin regular bedding in the massive sandstones contrasts with characteristic cross-stratification in the massive sandstones farther north. Although finely macerated carbonaceous particles and poorly preserved plant fossils are common in the sandstone parts of Tonganoxie outcrops south of central Anderson County, the absence of coal beds is striking. Excepting mention by C. C. Branson (personal communication, 1962) of a coal bed^{1/} present locally below the Westphalia (Bowring) Limestone near the town of Bowring in northeastern Osage County, Oklahoma, no records of coal beds in outcrops of the Stranger Formation south of southern Anderson County, Kansas are known currently.

From T. 26 S., Rs. 14 E. to 16 E., Woodson County, to T. 28 S., R. 14 E., Wilson County, the general sequence and the commonly gradational Weston-Tonganoxie contact, described above for the Anderson-northern Woodson County area, prevails. At one locality (SE corner sec. 28, T. 26 S., R. 15 E.), massive sandstone of the Tonganoxie overlies the Weston Shale disconformably. Representative development in the Woodson County part of this area is described as selected sections 42 and 43 in the appendix. In the northern Wilson County part of the area silty shale and siltstone are the predominant rock types in the Tonganoxie. Minor amounts of very fine-grained quartzose sandstone in very thin and thin regular beds is present. Current ripple marks are common and characteristic. Douglas rocks as exposed in Wilson County are admirably described by Wagner and Harris (1953) and mapped (Wagner, 1954, 1961) in the Fredonia and Altoona quadrangles, which cover the northern two-thirds of Wilson County.

^{1/}This coal bed is apparently extremely local, is associated with the Cheshewalla Sandstone, and was not observed by me in exposures studied in the vicinity of Bowring.

In T. 29 S., Rs. 13 E. and 14 E., massive cross-stratified quartzose sandstone of the Tonganoxie overlies siltstone in some exposures and silty shale in other exposures. The two rock types are characteristically separated by sharp erosional contact and basal conglomerate is commonly developed in the massive sandstone (see Wagner and Harris, op. cit.). This erosion surface affords practical placement of the boundary between Weston Shale and Tonganoxie Sandstone in this area. A generalized stratigraphic section of the Stranger Formation in Township 29 South is shown as Figure 17.

The Tonganoxie Member comprises largely silty shale and lesser amounts of sandstone in Townships 30 and 31 South.

South of Salt Creek (northern part of T. 32 S.) in Montgomery County exposures, in Chautauqua County exposures, and in Osage County, Oklahoma exposures of the Tonganoxie as far south^{1/} as the vicinity of Bowring, very fine- and fine-grained, massive, quartzose sandstone is characteristically the most striking rock type present. The vicinity of Niotaze and Peru (Township 34 South, Chautauqua County, Kansas) is apparently the only part of this southernmost Kansas-northernmost Oklahoma outcrop area in which sandstone is not well-developed in the Tonganoxie. However, throughout most of this area identification of the Tonganoxie part of the section is difficult because: (1) prominent sandstones are developed within shale of Weston lithology; (2) sandstones of the Stranger Formation

^{1/}Application of the term Tonganoxie south of the southern extent of the overlying Westphalia (Bowring) Limestone is not desirable. Usage of the name Tonganoxie is desirable as applied to the upper part of the section bounded below by the South Bend (Birch Creek of Oklahoma terminology) Limestone below and the Westphalia Limestone above. In Oklahoma, the shale-sandstone complex comprising the Bigheart Revard, Possum, Mission, and Cheshewalla sandstones and interbedded shales is correlative with the Tonganoxie.

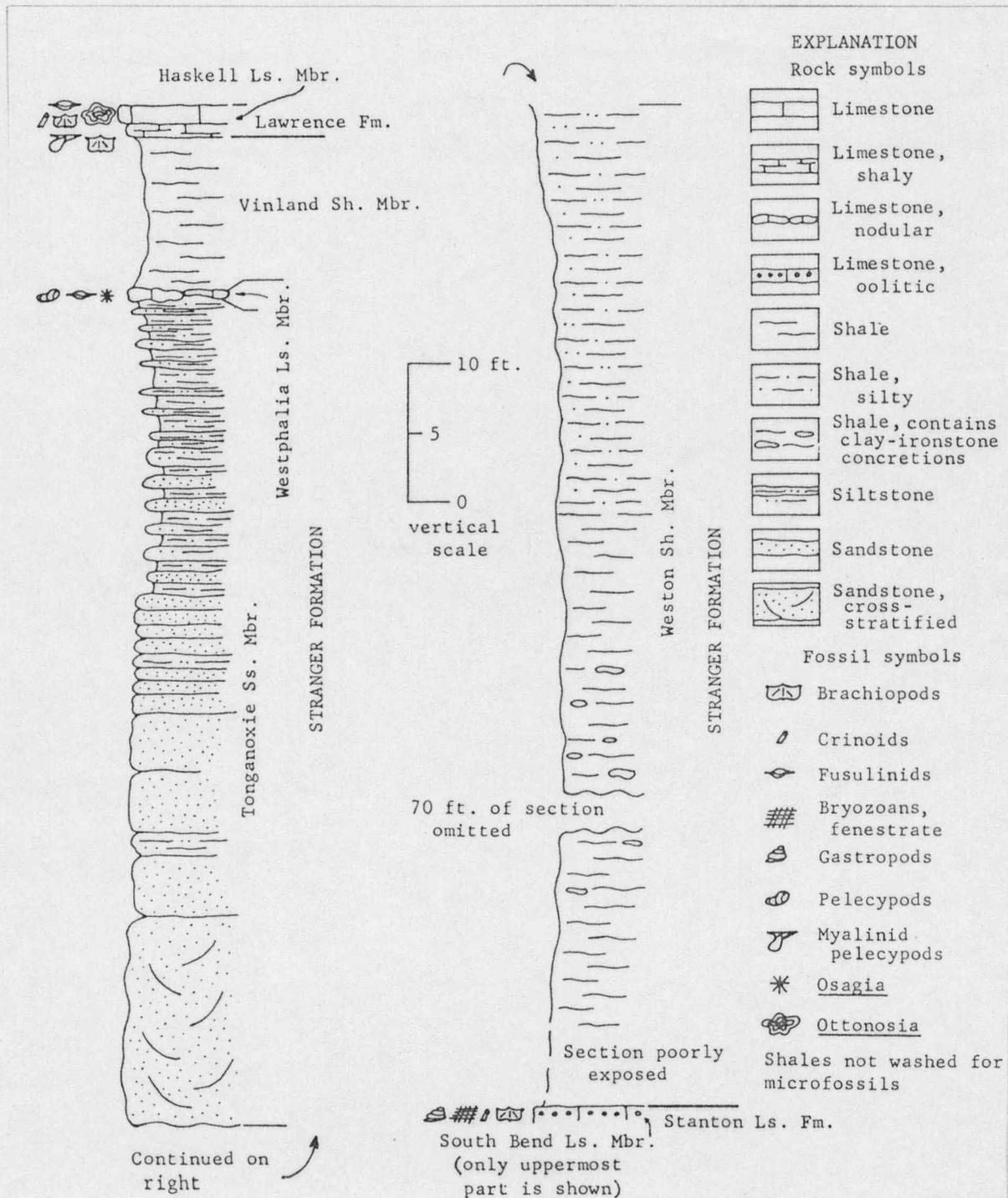


FIGURE 17.--Generalized stratigraphic section of the Stranger Formation in Township 29 South, Ranges 13 and 14 East, Wilson County, Kansas. Drawn from data collected by N. D. Newell (open files of State Geological Survey of Kansas), Wagner and Harris (1953), and during the course of this study.

are numerous and discontinuous; and (3) the overlying Westphalia (Bowring) Limestone is generally absent and is by no means continuous as reported by Tanner (1956, Pl. 1). Therefore, where the confining marker units, the South Bend (Birch Creek) Limestone below and the Westphalia (Bowring) Limestone or its approximate stratigraphic position (top of Cheshewalla sandstone) above can be identified, thickness of the Weston-Tonganoxie part of the Stranger Formation ranges from approximately 120 feet (T. 32 S., Rs. 13 E. and 14 E., Chautauqua and Montgomery Counties, Kansas) to approximately 250 feet (T. 26 N., Rs. 11 E. and 12 E., Osage County, Oklahoma). Sandstone parts of the Weston-Tonganoxie interval locally aggregate as much as approximately 100 feet of section and are concentrated in the middle and upper parts of the sequence (Fig. 11). Over-all, but not perfectly progressive thickening southward is noteworthy.

The northeastern Osage County, Oklahoma, part of the outcrop area contains the only exposures known to me in which sandstone parts of the Tonganoxie yield locally abundant indigenous marine invertebrates. Fauna of the Tonganoxie is discussed in the depositional environments part of the section on Historical Geology.

It should be pointed out that thicknesses reported for shale-sandstone complexes in the literature on northeastern Osage County, Oklahoma do not, for the most part, represent extremely accurate measurements of single exposures. Such thicknesses are as a rule composited over 2- to 4-mile distances and are subject to appreciable error. The extremely discontinuous nature of limestone reference units precludes anything but a crude approximation of local dip variation. Facies changes and erosional contacts, both of which characterize the sandstones in the section makes the

sandstones poor reference units. Thicknesses in excess of 100 feet that are reported for this area are, at most, 75 percent accurate even though such thicknesses were plane tabled and adjusted for dip estimations. Thicknesses of section between the Birch Creek and Bowring Limestones as reported by Tanner (1956, Fig. 1) are excessive. It is unreal and therefore misleading to depict contacts of lensing limestones or sandstones as solid lines entirely, or even nearly so, across map areas such as northeastern Osage County (see Tanner, op. cit., Pl. 1). Commonly in areas of thick sandstone development in the Tallant Formation the predominantly shale Barnsdall Formation is correspondingly thin. During this study a 72-foot thickness for the Barnsdall Formation as mapped by Tanner was plane tabled (NE $\frac{1}{4}$ sec. 15, T. 26 S., R. 11 E.). Thickness range given for the Barnsdall on Figure 1 (referred to above) is 130 to 160 feet. It so happens that the Tallant overlies the Barnsdall disconformably in this area as evidenced by the conglomerate exposed locally (e.g., in SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10, T. 26 S., R. 11 E.). This discussion is not meant to be critical of Tanner, for he (op. cit.) made many pertinent observations. Nonetheless, summation of maximum mapped thicknesses of dominantly sandstone and dominantly shale parts of shale-sandstone complexes reported as representative thickness of the combined sequence is inevitably misleading.

Summary. -- Except in areas where both the Iatan and Westphalia Limestone are absent (Iowa and locally in Nebraska) and sandstones within the member are not developed or cannot be accurately traced (locally in Montgomery and Chautauqua Counties, Kansas and northeastern Osage County, Oklahoma), the term Tonganoxie is applicable throughout surface parts of

the study area as far south as Township 26 North in Osage County, Oklahoma. Thickness range of the member based on measurements from exposures in which both contacts are objective features^{1/} is from about 9 feet in Platte County, Missouri to approximately 150 feet in northeastern Osage County, Oklahoma (selected sections 12 and 65 in appendix). Thickness variations result from the variable development of sandstone parts of the member.

In its type area, the Tonganoxie is mainly very fine- to fine-grained, cross-stratified, quartzose sandstone. However, considering the entire outcrop area, silty and clayey shales are the principal rock types in the member. Surface areas of maximum sandstone development in the member include southern Platte and Clay Counties, Missouri; southern Leavenworth and northern Douglas Counties, Kansas; southern Montgomery and Chautauqua Counties, Kansas, and northeastern Osage County, Oklahoma. Sandstones of the Tonganoxie are subgraywackes and the petrography as currently known is monotonously consistent.

Regular very thin and thin bedding is characteristic but trough-type cross bedding and current ripples are prominent and striking locally. Lamination and cross lamination was observed locally in the field and noted commonly in thin sections. W. K. Hamblin (report in preparation and personal communication, 1962) has found a variety of micro-structures in sandstones of the Tonganoxie. Other structures such as flow casts, interference ripples, and bottom markings were noted. None of the sedimentary structures of the Tonganoxie Sandstone have been adequately studied.

^{1/} Basal contact placed either at top of Iatan Limestone or at a sharp contact between coal, sandstone, or conglomerate and older strata. Upper contact placed at base of Westphalia Limestone or at top of Upper Sibley coal bed.

Fossils in the member comprise mainly land plant remains and sparse, apparently reworked, marine invertebrates. However, apparently indigenous marine invertebrates are known from: (1) siltstone in the lower part of the member at a single locality in Leavenworth County, Kansas; (2) greenish-gray mudstone at a single locality in Platte County, Missouri; (3) silty shale in the uppermost part of the member at several localities; and (4) in abundance from sandstone, siltstone, and shale parts of the member in northeastern Osage County, Oklahoma (see discussion of depositional environments in section on Historical Geology). Comprehensive search for and study of marine invertebrates in the Tonganoxie has not been conducted. Plant fossils from some northeastern Kansas exposures of the member are well known as the result of work by Cridland and others (1963).

Bounding contacts are characteristically gradational. All workers agree that sandstone parts of the member grade laterally and vertically into finer-grained rocks. Although apparently true, such lateral gradation is a purely objective feature in only a few localities. Basal contacts are commonly either sharp or gradational. Where sharp, the basal contact is locally disconformable.

I was unable to trace the Tonganoxie in the subsurface accurately. However, the Stranger Formation, which contains appreciable sandstone and siltstone (characteristically within the Tonganoxie Member and locally within the Vinland and Weston Members) along the outcrop as far north as southern Platte and Clay Counties, Missouri, contains little or no sandstone and siltstone in the area in which the formation is less than 50 feet

thick (Fig. 18). The reason that the Stranger is wedge-shaped^{1/} (thinner to the north and northwest and thicker to the south and southeast) is the presence of a large volume of sandstone unevenly distributed in the southern and southeastern parts of the study area. Areas of maximum sandstone^{2/} development in the Stranger are within the area in which the formation exceeds 100 feet in thickness (Fig. 18). Hence, the Tonganoxie Member is a predominantly shale and sandstone unit generally thicker to the south and southeast and thinner to the north and northwest.

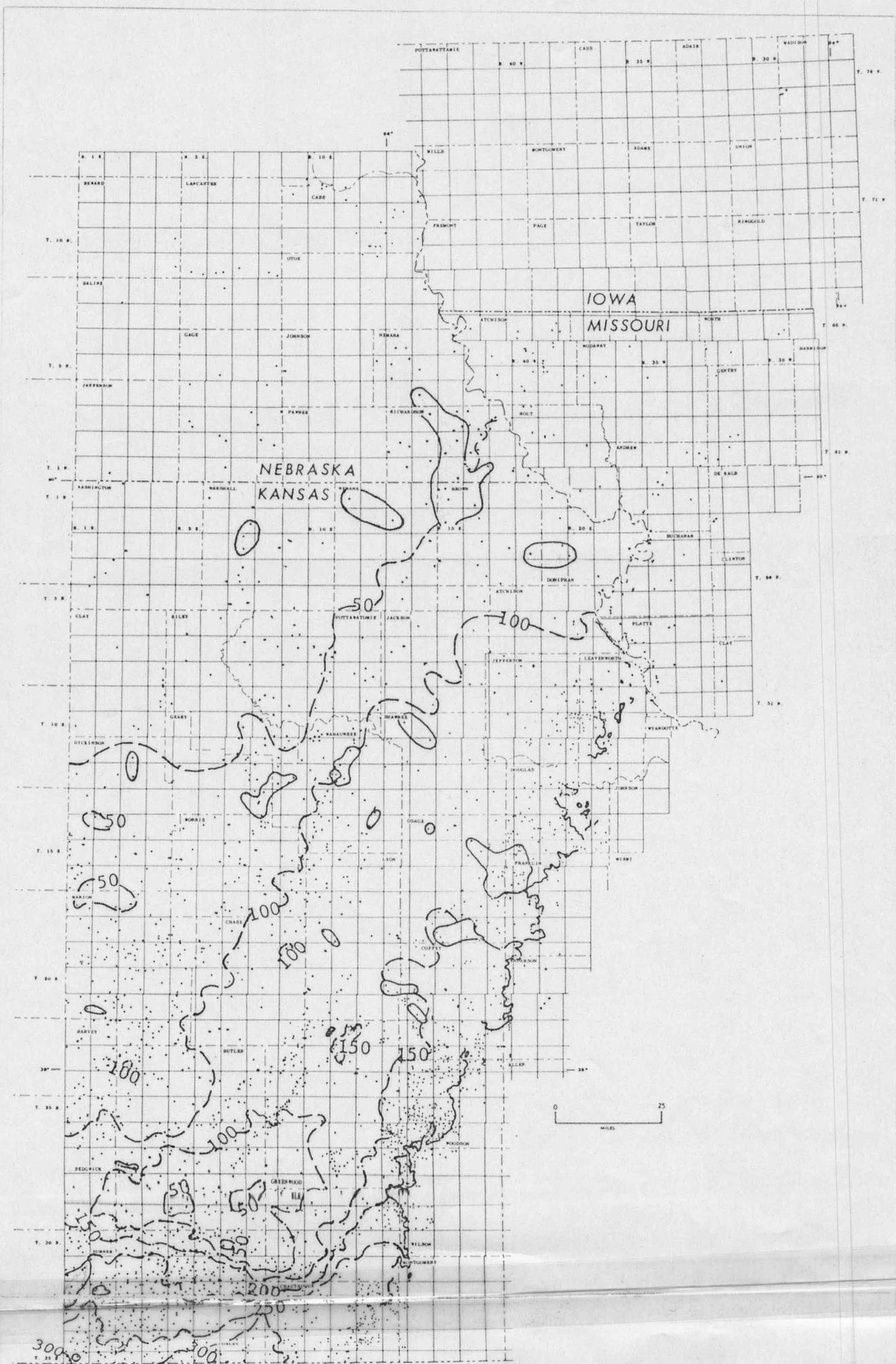
Westphalia Limestone Member

The Westphalia Limestone was named by Moore and Newell (in Moore, 1936, p. 150) for outcrops near the town of Westphalia in western Anderson County, Kansas. Stratigraphic application of the name Westphalia has not changed. Exposures designated as typical outcrops (op. cit.) do not now show well the stratigraphic relationships of the member. A road cut exposure (SW cor. NW $\frac{1}{4}$ sec. 19, T. 20 S., R. 18 E.) is proposed as a reference standard.

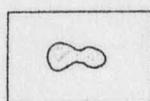
Description of standard reference section. -- A single unit about 2 feet thick and devoid of shale breaks or partings is well exposed except for the uppermost 0.1 to 0.2 foot. Both fresh and weathered rock surfaces are light brown. An outstanding outcrop characteristic is the myriad of fusulinids in bold relief on weathered surfaces (Pl. 19).

^{1/} Excepting the relatively small area in the south-central Kansas part of the study area.

^{2/} As in outcrops, most of the sandstone is in the upper part of the Stranger and probably represents mainly sandstone of the Tonganoxie part of the formation.



Areas in which formation top was not identified.



Areas in which formation base was not identified.



Approximate trace of Haskell Limestone base (bounds Stranger Formation above). Broken where breached by major drainage or covered by relatively thick Pleistocene deposits.

FIGURE 18.-- Stranger Formation thickness (in feet) map. See Figure 1 for qualification of control points.

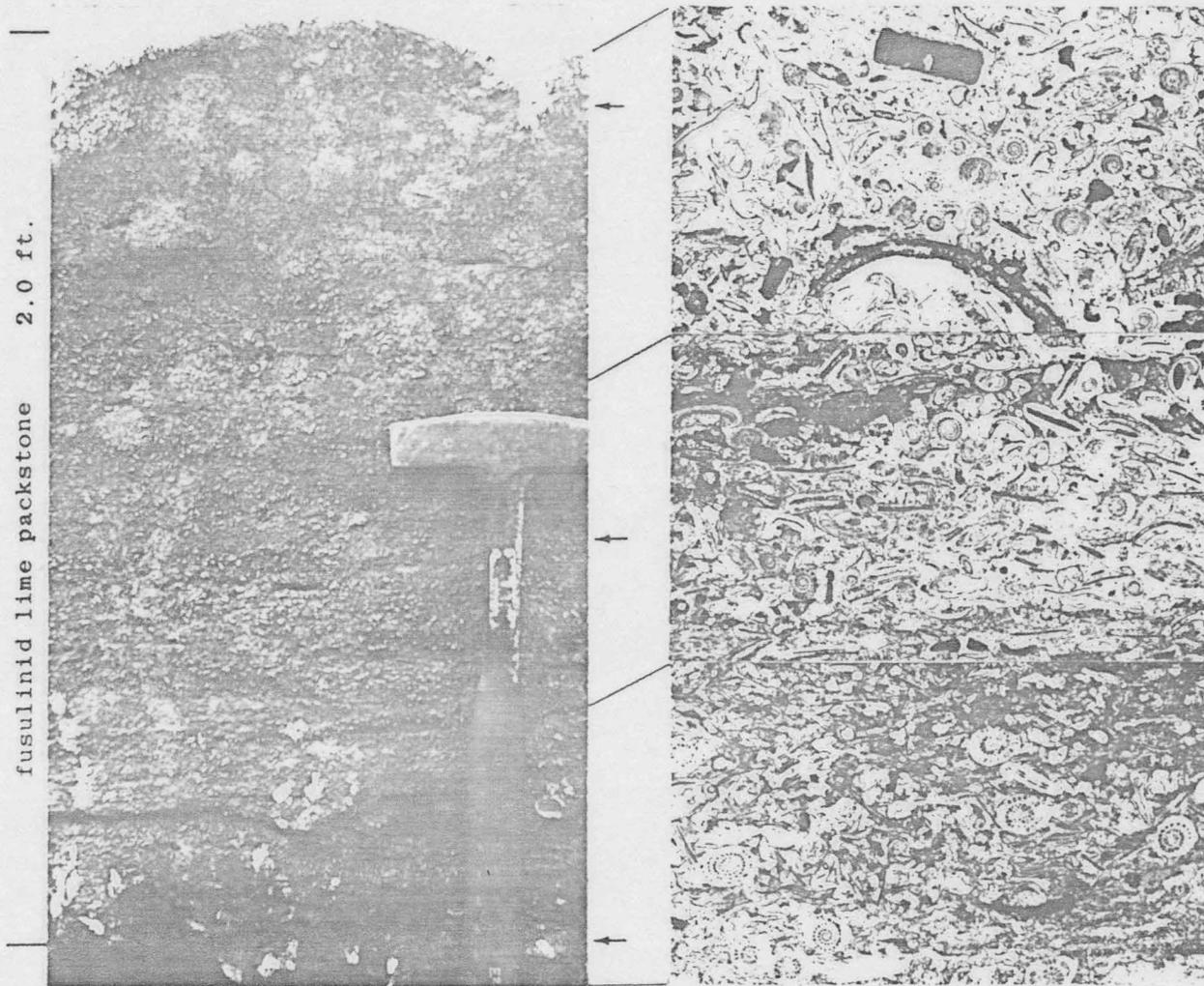


PLATE 19.-- Standard reference section of Westphalia Limestone. Road cut exposure at SW corner NW $\frac{1}{4}$ sec. 19, T. 20 S., R. 18 E., Anderson County, Kansas. Negative prints of thin sections (X3) on right. Arrows show exact positions of samples chosen as representative. Vertical surfaces, orientation as shown. Note orientation of fusulinids.

Hand sample and thin section study indicate that the rock is a fusulinid lime packstone. Skeletal grains (some coated with Osagia) include fusulinids, profuse throughout; brachiopods, mainly productid; myalinids, abundant in the basal 0.3 foot and sparse above; and sparse to common gastropods, bryozoans, crinoids, and echinoid debris. Other grains include about 3 to 5 percent fine silt- to very fine sand-size, angular to subrounded, elongate to equant quartz and about 1 percent clay minerals. Many of the grains show signs of abrasion and some grains show overly close packing with concave-convex and sutured contacts. About 75 percent of the fusulinids display transverse or obliquely transverse cross-sections and long axes of large grains are mostly aligned parallel to stratification.

Lime mud and 20-100 micron sparry calcite are distributed between grains in nearly equal proportions in the basal part of the unit. Lime mud apparently predominates in the upper part of the unit. Interstitial material is extensively iron-stained.

Geographic, thickness, and facies range. -- The principal area of Westphalia outcrops extends from northernmost Anderson County (selected section 46 in appendix) to east-central Chautauqua County, Kansas (near center sec. 10, T. 33 S., R. 13 E.). Within this area the member is nearly continuous as shown on Figure 11. Southward the Westphalia was not recognized in Kansas exposures, but is developed as lenses atop the Cheshewalla Sandstone in northern Osage County, Oklahoma. The southernmost exposure of the Westphalia (Bowring) Limestone observed during this study is about 1.5 miles south of Bowring (near center north line sec. 4, T. 27 N., R. 11 E., Osage County, Oklahoma; selected section 61 in appendix).

Throughout these outcrops the Westphalia is essentially an algal-fusulinid lime packstone (Pl. 20) similar to the facies of the standard reference section (Pl. 19). Obviously abraded and transported and generally, at least in part, Osagia-coated skeletal grains form the rock framework. Trace amounts to as much as 5 percent fine silt- to very fine sand-size, angular to subrounded, elongate to equant quartz particles are commonly present within the member. Locally in Chautauqua County, quartz particles form approximately 20 to 25 percent of the Westphalia. Matrix material comprises both lime mud and sparry calcite. Light gray to medium light gray or light brown color is characteristic. Thicknesses range from a featheredge to as much as about 5 feet and the member is generally a single bed or 2 "beds" separated by nodular limestone rubble.

From northernmost Franklin County, Kansas, to southern Buchanan County, Missouri, lenses of uniformly medium light gray or medium gray, thinly laminated to laminated, ostracode coaly lime mudstone (Pl. 21) form the Westphalia. Weathered surfaces of this facies are commonly yellowish gray. The invertebrate assemblage comprises ostracodes, gastropods, foraminifers, and rarely brachiopods. Argillaceous material and finely disseminated carbonaceous particles and lenticular stringers of coal are interlaminated with the lime mud. Thicknesses of this facies range from a featheredge to about 1.5 feet (selected section 45 in appendix).

Neither Nebraska nor Iowa outcrops of the Westphalia have ever been reported and none were recognized in this study.

Distribution (Fig. 19) of the Westphalia is more restricted than any other of the principal limestones (i.e., South Bend, Iatan, Haskell,

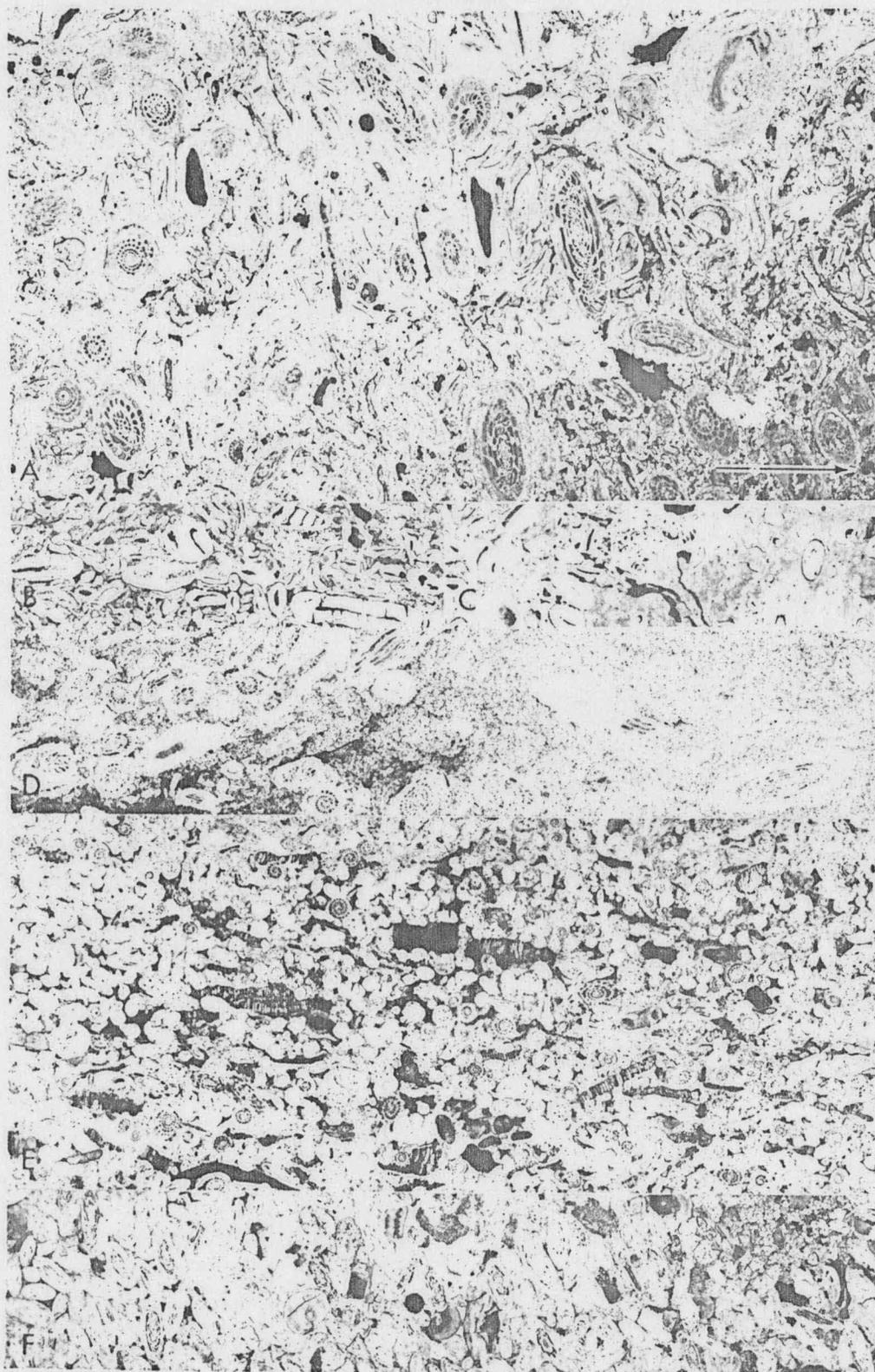
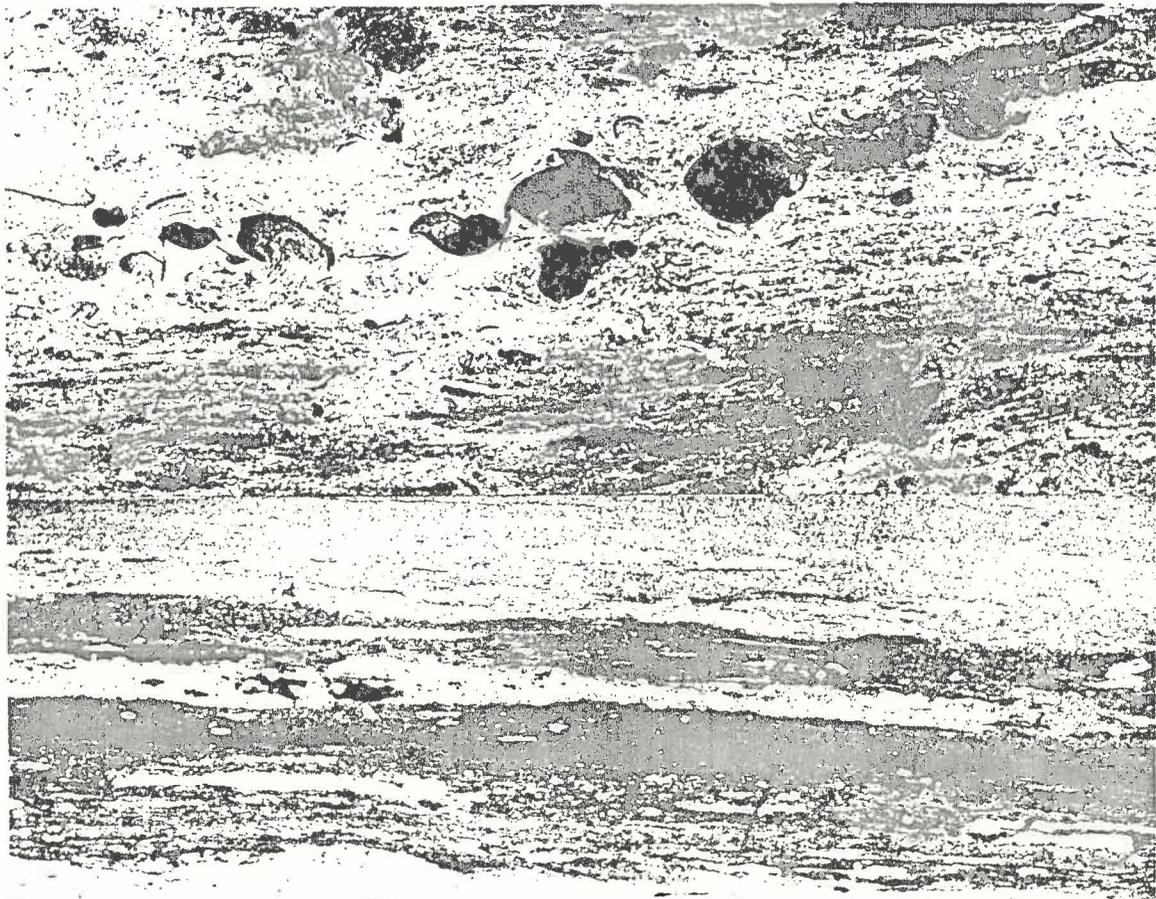
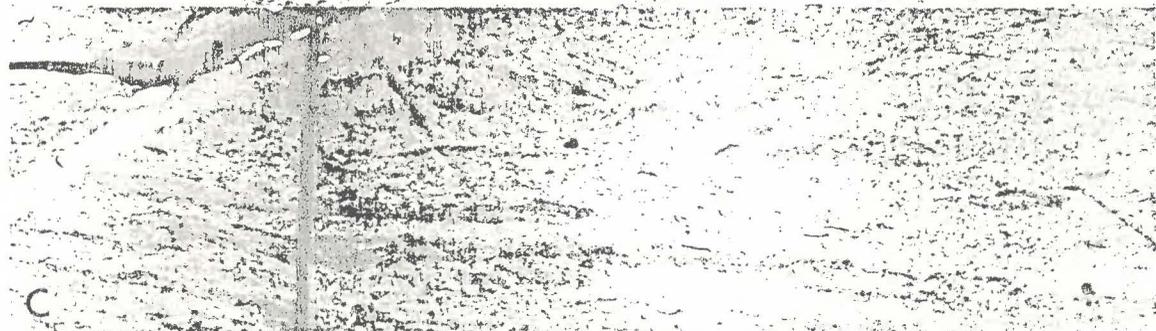


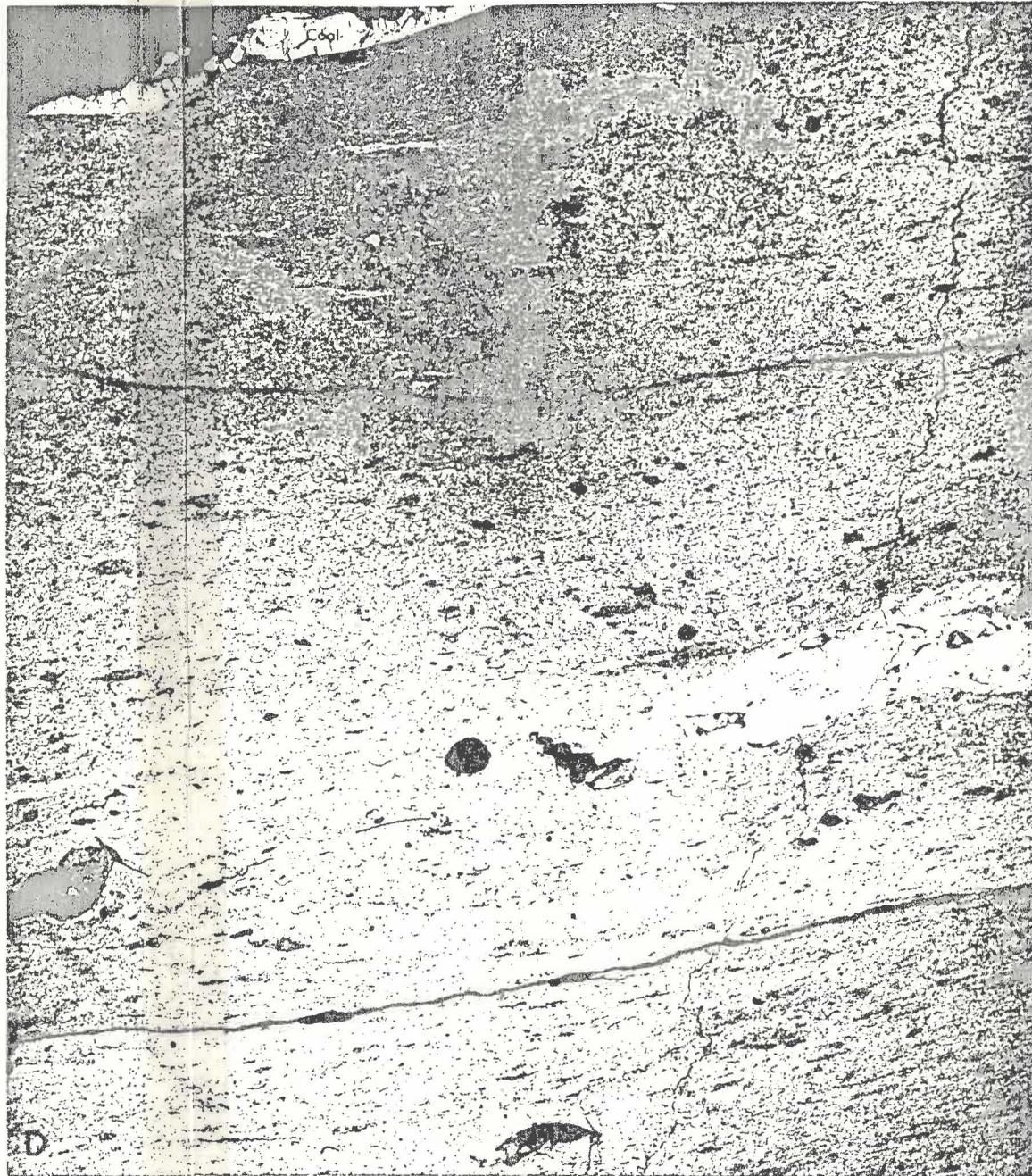
PLATE 20.-- Algal-fusulinid lime packstone facies of the Westphalia Limestone. Negative prints of thin sections; A (X2.5), B-F (X2.5); orientation as shown except in A as indicated by arrow. A, Sample taken near center NE $\frac{1}{2}$ sec. 23, T. 26 S., R. 14 E., Woodson County, Kansas. B, Sample taken near center SW $\frac{1}{2}$ sec. 19, T. 28 S., R. 14 E., Wilson County, Kansas. C, Same locality as B. Uppermost 1 foot of Westphalia is a mud-supported rock and is classed as wackestone rather than packstone. D, Sample taken near center sec. 3, T. 32 S., R. 13 E., Chautauqua County, Kansas. E, Sample taken near NE corner SE $\frac{1}{2}$ sec. 15, T. 28 N., R. 11 E., Osage County, Oklahoma; vertical surface. F, Same locality as E; horizontal surface. Note *Osagia* grain coatings and abraded grains in A-D. Note orientation of fusulinids in E-F. See also Plate 19.



B

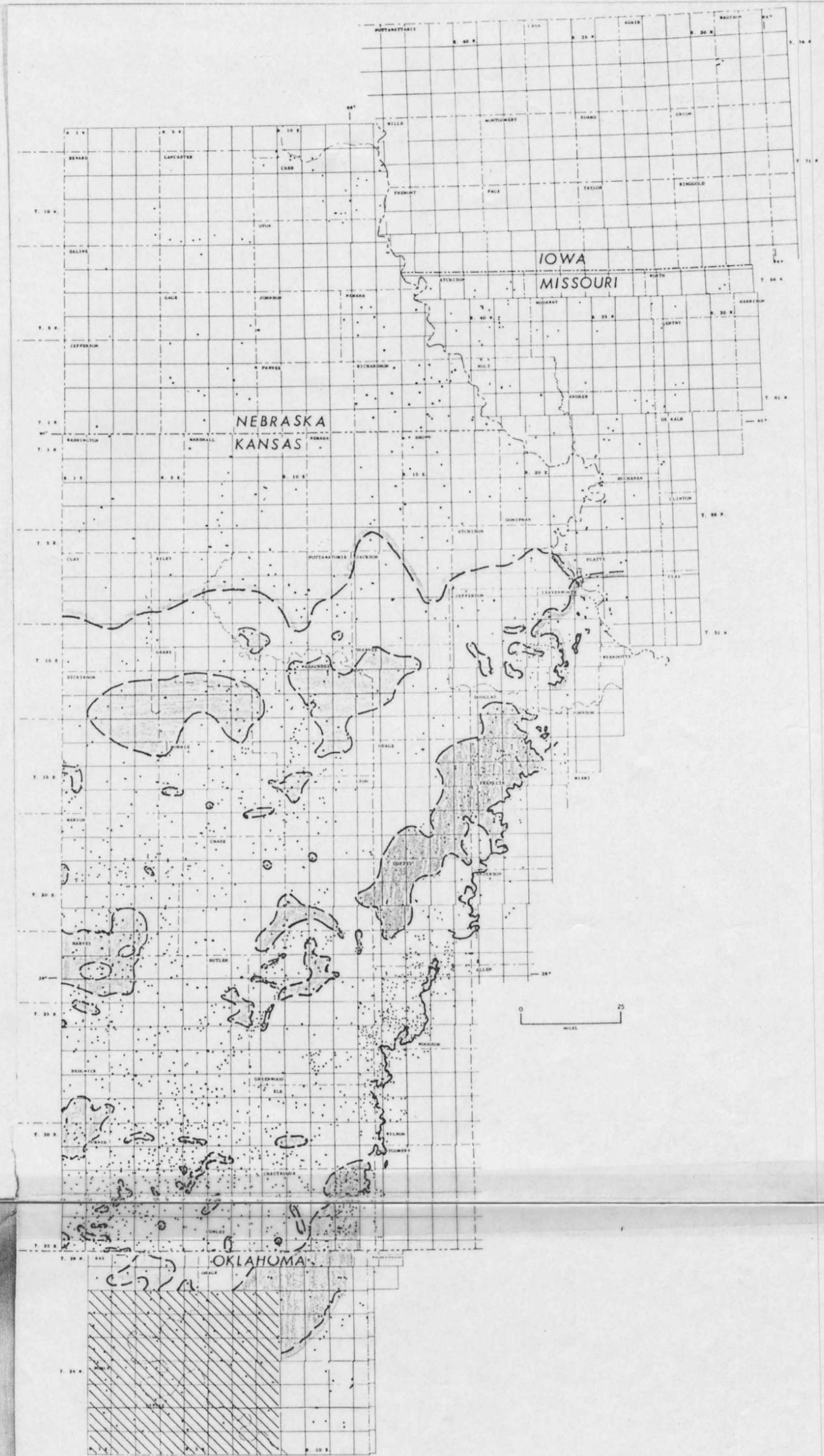


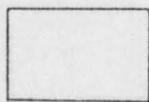
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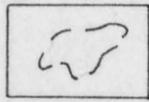
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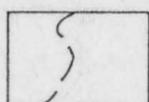
PLATE 21.-- Ostracode coaly lime mudstone facies of the Westphalia Limestone. Negative prints of thin sections (X4); vertical surfaces, orientation as shown. Argillaceous coaly material appears white. Coal stringer labeled at upper left-hand corner of D. A, Upper bed of Westphalia near center NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 30, T. 54 N., R. 36 W., Platte County, Missouri. B, Lower bed of Westphalia, same locality as A. C, Sample taken near center west line NW $\frac{1}{4}$ sec. 22, T. 14 S., R. 20 E., Douglas County, Kansas. D, Sample taken at SW corner NE $\frac{1}{4}$ sec. 4, T. 8 S., R. 22 E., Leavenworth County, Kansas.

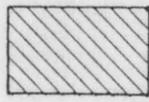


- 

Area of general continuity.
- 

Areas of discontinuity.
- 

Areas in which not identified and believed to be absent.
- 

Limit of areas in which not identified and believed to be absent.
- 

Correlation not established.
- 

Surface trace of Haskell Limestone base in Kansas approximates that of Westphalia Limestone, which was not mapped. Broken where breached by major drainage or covered by Pleistocene deposits.

FIGURE 19.-- Distribution map of the Westphalia (Bowring) Limestone. The subsurface of southwestern Iowa was not studied. See Figure 1 for qualification of control points. Westphalia Limestone exposures have not been identified south of Township 27 North in Oklahoma.

Amazonia and Toronto) considered in this study. More control may ultimately show that the Westphalia extends farther northwest. However, the ostracode coaly lime mudstone facies characteristic of the northern part of the outcrop area indicates that the member does not extend any great distance northward. Utilization of more control will probably extend distribution of the Westphalia at least a few miles southwestward in the subsurface of Osage County, Oklahoma. Thickness range, both surface and subsurface, of the Westphalia Limestone is from a featheredge to approximately 10 feet.

Pertinent characteristics of the Westphalia Limestone are easier to summarize than those of any other limestone unit studied and include: (1) irregular distribution; (2) markedly different development, both lithologically and geographically, into two facies, a typical southern algal-fusulinid lime packstone that contains appreciable silt- and sand-size quartz particles, and a northern argillaceous, ostracode, coaly lime mudstone; and (3) the commonly gradational basal contact with quartzose sandstone or silty shale south of northernmost Anderson County, Kansas and with the upper Sibley coal bed north of northernmost Franklin County, Kansas.

Vinland Shale Member

Patterson and Addison (1933, p. 17) named the predominantly shale section between the top of the upper Sibley coal below and base of Haskell Limestone above, the Vinland Shale. Application of the name was restricted (Moore, 1936, p. 151) to strata between the Westphalia and Haskell Limestones and remains unchanged. A section (center east line SE $\frac{1}{4}$ sec. 2, T. 14 S., R. 20 E.) exposed on the west side of the north-south county road 2 miles northeast of Vinland, Kansas, is proposed as the type section (Fig. 20).

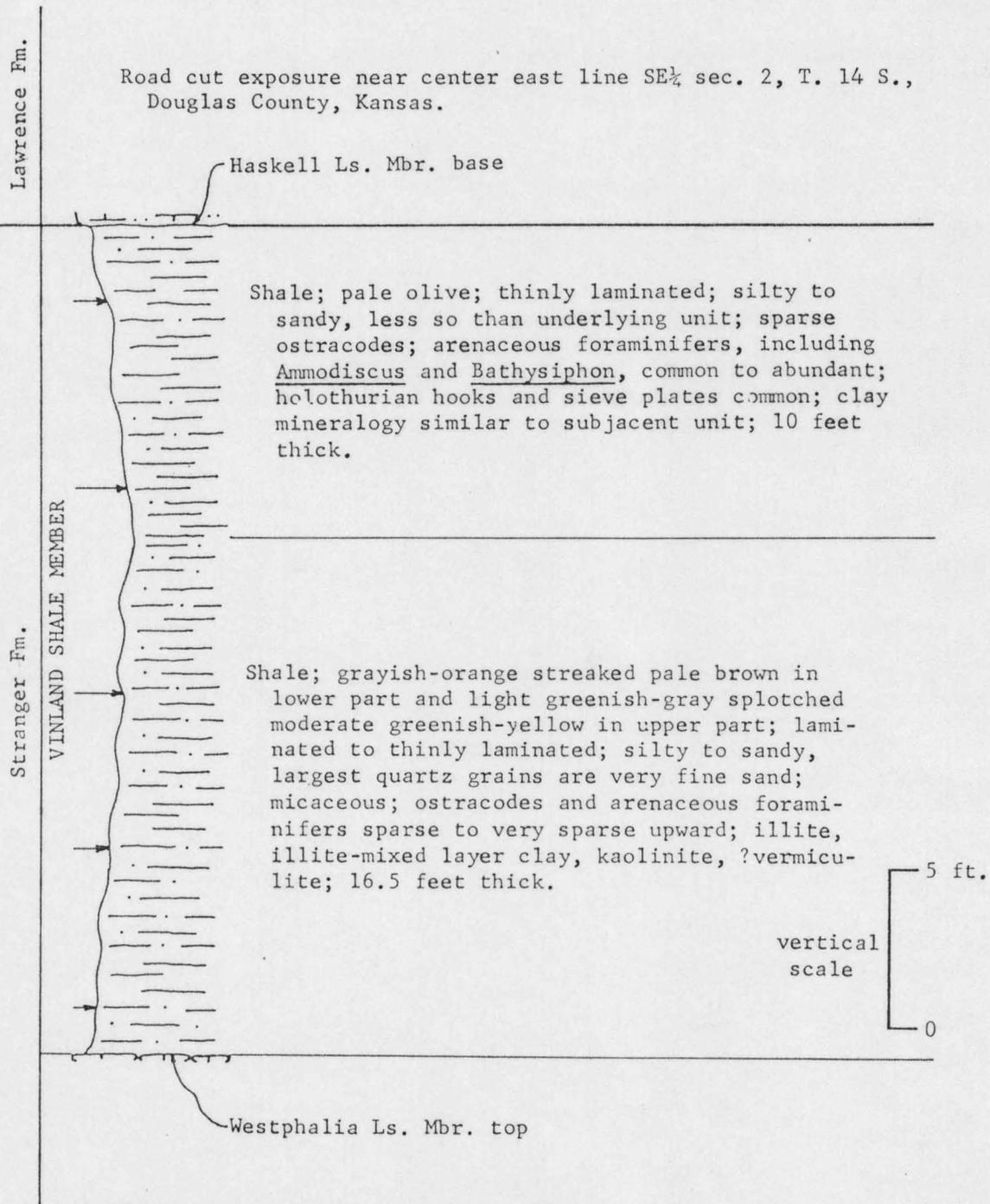


FIGURE 20.-- Type section of the Vinland Shale. Arrows indicate stratigraphic position of samples washed for fossils and analyzed for clay minerals. See selected section in appendix for description of Tonganoxie and Westphalia Members of the Stranger Formation and the Haskell Member of the Lawrence Formation.

Description of type section. -- The lower 6 feet of the Vinland is grayish orange (streaked pale brown) shale, which is silty to sandy and micaceous. Fossils recorded from washings include sparse ostracodes and arenaceous foraminifers.

About 8 feet of light greenish gray, spotted moderate greenish yellow shale succeeds the lower unit and similarly contains sparse ostracodes and arenaceous foraminifers. This part of the member also contains mica flakes, quartzose silt, and very fine-grained, quartzose sand.

The upper 12 feet of the Vinland is predominantly pale olive shale, but includes calcareous siltstone in the upper part. Sparse ostracodes, arenaceous foraminifers, and holothurian hooks and sieve plates in the lower half, and common to abundant ostracodes and arenaceous foraminifers in the upper half comprise the fauna.

An illite, kaolinite, illite-mixed layer clay, ?vermiculite clay-mineral assemblage is notably uniform vertically (Fig. 20). Shape and size of corresponding peaks on the diffractometer patterns do not indicate marked quantitative variation of component minerals, but quantification by constituent percentages was not attempted.

Geographic, thickness, and facies range. -- The Vinland Shale is essentially continuous throughout the northern Midcontinent surface part of the study area. It does not follow that the member is everywhere bounded by Westphalia Limestone top below and Haskell Limestone base above. Where one or both of these bounding limestones were not identified (compare Fig. 19 and 21), presence of the Vinland is commonly shown by the characteristically molluscan but locally brachiopodal fauna^{1/} in its upper

^{1/} Described in discussion of Vinland facies.

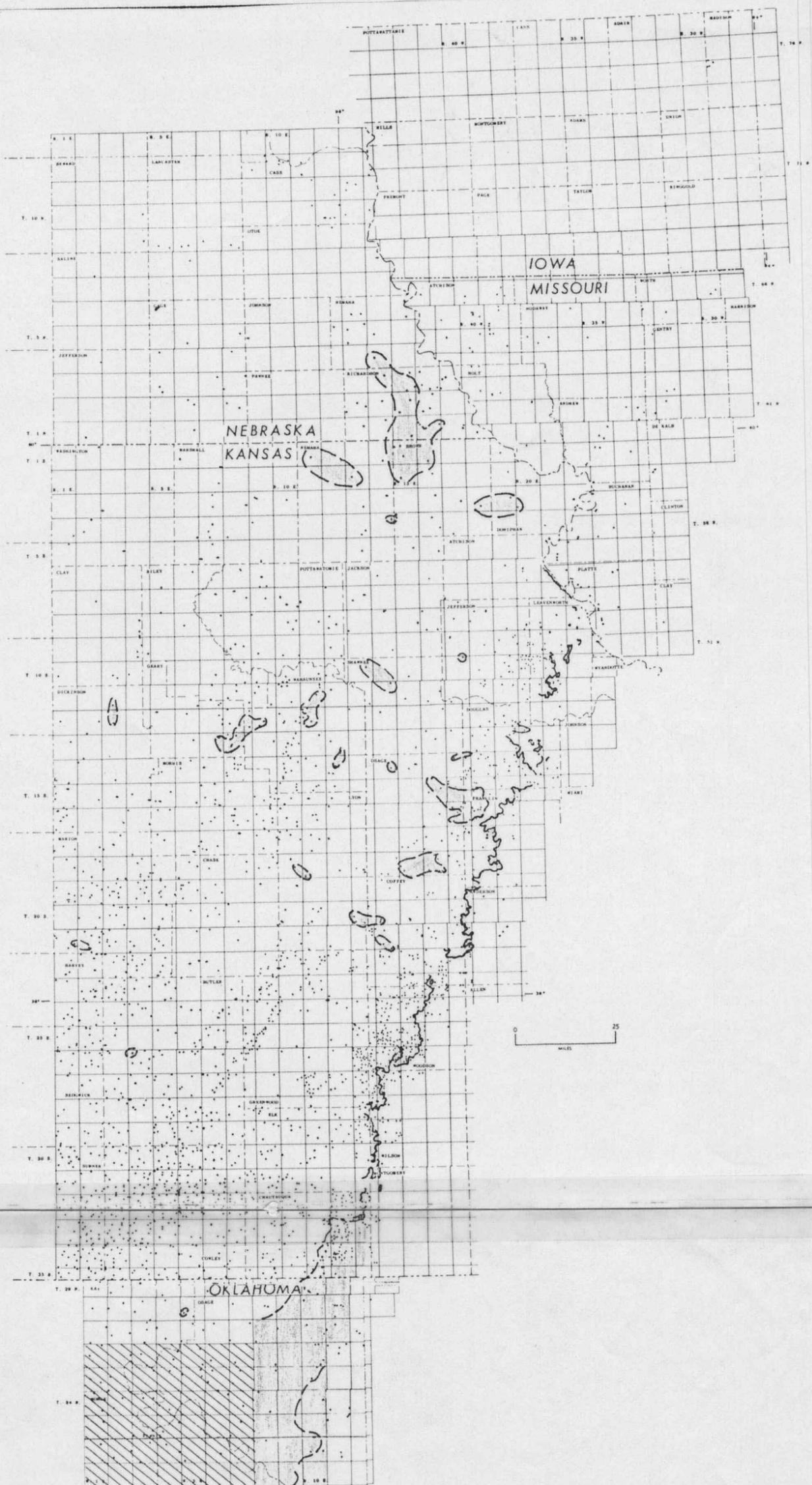


FIGURE 21.--Distribution map of the Haskell (Shoemaker; Labadie) Limestone. The subsurface of southeastern Iowa was not studied. See Figure 1 for qualification of control points. Haskell Limestone exposures have not been definitely identified south of Township 25 North in Oklahoma. If the proposed correlation of the Haskell with the Wildhorse dolostone is correct, the southern limit of Haskell outcrops extends to Township 21 North in Oklahoma.

part or by the limestone septaria zone^{1/} in its central or upper part. The term Vinland is generally applicable from west-central DeKalb County, Missouri (T. 59 N., R. 33 W., selected section 24 in appendix) southwestward to northeastern Osage County, Oklahoma (T. 25 N., R. 10 E.; selected section 61 in appendix). Unquestionably, the member extends farther northeastward but no further exposures were located during this study. Extension as far south as the northern part of Township 20 North, Osage County, Oklahoma, is warranted if my (and other's) correlation of the Labadie (Haskell) Limestone with the Wildhorse dolostone is correct (see discussion in correlations part of section on Historical Geology). The Vinland was recognized as the upper part of the section immediately below the Haskell (Shoemaker) Limestone in Nebraska exposures.

Combined lack of recognition of: (1) the Westphalia Limestone; (2) either the molluscan or the septaria zones in the Vinland; and (3) the Haskell Limestone preclude recognition of the Vinland locally. Such outcrop areas include parts of Chautauqua County, Kansas and Osage County, Oklahoma. The Vinland Shale is possibly in part or wholly absent locally (e.g., see O'Connor, 1960, p. 35-37; Ball and others, 1963, p. 27).

Throughout most of the subsurface part of the study area the Vinland Shale is recognized as that part of the section immediately below the Haskell Limestone. Areas in which neither the underlying Westphalia nor the overlying Haskell Limestones are identified are the only areas in which the member is not recognized.

Measurements of Vinland Shale thicknesses from outcrops in which boundaries of the member are based on objective criteria^{2/} indicate a range

^{1/} Described in discussion of Vinland facies.

^{2/} Where bounding limestones are present.

from about 2 feet (near center east line sec. 22, T. 26 S., R. 14 E., Woodson County, Kansas) to approximately 72 feet (T. 27 N., R. 11 E., Osage County, Oklahoma; selected section 61 in appendix). Relatively thicker sections of the Vinland occur at one locality in Leavenworth County, Kansas (about 40 feet in SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 8 S., R. 22 E.), in the northwestern Montgomery-northeastern Chautauqua Counties, Kansas area (35- to 45-foot range based on measurements from four localities) and at the one locality referred to above in northeastern Osage County, Oklahoma (approximately 72 feet). The member is relatively thin in Woodson County, Kansas (2- to 6-foot range based on measurements from five localities) and in southeastern Atchison County, Kansas-Platte County, Missouri area (4- to 14-foot range based on measurements from six localities). The only significant trend that is apparent extends from the average 6-foot thickness in northern Wilson County, Kansas (Wagner and Harris, 1953) to the maximum 72-foot thickness in northeastern Osage County, Oklahoma.

On the basis of available subsurface records, thicknesses of the Vinland Shale are generally in agreement with thicknesses cited for corresponding ranges of latitude at the surface.

Rock types developed in the Vinland Shale Member include clayey shale, greenish-gray mudstone, silty shale, argillaceous limestone, limestone septaria, arenaceous limestone, quartzose sandstone and siltstone, and negligible coal. Shades of greenish gray and olive gray, clayey to silty shale form the characteristic facies of the Vinland. The upper part of the shale is commonly calcareous and abundantly fossiliferous in Missouri, Kansas, and Osage County, Oklahoma exposures of the member. This zone is

so calcareous locally, especially so in northern Leavenworth County, southeastern Atchison County, and Missouri outcrops, that its classes as either argillaceous limestone or calcareous mudstone.

The fauna in the upper part of the Vinland is the most abundant and most widely developed megafauna in shale and sandstone parts of the Douglas Group. Present in every Missouri outcrop observed, in many Kansas outcrops, and locally in Osage County, Oklahoma, outcrops of the Vinland, this profusely fossiliferous development is an excellent stratigraphic marker. The assemblage is strikingly molluscan in the Missouri, Kansas, and Oklahoma areas. Myalinid clams are found at nearly all localities and are the keynote group represented in the fauna. Almost invariably the myalinid remains are single valves aligned parallel to stratification in excavated exposures or scattered over and concentrated at the base of weathered slopes. Calcareous, partial or entire coatings on the pelecypods as well as the other groups present were noted in a number of Kansas exposures. These coatings are definitely algal in some cases (e.g., Pl. 22). Brachiopods are generally an important element of this fauna, are especially abundant in Missouri exposures, and vastly predominate over other groups at the single locality in which this fossil zone was observed in Nebraska (selected section 3 in appendix and Pl. 23A). Locally fossils of the upper Vinland assemblage are entombed in very fine-grained quartzose sandstone (Pl. 23B) rather than the usual calcareous shale or mudstone-argillaceous limestone facies.

Limestone septaria are present in the upper or central part of the Vinland Shale in many exposures between northern Platte County, Missouri,

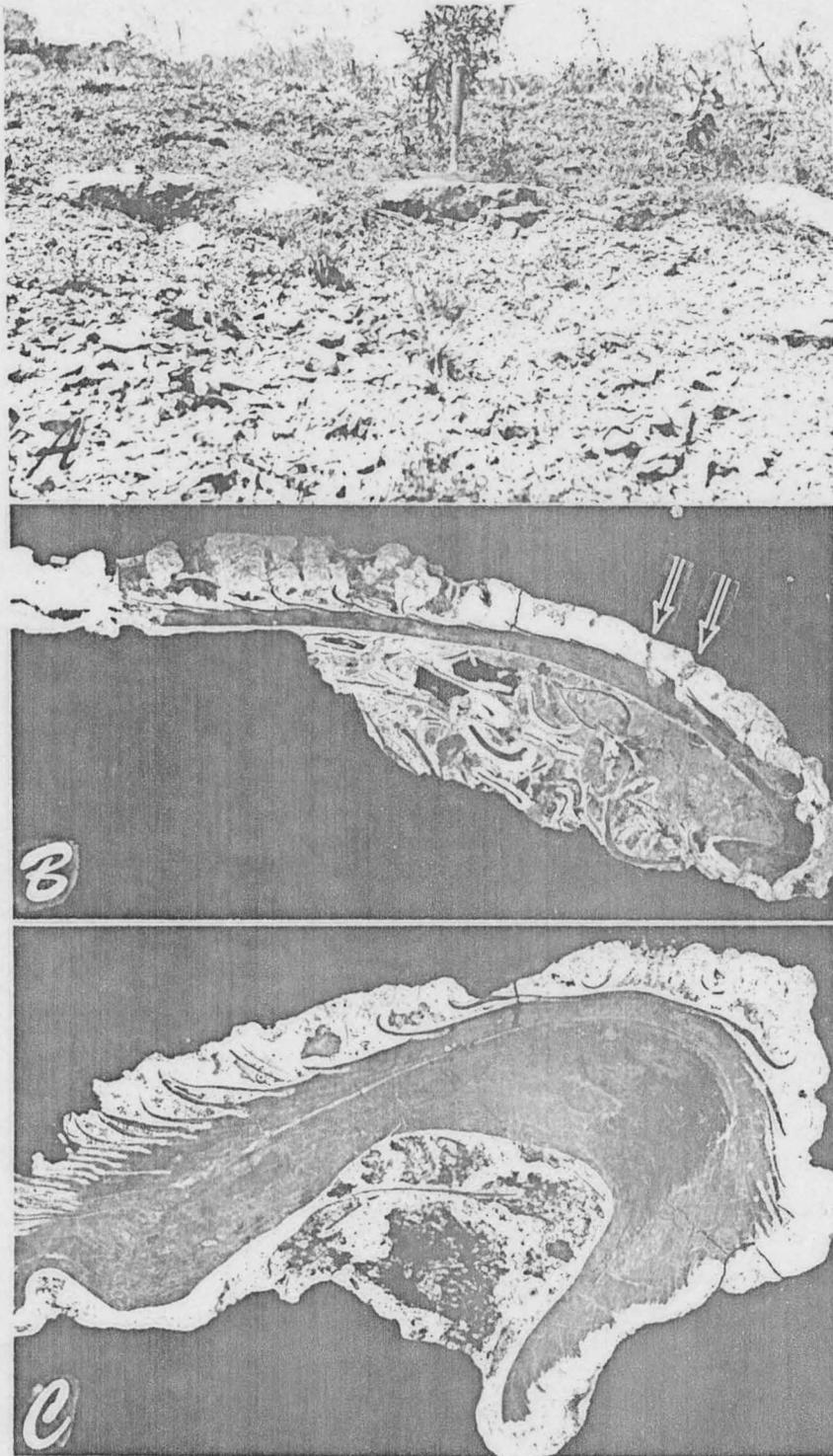


PLATE 22 -- Myalinid zone in uppermost Vinland Shale. A, Outcrop in SW $\frac{1}{2}$ NE $\frac{1}{2}$ SW $\frac{1}{2}$ sec. 4, T. 33 S., R. 13 E., Chautauqua County, Kansas. Note prolific lag concentration of fossils at foot of slope. B, Negative print (X2) of a longitudinal section through a myalinid clam valve. Specimen collected in SE $\frac{1}{2}$ sec. 16, T. 14 S., R. 20 E., Douglas County, Kansas. C, Negative print (X2.5) of a transverse anterior section of a myalinid clam valve. Specimen from same locality as B. Note post-mortem algal coatings in B and C. Note subsequent burrowing in anterior part of B. Burrow apertures indicated by arrows.

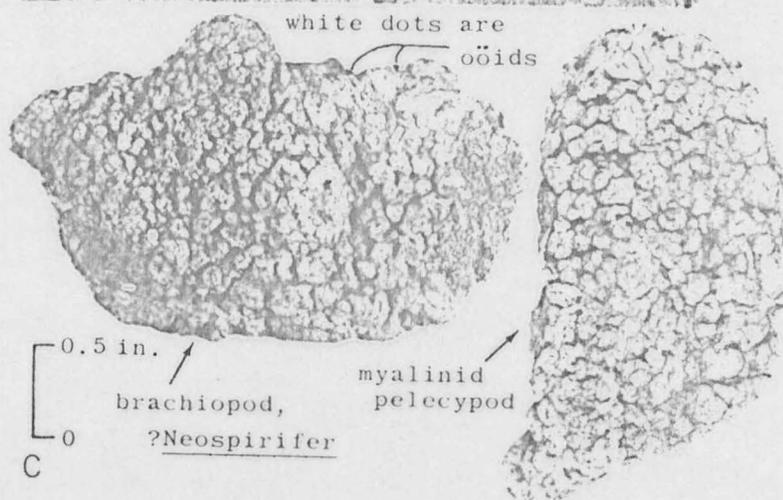
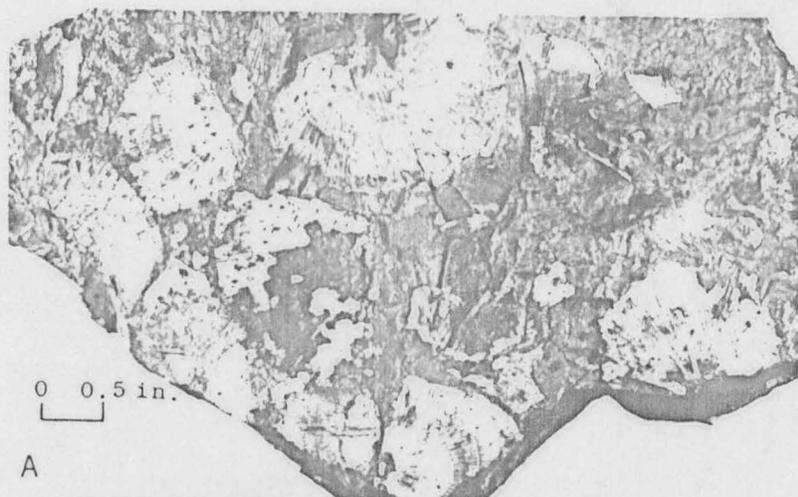


PLATE 23.-- Vinland Shale fauna. A, In calcareous mudstone matrix near NE corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 12, T. 10 N., R. 12 E., Cass County, Nebraska. B, In quartzose sandstone matrix in SW $\frac{1}{4}$ sec. 18, T. 15 S., R. 20 E., Douglas County, Kansas. C, Algal-coated single valves of a brachiopod and a pelecypod. Hinge areas coated in both cases. Specimens collected in NW $\frac{1}{4}$ sec. 26, T. 14 S., R. 20 E., Douglas County, Kansas.

and southern Franklin County, Kansas (Fig. 16). Bowsher and Jewett (1943, p. 46) point out that the septaria are remarkable persistent in the Vinland and where found they are an excellent stratigraphic marker.

Quartzose very fine- and fine-grained sandstone and siltstones occur locally in all parts of the Vinland Shale in Kansas and Oklahoma exposures of the member. Aggregate amount of sandstone and siltstone rarely exceeds that of other rock types. According to observations made during this study, sandstone and siltstone are the dominant rock types only in parts of southeastern Douglas, northeastern Franklin, and west-central Anderson Counties, Kansas and in parts of northeastern Osage County, Oklahoma. Neither sandstone nor siltstone were observed in the Vinland in Missouri outcrops or in the Tonganoxie-Vinland Shale in Nebraska exposures. The Vinland Shale was not definitely recognized in Iowa exposures.

Cable tool sample log descriptions are so few in number as to preclude detailed discussion of Vinland facies distribution in the subsurface. However, two meaningful statements can be made. Firstly, there are no sample log records of sandstone in the Tonganoxie-Vinland Member or the Vinland Shale in the area in which the Cass Limestone is essentially continuous (Fig. 23) and sandstone is not apparent on mechanical logs available for this part of the section and this area. Southward and southeastward from the area in which the Cass is essentially continuous, sandstone is commonly an important part of the Tonganoxie-Vinland Member and less commonly so of the Vinland Shale Member. Secondly, the molluscan zone in the Vinland so characteristic of the member along the main outcrop area in Missouri, Kansas, and Oklahoma, was recognized in the subsurface only as

far northwest of the outcrop area as Well 5 on Plate 2 (log description 1 in appendix). The molluscan zone probably does not extend more than approximately 20 to 25 miles northwest of the principal outcrop area. As mentioned above, at the only locality in which the fossil zone in the Vinland was recognized in Nebraska exposures, it is brachiopodal and not molluscan.

Summary. -- The Vinland Shale Member of the Stranger Formation is widespread throughout the northern Midcontinent^{1/} part of the study area and ranges from approximately 2 to 72 feet in thickness. The member is typically a shale or shale and sandstone unit or, less commonly, a shale and calcareous mudstone or argillaceous limestone unit. The prodigious fossiliferous zone in the upper part of the Vinland contains more abundant and a greater variety of megafossils than any other shale or sandstone unit in the Douglas Group. These fossils are widespread along the area of outcrops (Missouri, Kansas, and Oklahoma), but may be largely restricted to the southeastern marginal part of the study area. Microfauna of the Vinland Shale is poorly known. Data reported by Patterson (1933) and shale washings from four localities (selected sections 12, 47, 48, and 53 in appendix) are the only available records of Vinland microfossils.

Clay mineralogy of the member is poorly known. The only clay-mineral data available are recorded in descriptions of selected sections 47 and 53 in the appendix.

^{1/}See definition of northern Midcontinent in glossary of terms.

Lawrence Formation

Haskell Limestone Member

The Haskell Limestone was named by Moore (1932, p. 93) for limestone outcrops close to Haskell Institute, which is located at Lawrence, Kansas. A road cut exposure (NE cor. NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 5, T. 13 S., R. 20 E.) was designated as type and a summary description given by Moore (1936, p. 153). Name application and stratigraphic rank of the Haskell have remained unchanged to the present time.

Description of type section (Pl. 24). -- The basal unit grades upward from calcareous siltstone to silty lime mudstone. Fresh rock surfaces are pale yellowish brown and weather moderate yellowish brown. Compared to other units within the Haskell, this unit is less resistant to weathering and much more thinly stratified, although the total thickness of 0.9 foot is greater than that of the next higher unit. Stratification ranges from 0.1 to 0.2 foot in thickness. Fossils include brachiopods, mainly productids, and sand-size crinoid fragments. Abundance of brachiopod remains increases from sparse to common upward, whereas crinoids are extremely sparse throughout.

In thin section, it can be seen that the rock is composed of fine silt to very fine sand particles of quartz, mica flakes, and sparse fossil debris in a calcite matrix. Sand/silt ratio is less than 1/10 and percentage of silt-sand fraction diminishes upward from about 55 to about 35. The quartz grains are angular to subangular, poorly sorted, and loosely packed. Fossils and mica flakes amount to less than 5 percent of the rock. Calcite cement percentage increases upward from about 35 to about 55.

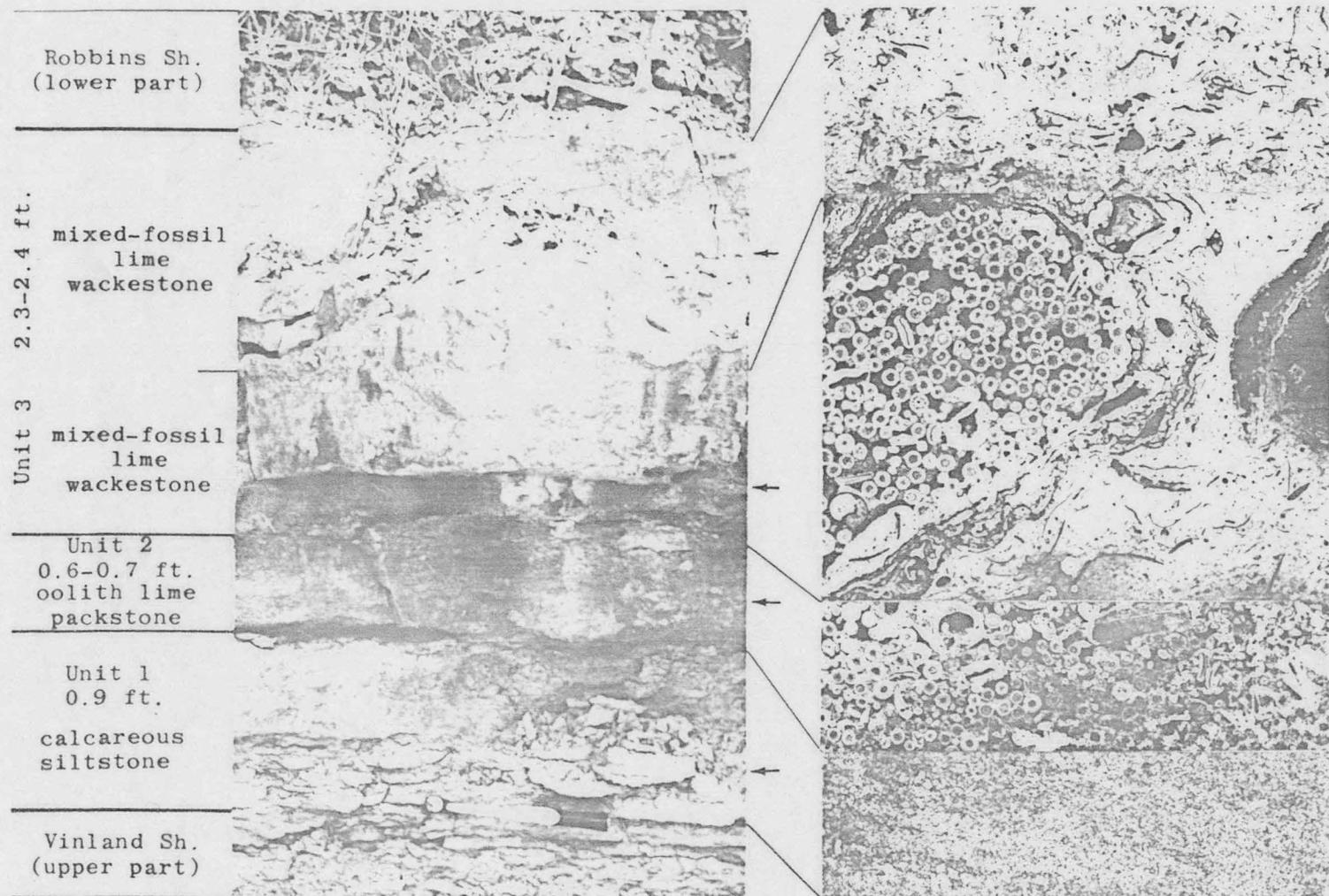


PLATE 24.-- Type section of Haskell Limestone. Road cut exposure at NE corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 5, T. 13 S., R. 20 E., Douglas County, Kansas. Negative prints of thin sections (X3) on right. Arrows show exact positions of samples chosen as representative of footages indicated and described in text. Vertical surfaces, orientation as shown. Note algal-coated lithiclast derived from unit 2 and incorporated in lower part of unit 3.

The next higher unit (2, Pl. 24) comprises a 0.6 to 0.7 foot oolith lime packstone devoid of partings. Both fresh and weathered surfaces are pale yellowish brown. Fossils include abundant minute gastropods, sparse Composita, fragmented productid brachiopods, crinoid detritus, and sparse foraminifers.

Thin section study shows that ooliths, fossils, and quartz silt are cemented by sparry calcite. The ooliths have both concentric and radial structure, are spherical to ellipsoidal, range from 0.25 to 1 mm in diameter, and are moderately to tightly packed. Most of the ooliths have formed around silt- to very fine sand-size quartz nuclei, which are subangular to subrounded.

The upper unit (3, Pl. 24) is 2.3 to 2.4 feet thick, pale yellowish brown on both fresh and weathered surfaces, and thin-bedded. About 20 percent of the rock consists of fossils, which include productid and other brachiopods, crinoids, gastropods, sparse foraminifers, and Ottonosia-like algae. Lithiclasts, oolite blebs and fossils coated with algae, form about 5 percent of the rock in the lower foot of this unit. Microcrystalline calcite ooze matrix amounts to about 75 to 80 percent.

Contacts between various strata within the Haskell are gradational as are contacts with contiguous stratigraphic units. Other aspects such as resistance to weathering, conchoidal fracture, denseness and vertical jointing can be observed on the various parts of Plate 24. This locality is a particularly good type inasmuch as the underlying Vinland Shale and the lower few feet of the overlying Robbins Shale are also exposed. A detailed measured section and description of bedrock cropping out here is included in the appendix.

Geographic, thickness, and facies range. -- Within the study area, the Haskell Limestone is the most widespread limestone member (Fig. 21) of the Douglas Group and is well suited as a formational bounding unit in both surface and subsurface mapping. Local areas of cover by Pleistocene deposits or absence due to Pleistocene erosion (T. 8 S., and T. 9 S., Leavenworth County, Kansas, and Platte, Buchanan, and DeKalb Counties, Missouri) and local absence probably due to Pennsylvanian erosion in southeastern Douglas (O'Connor, 1960) and Franklin Counties, Kansas (Ball and others, 1963) present minor problems in surface mapping. Absence of the Haskell has been reported for local areas in Leavenworth County, Kansas (Lins, 1950) and absence is suspected in a small part of southwestern Johnson County, Kansas (H. G. O'Connor, personal communication, 1960). Removal of the Haskell Limestone by erosion prior to deposition of the Ireland Sandstone Member of the Lawrence Formation is the interpretation made by both men. I regard this interpretation highly improbable as it relates to the Leavenworth County exposures, but certainly possible yet purely subjective in regard to the Johnson County exposures (see discussion of disconformities in section on Historical Geology). Elsewhere between west-central DeKalb County, Missouri (T. 59 N., R. 33 W., selected section 24 in appendix) and northeastern Chautauqua County, Kansas (T. 33 S., R. 13 E., Fig. 21), the Haskell is apparently continuous. Colluvial cover makes mapping of the Haskell difficult locally (e.g., Ball and others, 1963, p. 27), but in most areas numerous exposures establish the remarkable continuity of the member. No outcrops of the member were definitely observed northeast of west-central DeKalb County, Missouri. Presence of the Haskell Limestone in Iowa exposures may eventually be recognized but such

presence was not verified during this study (see selected section 7 in appendix and discussion in correlations part of section on Historical Geology). The Shoemaker Limestone of Nebraska is correlative with the Haskell Limestone (see discussion in correlations part of section on Historical Geology) and is continuous. South of northern Chautauqua County (sec. 5, T. 33 S., R. 13 E.) Kansas outcrops of the Haskell were located only between Niotaze and Peru (T. 34 S., R. 12 E.). The Labadie Limestone of northeastern Osage County, Oklahoma is correlative with the Haskell Limestone. If my (and others') correlation of the Labadie (Haskell) Limestone with the Wildhorse dolostone is correct, the Haskell and its correlatives extend southward to the northern part of Township 20 North, Osage County, Oklahoma.

Plates 2 to 9 (in pocket) document the extreme persistence of the Haskell Limestone in the subsurface. Areas in which the member was not recognized are delimited on Figure 21. As on the surface, the member is discontinuous in the shallow subsurface of southeastern Chautauqua County, Kansas and northeasternmost Osage County, Oklahoma. Amount of control (Fig. 1) utilized for the Oklahoma subsurface was insufficient to warrant extension of the Haskell distribution map south of Township 28 North. On the basis of surface observations and study of the electric logs located on Figure 1, general discontinuity of the member in the east ranges south of Township 28 North is probable. Lukert (1949, Pl. 2) did not recognize the Haskell in Township 22 North, Ranges 1 to 7 East (Noble, Pawnee, and Osage Counties, Oklahoma).

As classed in this report, the Haskell Limestone ranges from 0.1 foot to 1.3 feet and averages 0.6 foot in thickness in the 10 Missouri exposures

studied. A thickness range of 0.3 foot to 1.3 feet and an average 0.9-foot thickness were recorded for the 4 Haskell (Shoemaker) Limestone outcrops measured in Nebraska. Haskell outcrops in the southeastern Atchison-northeastern Leavenworth Counties, Kansas area (T. 7 S. to T. 9 S.) range from 0.4 foot to 1.5 feet (5 measurements) thick and average 0.9 foot. Relatively thick (about 1.5 to 7 feet) development of the member is characteristic of the southern Leavenworth-northern Douglas Counties, Kansas area (T. 10 S. to southern part of T. 14 S.). From southeastern Douglas to northeastern Chautauqua County, all aspects of the Haskell Limestone are astonishingly persistent. Virtually all known Haskell exposures indicate a thickness range from 1.1 to 2.2 feet in this stretch of the outcrop area, an approximate 115-mile airline distance (sec. 27, T. 14 S., R. 20 E., Douglas County to sec. 8, T. 32 S., R. 13 E., Chautauqua County), of the outcrop area. The abandoned quarry in west-central Wilson County (NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 28 S., R. 14 E., selected section 50 in appendix) exposes the only exceptional thickness, about 6 feet, measured in this area. One to two miles northeast, northwest, and southwest of this exposure normal thicknesses prevail. The Haskell Limestone thins southward from about 1 foot near the southeast corner sec. 17, T. 32 S., R. 13 E. to 0.3 foot in the NW $\frac{1}{4}$ sec. 9, T. 33 S., R. 13 E. and thence grades into shale between the latter locality and exposures on the mound 1.5 miles eastward (near center NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10, T. 33 S., R. 13 E.). No Haskell Limestone exposures were located between Bee and Middle Caney Creeks in east-central Chautauqua County, Kansas. The maximum known thickness, about 12 to 14 feet, of the member in Kansas exposures is developed near Peru in southeastern Chautauqua County. About 11.5 feet of this thickness is

exposed in the abandoned quarry near the northeast corner sec. 15, T. 34 S., R. 12 E. and the remainder, the lowermost part, along the banks of Middle Caney Creek about 50 yards west-northwest of the quarry. One and a half miles east of the quarry ($SE\frac{1}{4}NW\frac{1}{4}$ sec. 13, T. 34 S., R. 12 E.) thickness of the Haskell is 3 to 4 feet and approximately two and a quarter miles southeast of the quarry near center south line $NW\frac{1}{4}SW\frac{1}{4}$ sec. 24, T. 34 S., R. 12 E. the member is 0.3 foot thick. No exposures of the Haskell (Labadie) Limestone were located between the last-mentioned locality and an exposure near the cen. sec. 25, T. 28 N., R. 10 E., Osage County, Oklahoma where the member is about 3 feet thick. The topography mapped by Tanner (1956a, Pl. 1) as the Labadie in the area northeast of this locality (west-central part of T. 28 N., R. 11 E.) is formed by sandstone and does not represent the horizon of the Labadie as reported by Tanner (op. cit., p. 46). The Labadie ranges from 4 to 17 feet in thickness (selected sections 61 and 70 in appendix). Tanner reports a 23-foot thickness (1956a, p. 46). He also (ibid.) reports a 35-foot thickness from the area of limestone exposures mapped as an inlier of Labadie in the west-central part of his map area (op. cit., Pl. 1). The 35-foot thickness probably does not apply to the Labadie (Haskell) Limestone (see correlations part of section on Historical Geology). In this report, thickness of the Labadie Limestone is considered to range from a feather-edge to approximately 23 feet. If correlation of the Labadie (Haskell) Limestone with the Wildhorse dolostone is correct, the maximum known surface thickness of the Haskell Limestone or its correlatives is extended to from 24 to 25 feet. Thickness of the Wildhorse lens ranges from a featheredge to in the $SW\frac{1}{4}SE\frac{1}{4}$ sec. 14, T. 22 N., R. 9 E., Osage County, Oklahoma, about 25 feet.

North of Township 28 North in Oklahoma there are no subsurface records that indicate Haskell Limestone thicknesses in excess of approximately 20 feet and generally the member is less than 10 feet thick. Insofar as can be determined, the Haskell is less than 5 feet thick in the subsurface north of Township 9 South in Kansas, in Missouri, and in Nebraska (see Plates 3 to 5). Commonly on electric logs the Haskell is inseparable from the next younger and much thicker limestone, the Cass Limestone, in northwestern Kansas and Nebraska (e.g., see Plate 3, in pocket).

Rock types developed in the Haskell Limestone include several classes of limestone, dolostone^{1/}, and calcareous siltstone and sandstone. In order of apparent decreasing volume, the limestone classes are mixed-fossil lime wackestone or lime mudstone (Pl. 25), crinoidal (Pl. 26B, C, D, and E) or mixed-fossil (Pl. 26A and F) lime packstone, oolith lime packstone (Pl. 24, unit 2), and impure varieties of these rock types (Pl. 27).

The sequence of rock types exposed in the type section is generally characteristic of the Haskell in the southern Leavenworth-northern Douglas Counties, Kansas area. The basal impure and succeeding oolitic facies are discontinuous. Other aspects of the member in this area include greatest average thickness, about 3.5 feet, north of the vicinity of Peru^{2/}, Kansas; multiple, very thin, slightly irregular to relatively even beds; and vertical jointing in which individual joints do not generally extend from top to base of the member. A mixed-fossil assemblage

^{1/} Common in the Labadie Limestone and typical of the Wildhorse dolostone.

^{2/} Southeastern Chautauqua County.

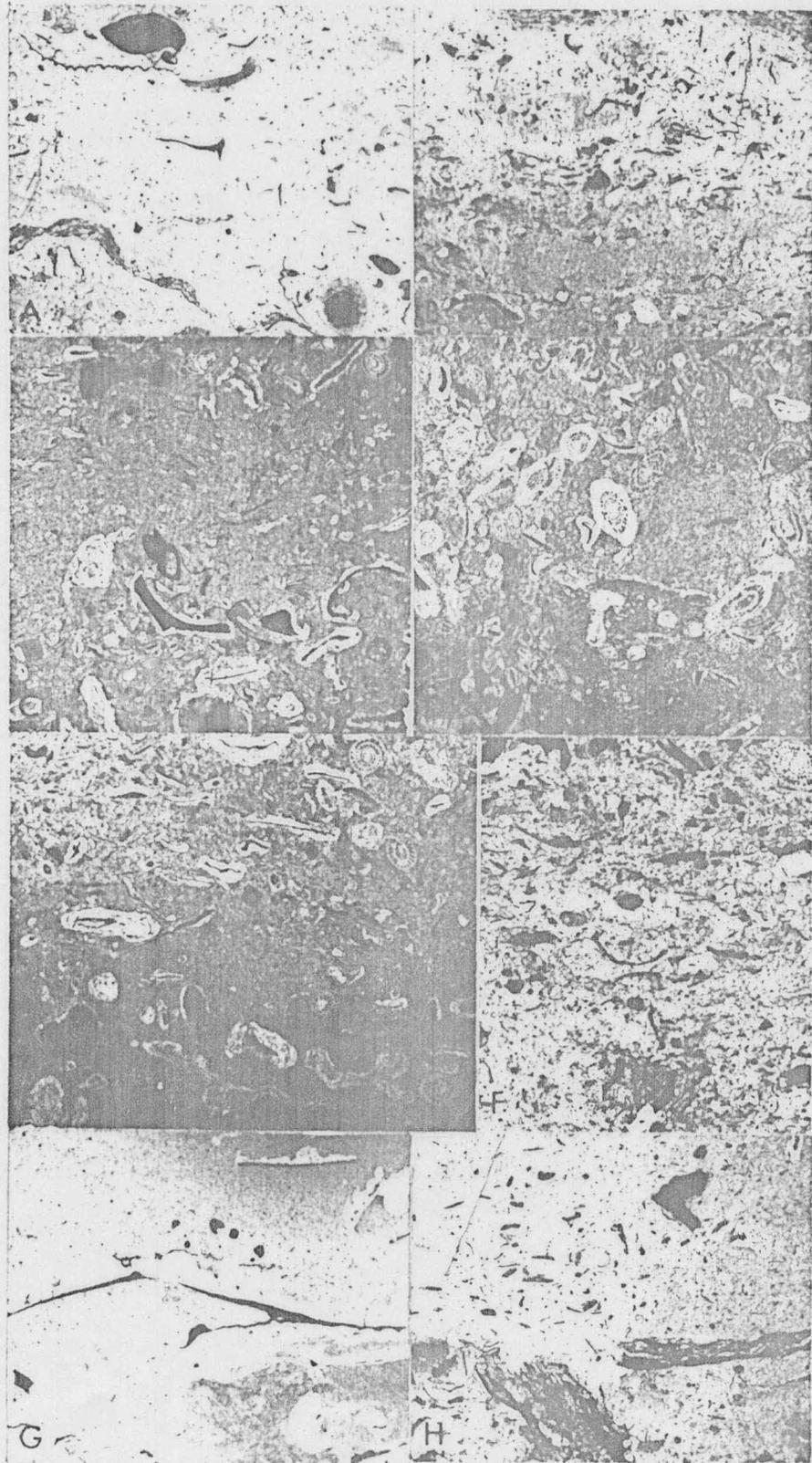


PLATE 25.-- Mixed-fossil lime wackestone to mudstone facies of the Haskell Limestone. Negative prints of thin sections (X2); vertical surfaces, orientation as shown; Kansas samples. A, Sample taken in SW₄ SE₄ sec. 25, T. 9 S., R. 21 E., Leavenworth County. B, Sample from exposure at NE corner NW₄ NE₄ sec. 5, T. 13 S., R. 20 E., Douglas County. C, Sample taken in NE₄ SE₄ SW₄ sec. 26, T. 15 S., R. 19 E., Franklin County. D, Sample taken near SE corner SW₄ SW₄ sec. 16, T. 19 S., R. 18 E., Franklin County. E, Sample from exposure near center east line NE₄ sec. 34, T. 24 S., R. 15 E., Woodson County. F, Sample taken near center NE₄ sec. 23, T. 26 S., R. 14 E., Woodson County. G, Sample taken in NE₄ NW₄ SW₄ sec. 19, T. 28 S., R. 14 E., Wilson County. H, Sample from exposure in SE₄ NE₄ sec. 3, T. 32 S., R. 13 E., Chautauque County. Note algal coatings on grains and abraded grains.



PLATE 26.-- Lime packstone facies of the Haskell Limestone. A, Sample from creek bank exposure near SE corner sec. 10, T. 58 N., R. 33 W., DeKalb County, Missouri. B, Sample from creek bank exposure near center south line NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 24, T. 56 N., R. 35 W., Buchanan County, Missouri. C, Sample from bluff above railroad cutbank exposure of Iatan Limestone at NW corner NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 54 N., R. 36 W., Platte County, Missouri. D, Sample taken near SW corner NW $\frac{1}{4}$ sec. 21, T. 6 S., R. 21 E., Atchison County, Kansas. E, Sample taken near SW corner NE $\frac{1}{4}$ sec. 4, T. 8 S., R. 22 E., Leavenworth County, Kansas. F, Sample taken near center west line sec. 24, T. 34 S., R. 12 E., Chautauqua County, Kansas. A-C (X3) are negative prints of thin sections; D-F (X3) are negative peel prints. Vertical surfaces, orientation as shown.



PLATE 27.-- Facies locally developed in lower part of Haskell Limestone. A, Argillaceous mixed-fossil lime mudstone; sample from creek bank exposure near SE corner sec. 10, T. 58 N., R. 33 W., DeKalb County, Missouri. B, Quartzose mixed-fossil lime wackestone; sample from exposure near center south line SE $\frac{1}{4}$ sec. 25, T. 9 S., R. 21 E., Leavenworth County, Kansas. C, Quartzose molluscan lime wackestone; sample taken near NW corner sec. 19, T. 14 S., R. 21 E., Douglas County, Kansas. D, Coated-grain lime wackestone; sample taken near center NE $\frac{1}{4}$ sec. 23, T. 26 S., R. 14 E., Woodson County, Kansas. Note abraded skeletal grains and *Osagia* grain coatings. E, Argillaceous brachiopod lime mudstone; sample taken near center SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 17, T. 34 S., R. 12 E., Chautauqua County, Kansas. Note current-strewn brachiopod valves at left side of photograph. A (X4), B (X4), and D (X5) are negative prints of thin sections. C (X4) and E (X4) are negative peel prints. Vertical surfaces, orientation as shown.

composed primarily of brachiopodal, algal, crinoidal, and foraminiferal remains is characteristic. Mollusks are common locally and seem to be the only group found mainly in a particular part of the member; the lower impure part. This molluscan facies (Pl. 27C), where considered a part of the Haskell, is so classed on the basis of practicality and represents a transitional unit between the Vinland Shale and the Haskell Limestone.

The crinoidal and mixed-fossil lime packstone facies (Pl. 26) of the Haskell is largely restricted to and characteristic of northern Leavenworth and Atchison Counties, Kansas and Missouri exposures. Generally a single very thin bed, or single ledge where locally cross-stratified (e.g., near NE corner sec. 30, T. 9 S., R. 22 E., Leavenworth County, Kansas), forms the Haskell in this area. The only other localities observed in which the member is represented by this facies are at the south end of the outcrop trace in northeastern Chautauqua County, Kansas (selected section 51 in appendix) and in the southeasternmost exposures between the towns of Peru and Niotaze, southeastern Chautauqua County, Kansas (Pl. 26F). As in the northern area, the crinoidal and mixed-fossil lime packstone facies is again associated with a single, very thin bed development of the Haskell.

The Haskell (Shoemaker) Limestone of Nebraska generally comprises two very thin limestone beds bounding a greenish gray, calcareous, very thin mudstone (selected section 3 in appendix) or a greenish gray calcareous shale parting (selected section 1 in appendix). Brachiopod lime wackestone (Pl. 33, unit 3) forms the upper limestone bed in which the abundant remains of a single form, Crurithyris planoconvexa, is striking.

Mixed-fossil lime mudstone forms the lower limestone bed in which the fauna includes mainly bryozoans, brachiopods, and crinoids. Locally (e.g., NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 12 N., R. 10 E.) a single limestone bed 0.3 foot thick forms the Haskell. There the uppermost 0.1 foot of the bed is brachiopod lime wackestone in which C. planoconvexa is the keynote form and the lowermost 0.2 foot is mixed-fossil lime mudstone. The Haskell (Shoemaker) Limestone of Nebraska exposures displays a remarkably persistent facies. In contrast to facies developed along the principal area of outcrop (Missouri, Kansas, Oklahoma), the Haskell in Nebraska characteristically contains a shale or mudstone unit; lacks crinoidal, mixed-fossil, or oolitic lime packstone; displays a much less diverse fauna^{1/} noticeably lacking recognizable fossil algae and lacks quartz silt or sand. Facies similar to that of the Haskell (Shoemaker) Limestone were observed elsewhere only in the two northernmost outcrops studied in Missouri (see discussion in correlations part of section on Historical Geology).

Essentially one facies, mixed-fossil lime wackestone (Pl. 25C to F and H) similar to unit 3 of the type section (Pl. 24), forms the Haskell Limestone in the southeastern Douglas to northeastern Chautauqua Counties, Kansas area. Other general aspects of the member in this area include development of a single bed vertically jointed through its entire thickness, thickness within a 1.1 to 2.2 feet range, and color range through various shades of gray with either bluish or greenish overtones locally. Mixed-fossil lime packstone or coated-grain lime wackestone (e.g., Pl. 26D) to packstone were noted locally in top and bottom marginal areas of the

^{1/} Excepting the dolostone of the Labadie Limestone and the Wildhorse dolostone.

member. The characteristic single bed aspect is masked by weathering into a rubble of irregularly-surfaces limestone "plates" in a few localities. This weathering feature is negligible except in the east-central part of the Wilson County, Kansas outcrop area. Wagner and Harris (1953) suggest differential weathering of clayey laminae as the cause. Brachiopod and crinoid fragments, foraminifers, especially fusulinids, and algae are the principal fossils found in this area.

North of New Albany in west-central Wilson County, Kansas, the Haskell Limestone is locally about three times (selected section 50 in appendix) normal maximum thickness for the southeastern Douglas to north-eastern Chautauqua Counties, Kansas area. Other aspects of this facies are equally exceptional, for example the very thin wavy bedding and the abundance of sparry calcite stringers, angular fragments, and irregular blebs, some of which are algal-coated (e.g., Pl. 25G). Similar facies form the Haskell in only two other areas, the vicinity of Peru in south-eastern Chautauqua County, Kansas and from approximately 3 to 5 miles south and southwest from Bowring in northeastern Osage County, Oklahoma (selected sections 52 and 61 in appendix).

The Labadie Limestone is largely mixed-fossil lime wackestone to mudstone north of the north-south center line of T. 27 N., Rs. 10 E. and 11 E., and is largely mixed-fossil dolostone southward. Very thin wavy beds are a striking characteristic. Southernmost exposures of the Labadie studied show arenaceous fusulinid lime wackestone (selected section 68 in appendix) and argillaceous fusulinid lime mudstone to wackestone and interbedded fusulinid-bearing shale (selected sections 69 and 70 in appendix).

The Wildhorse "bed" is mainly dolostone in the exposures studied. Oakes (1952, p. 91) reported that the Wildhorse is silty and sandy in the southern part of its outcrop area. I did not study this silty and sandy facies.

Robbins Shale Member

The Robbins Shale (Moore and Newell, in Moore, 1936) was named from the Robbins farm in sec. 11, T. 26 S., R. 15 E., Woodson County, Kansas. A type section was not designated. Although partially covered the spillway cut at Lake Fegan (SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 26 S., R. 14 E., Fig. 22) shows stratigraphic relationships of the Robbins better than any other exposure in southwestern Woodson County and is designated the type section.

Description of type section. -- The Robbins Shale aggregates about 84 feet of shale, mudstone, and siltstone and is conveniently subdivided into a lower shale-mudstone unit (about 63 feet thick) and an upper shale-siltstone unit (about 21 feet thick). Shades of gray, clayey to slightly silty, micaceous, noncalcareous to moderately calcareous, ferruginous pellet-bearing shale that contains calcareous clay-ironstone concretions and finely disseminated carbonaceous matter from 3 to 8 feet above the base forms the lower 13 feet of the lower unit (Fig. 22). Arenaceous foraminifers, ostracodes, mollusks, and conodonts were identified in washings of the samples taken from this part of the member.

From 13 to 46 feet above the base of the member, the section is mostly covered by a mantle of Pleistocene clay, silt, and sand, which is of variable thickness and at least 3 feet thick in places. Where exposed locally, this part of the section is similar to the subjacent rock type (Fig. 22).

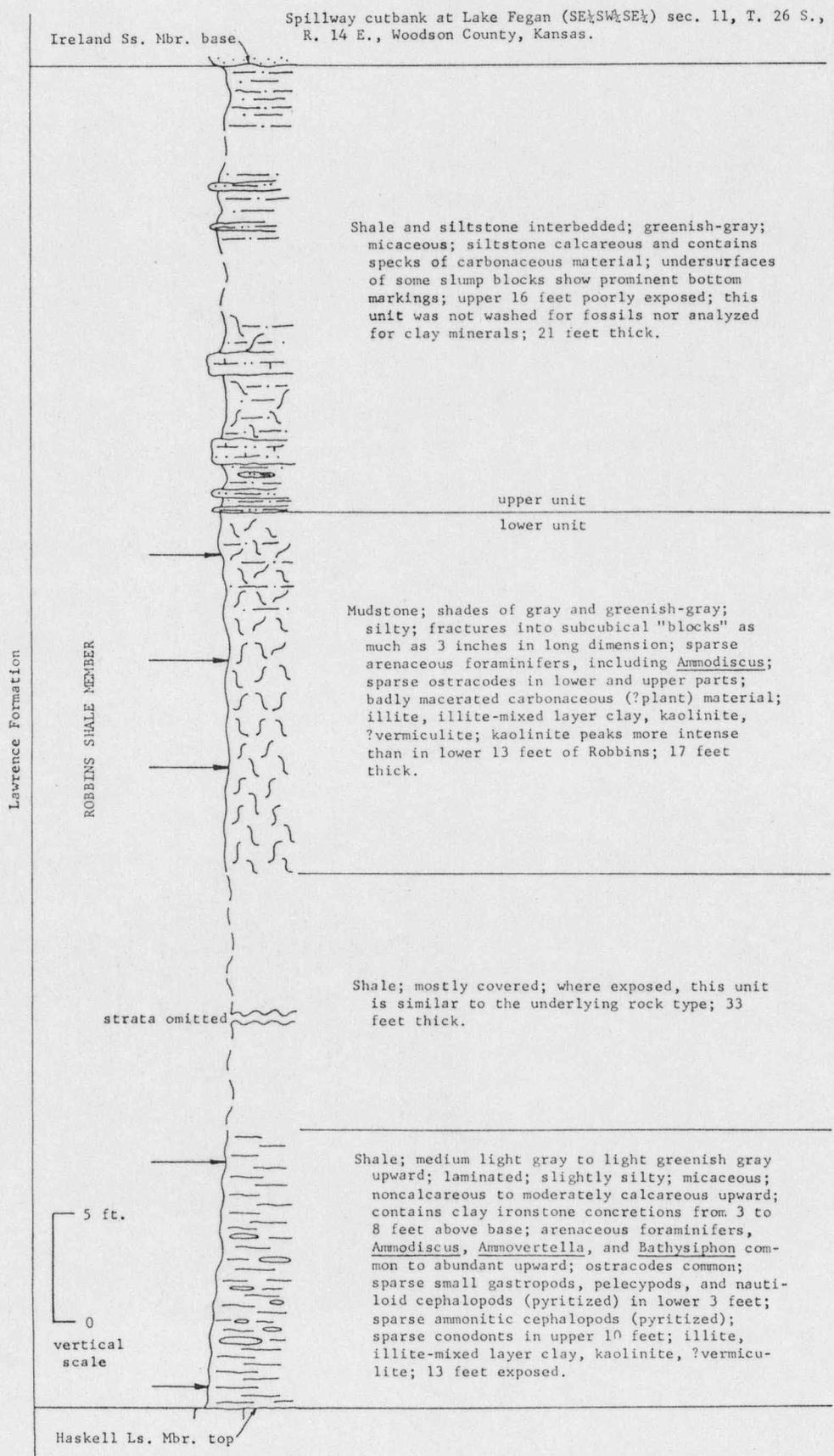


FIGURE 22.--Type section of Robbins Shale. Arrows indicate stratigraphic position of samples washed for fossils and analyzed for clay minerals. See selected section 53 in appendix for description of Tonganoxie, Westphalia, and Vinland Members of the Stranger Formation and the Haskell and Ireland Members of the Lawrence Formation.

The upper 17 feet of the lower unit comprises shades of gray silty mudstone that shows blocky fracture into fragments as much as 3 inches in long dimension. Fossils include minute fragments of plants as well as sparse arenaceous foraminifers and ostracodes.

Clay mineralogy of the Robbins Shale is notably uniform. Illite, kaolinite, ?vermiculite, and illite-mixed layer clay form the assemblage. Relative peak sizes suggest the possibility that the kaolinite/illite ratio increases upward in association with the increase in silt content.

The lower 5 feet of the upper unit is composed of alternating greenish gray, silty, micaceous shale and calcareous, micaceous siltstone section in which the siltstone beds weather grayish orange. Abundant bottom markings and finely disseminated carbonaceous matter characterize the siltstones. Although only partially exposed, the upper 16 feet of the Robbins is apparently silty shale and siltstone and compares lithologically to the lower 5 feet of the upper unit. The Robbins Shale-Ireland Sandstone contact is arbitrarily placed at the base of the first sandstone above the Haskell Limestone.

Contacts of the Robbins Shale are sharp and gradational at base and top respectively. A detailed measured section and description of the bedrock cropping out at this locality is included in the appendix.

Geographic, thickness, and facies range. -- The Robbins Shale is generally continuous throughout the surface part of the area of detailed study (Fig. 1). Southeastern Douglas (O'Connor, 1960) and Franklin (Ball and others, 1963) Counties, Kansas, contain the only surface areas in which local absence of the member is definitely established. The Robbins may also be absent in a small part of southwestern Johnson County,

Kansas (H. G. O'Connor, personal communication, 1960). Like Sanders (1959, p. 145), this report describes the improbability of recorded (Lins, 1950, p. 129-130) local absence of Robbins Shale, Haskell Limestone, Vinland Shale, and a part of the Tonganoxie Sandstone in Leavenworth County, Kansas (see discussion of disconformities in section on Historical Geology).

Two methods of classing the Robbins Shale are used. The member is bounded below by Haskell Limestone top. Where sandstone parts of the Ireland Member are well developed, Robbins top is placed arbitrarily at base of the oldest massive sandstone assigned to the Ireland. Where massive sandstone parts of the overlying Ireland are wholly lacking or where contact between the two members is imperceptible because of apparently complete gradation, section between the Haskell and Amazonia Limestones is classed as Robbins-Ireland Shale or Robbins-Ireland Member. Use of the second method, that of hyphenation, requires that the compounded designation represent a recognizable segment of section. The name is generally applicable in Kansas (singly or compounded), in Missouri (compounded), and locally as far south as 7 miles into Oklahoma (compounded). Application of the name to Nebraska exposures in which recognition of the Little Pawnee Shale and Cass Limestone in the lower part of the Lawrence Formation is far more practical is not recommended. During this study the Robbins Shale was not recognized in Iowa exposures.

If necessary, classification of the Robbins Shale Member can be applied in subsurface study by the same procedures as used on the surface. The Robbins can be recognized in the subsurface as the lower part of the shale-sandstone complex between Haskell Limestone top and base of the first younger recognizable limestone marker unit. However, there is no

means by which top of the member can be accurately traced in the subsurface. Therefore, compounding by hyphenation is the only meaningful method of classing the Robbins in subsurface studies. Where the Haskell Limestone cannot be identified (Fig. 21), the Robbins Shale cannot be recognized.

Thickness of the Robbins Shale is indeterminate in surface outcrops north of approximately the north-south center line of T. 14 S., Douglas County, Kansas^{1/}. Negligible development or complete lack of sandstone part of the section, except along Missouri River; and apparently complete gradation from clayey shale at base to silty shale and minor amounts of siltstone and sandstone above combine to preclude meaningful separation of the Robbins Shale and the Ireland Sandstone in this area. Thickness of strata classed as the Robbins Shale ranges from a featheredge locally in the southeastern Douglas and Franklin Counties, Kansas area to as much as approximately 120 feet locally in southern Wilson County and in Chautauqua County. This thickness range represents the lower predominantly shale part of a shale-sandstone complex in which placement of member boundaries requires utilization of more than one stratigraphic datum. Only two meaningful statements concerning thickness variations of the Robbins Shale-Ireland Sandstone part of the Lawrence Formation between Douglas and Chautauqua Counties, Kansas, can be made. Section bounded by the Haskell Limestone below and the zone of limestone lenses^{2/} in the upper part of the Lawrence Formation above (Fig. 11) ranges from approximately

^{1/}See O'Connor (1960, p. 33), Reynolds (1957, p. 24), McLaren (1958, p. 37-39), Howe and Koenig (1961, p. 109-110), and Hershey and others (1960, p. 23-24) for discussion of specific parts of this area.

^{2/}Occupy stratigraphic position of and are probably correlative with Amazonia Limestone.

110 feet thick in southernmost Douglas County to approximately 200 feet thick in southernmost Wilson County and displays general but not perfectly progressive southward thickening. Thickness of component members, the predominantly shale Robbins below and the predominantly sandstone Ireland above, is highly variable through this stretch of outcrop area.

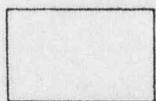
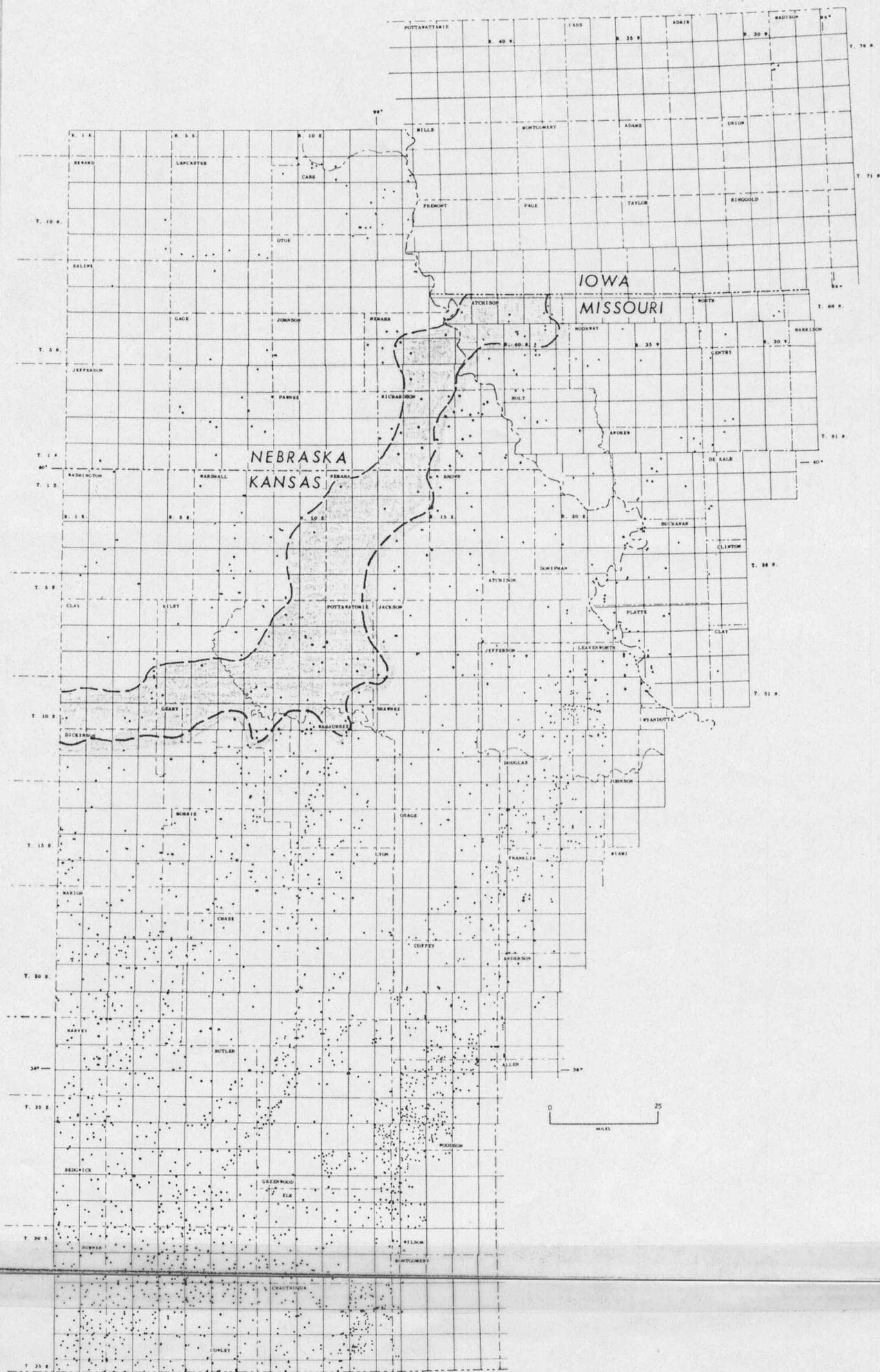
Rock types developed within the Robbins Shale include clay-ironstone bearing clayey shale, silty shale, minor amounts of siltstone and sandstone, goethite, phosphatic nodules, black fissile shale, and limestone.

Shades of greenish gray or olive gray shale commonly containing clay-ironstone concretions form the characteristic facies of the Robbins. This facies is especially well developed from central Woodson County, Kansas, southward; generally forms the lower 10 to 40 feet of the member; displays the same clay-mineral assemblage as the type section in the 5 localities from which samples were prepared and slides x-rayed; contains an abundant macrofauna locally, a sparse to common microfauna commonly, and at least some marine fossils generally; and excepting faunal differences is remarkably like the corresponding part of the older Weston Shale. The basal foot of the Robbins Shale is an important part of the principal sequence, Westphalia Limestone to lower Robbins Shale, used in this report to establish regional correlations. Importance of this small segment of the section is that it yields the only goethite, the only phosphatic nodules, and the only black, fissile shale known from Douglas Group rocks. Phosphatic nodules are known from numerous localities between central Buchanan County, Missouri, and southeastern Elk County, Kansas. The goethite bed is known from several localities between central Buchanan County, Missouri, and at least as far south as southwestern Franklin

County, Kansas. Description of the locally abundant marine invertebrates and fish from the basal Robbins in Douglas County, Kansas, is presented by Miller and Swineford (1957). The basal Robbins fauna where known along the main line of outcrop in Kansas is strikingly molluscan and where known in Nebraska is strikingly brachiopodal (see discussion and reference to specific localities in correlations part of section on Historical Geology). Section from 1 to 40 feet above Robbins Shale base locally yields abundant mollusks, brachiopods, ostracodes and arenaceous, foraminifers in Kansas exposures (e.g., near SW corner sec. 12, T. 29 S., R. 13 E., Wilson County and NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 22, T. 34 S., R. 12 E., Chautauqua County); commonly contains one or two limestones in northernmost exposures in Kansas and Missouri (e.g., near center east line NW $\frac{1}{4}$ sec. 20, T. 6 S., R. 21 E., Atchison County, Kansas and selected sections 16 and 23 in appendix); and is represented, at least partially, by the widespread Cass Limestone (Fig. 23) in the subsurface to the northwest and in Nebraska outcrops. Section from about 40 feet above its base to "top"^{1/} of the Robbins locally contains sparse ostracodes and arenaceous foraminifers at least locally and is characteristically siltier than the lower part of the member.

Very fine- and fine-grained quartzose sandstone thick enough to be escarpment-forming is locally developed in the lower part of the Robbins-Ireland Member (e.g., vicinities of Niotaze and Peru in Chautauqua County) in southernmost Kansas exposures and is developed extensively in the Robbins-Snyderville part of the section in northernmost Osage County,

^{1/} Top of the Robbins Shale is not a good reference horizon and can be traced only by selection of a new datum with loss of an old one.



Area of general continuity.



Area of discontinuity.



Northwestern limit of area in which Cass Limestone is believed to be essentially absent. Within this area, strata tentatively referred to the Cass are known only from a small area in Missouri.

FIGURE 23.-- Distribution map of the Cass Limestone. The subsurface of southwestern Iowa was not studied. See Figure 1 for qualification of control points.

Oklahoma. Only negligible amounts of sandstone are known in the Robbins Shale of the northeastern Chautauqua to southeastern Douglas Counties, Kansas area. Virtually no sandstone occurs in the lower part of the Robbins-Ireland Member of northern Kansas and Missouri exposures. No sandstone whatsoever is known from Nebraska exposures of the Lawrence Formation.

I was unable to trace the Robbins Shale accurately in the subsurface. However, the lower half of the Lawrence Formation, which contains the Robbins, is a limestone-shale facies in the area of essential continuity of the Cass Limestone (Fig. 23).

Ireland Sandstone Member

Moore (1932, p. 93) named the Ireland Sandstone for exposures along Ireland Creek about 5 miles southwest of Yates Center in Woodson County, Kansas. The Ireland has heretofore been defined as the predominantly sandstone lower part of the section bounded by Robbins Shale below and Amazonia Limestone or its approximate correlatives above. However, in practice, geologists have applied the term Ireland to all of the section between the Robbins and the Amazonia (e.g., Verville and others, 1958, p. 26). Moore (1936, p. 155) pointed out that the upper limit of the Ireland is indefinite and probably does not constitute a single stratigraphic horizon. Viewed regionally, there is simply no way to subdivide section objectively between the Robbins Shale below and the Amazonia Limestone above. Therefore, the Ireland Sandstone Member has been redefined (Ball, in O'Connor, 1963, p. 1876-1877) to comprise all the section between the Robbins Shale and the Amazonia Limestone. As pointed out by

Bowsher and Jewett (1943, p. 33) sandstones of the Ireland part of the section, like those of the Tonganoxie Sandstone, grade upward and laterally into surrounding shales. Where such lateral gradation of sandstone parts of the Ireland Member is nearly or wholly complete, for example, north of approximately the north-south center line of T. 14 S., Douglas County, Kansas and the southernmost Franklin-northernmost Anderson Counties, Kansas area (south half T. 18 S. and T. 19 S., Ball and others, 1963, p. 30), strata between Haskell Limestone top and Amazonia Limestone base (or base of the zone of limestone lenses tentatively correlated^{1/} with the Amazonia) are classed as the Robbins-Ireland Shale. Where local scour surfaces bound the Ireland Sandstone below (see discussion of disconformities in section on Historical Geology), its basal contact is definite. Elsewhere base of the Ireland Sandstone is arbitrarily placed at base of the first escarpment-forming sandstone above the Haskell Limestone. Thus, the Ireland Sandstone Member is the upper predominantly sandstone part of the section bounded below by Haskell Limestone top and above by Amazonia Limestone base. Viewed regionally, neither lower nor upper contacts of the member represent single stratigraphic horizons. Rigid definition of the Ireland is not feasible.

Thickness of the member where definable ranges from approximately 30 feet to 120 feet and displays marked lateral variations. If local disconformity below the Ireland extends as low stratigraphically as the Weston Shale (see discussion of disconformities in section on Historical Geology), this thickness range is in error.

^{1/}Tentative correlation first reported by Bowsher and Jewett (1943), followed by Moore and others (1951), Wagner and Harris (1953), O'Connor (1960), and this report.

Rocks types developed within the Ireland include quartzose sandstone and siltstone, silty shale, clayey shale, coal, and sandstone-limestone-shale pebble conglomerate.

Sandstone parts of the Ireland are best developed in the southern Douglas to southern Franklin, southern Woodson to central Wilson, and southeastern Elk to Chautauqua^{1/} Counties, Kansas areas. Sandstone aggregates approximately as much as 80-, 70-, and 85-foot thicknesses respectively in these areas (see Ball and others, 1963; Wagner and Harris, 1953; and Verville, 1958). Dark yellowish orange^{2/} and shades of brown sandstone composed predominantly of very fine- and fine-grained, subangular to subrounded, elongate to equant quartz particles characterizes the prominent cliff-forming sandstones in these areas. Quartz silt grains are commonly an important constituent of the Ireland. Thin sections cut from hand samples of the massive sandstones generally contain less than 5 percent mica flakes whereas mica percentage in the siltier sandstones commonly ranges from 5 to 10. However, in some areas mica flakes are sparse in lower parts of the member (Wagner, 1954). Bowsher and Jewett (1943, p. 32) noted an apparent decrease in the ratio of megascopic mica flakes to quartz as the quartz grains approach sand size. This observation has been corroborated by Lins (1950, p. 121), Sanders (1959, p. 147) and field work during the course of this study. Decrease in amount of mica as quartz

^{1/}At least in greater part referable to the Ireland. If the lenticular limestone in the Lawrence Formation in Chautauqua County, Kansas ultimately proves to be correlative with the Amazonia Limestone, an important part of the sandstone developed in the Lawrence Formation of southern Kansas is younger than the Ireland. The Lawrence Formation of Chautauqua County is not subdivided above the Robbins Shale in this report.

^{2/}Wagner and Harris (1953) report a grayish-orange color for parts of the Ireland Sandstone.

grain size increases is apparently characteristic of sandstones throughout the Douglas Group. From traces to about 3 percent feldspars, trace amounts of unidentified heavy minerals, and from traces to about 4 percent carbonaceous material were noted in the 17 thin sections of the Ireland studied. Ferruginous minerals (?limonite), calcium carbonate, silica or combinations thereof form the matrix. Sandstones of the Ireland class as subgraywackes and are monotonously similar to sandstones of the Tonganoxie Member in over-all aspect.

Alternating clayey shale, silty shale, and siltstone in various sequence characteristically comprise the upper part of the Ireland and commonly grade laterally and vertically into sandstone. The complex variation in this part of the member is well shown on the cross section presented by Wagner and Harris (1953). In general aspects, this cross section is typical of the Ireland Member from southeastern Douglas County southwestward. North of approximately the north-south center line of T. 14 S., Douglas County, clayey shale, silty shale, and much lesser amounts of siltstone are the vastly predominant rock types developed in the Robbins-Ireland Shale of Kansas and Missouri exposures. Neither top nor base of the Ireland were recognized in Nebraska and Iowa exposures.

The Lower Williamsburg coal bed (Bowsher and Jewett, 1943, p. 52) forms a part of the member from west-central Franklin County (vicinity of Pomona) northward to north-central Douglas County (west of Lawrence). A persistent coal bed, from a featheredge to 1 foot thick, crops out from 30 to 53 feet below the Toronto Limestone Member of the Oread Limestone in Leavenworth County, Kansas (Reynolds, 1957, p. 26-28 and McLaren, 1958, p. 40-41) and extends as far north in Kansas as southeasternmost Doniphan

County (near center sec. 8, T. 5 S., R. 21 E.). A 0.7-foot thick coal bed crops out from 26 to 28 feet below the Toronto Limestone in southwesternmost Buchanan County, Missouri. In areas where ?Amazonia Limestone lenses are not developed between the Lower and Upper Williamsburg coal beds, grayish-red mudstone commonly forms a distinctive part of the section between these coal beds. Throughout the area north of north-central Douglas County, Kansas, the grayish-red mudstone in the upper part of the Lawrence Formation is persistent and is younger than the only well-developed coal, which is considered correlative with the Lower Williamsburg coal bed. Stratigraphy and lithology of this coal are amply described by Bowsher and Jewett (op. cit.).

Bedding and other sedimentary structures developed in the Ireland Member (Pl. 28) are similarly developed in sandstone parts of the Tonganoxie. Characteristic structures include very thin, thin, and thick even beds, cross beds, and current ripple marks. Contorted bedding is strikingly developed locally from central Woodson County (near center east line NE $\frac{1}{4}$ sec. 34, T. 24 S., R. 15 E.) southward. Bower (1961, p. 10-12) described cross-stratification and ripple marks of Douglas Group rocks and Tanner (1956) emphasized sedimentary structures in his study of northeastern Osage County, Oklahoma, strata, which include the Jonesburg Sandstone (Goldman, 1920, p. 325-330). The Jonesburg of Goldman's type area (eastern part of sec. 18, T. 35 S., R. 12 E.; Chautauqua County, Kansas) is in the central part of the Lawrence Formation.

The Ireland Sandstone Member is sparsely fossiliferous. Land plants fossils are common locally. Of the 17 localities from which plants are recorded (Cridland and others, 1963, p. 86) from the Lawrence Formation,

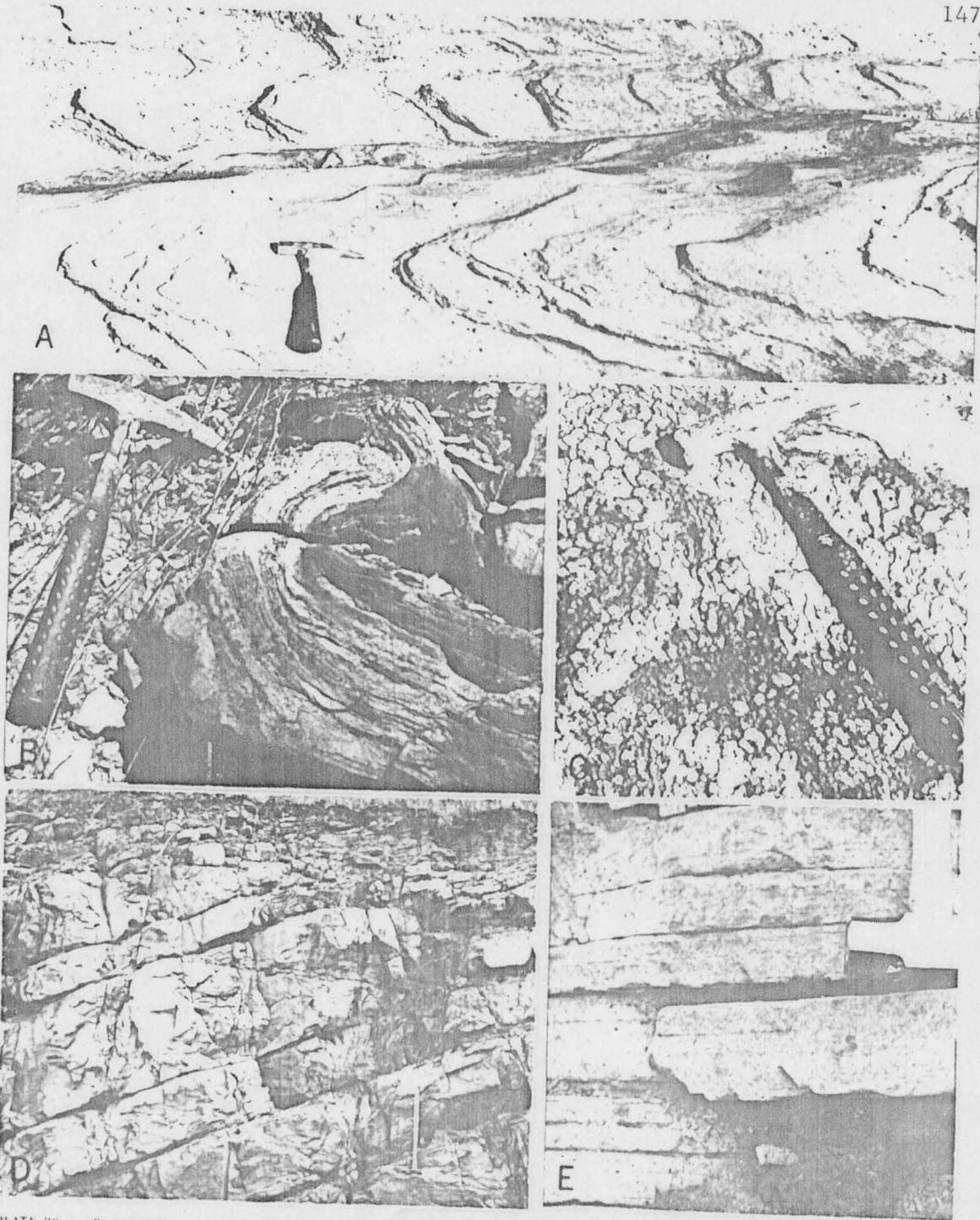


PLATE 28.-- Sedimentary structures developed in Ireland Sandstone. Kansas exposures. A, Cross stratification near center north line NW $\frac{1}{2}$ sec. 16, T. 17 S., R. 18 E., Franklin County. B, Contorted bedding in SE $\frac{1}{2}$ SW $\frac{1}{2}$ SE $\frac{1}{2}$ sec. 11, T. 26 S., R. 14 E., Woodson County. C, Mold of filled surface on underlying bed, same locality as B. D, Dipping, thin to thick, even beds at east end of Toronto Dam (near center north line SW $\frac{1}{2}$ sec. 32, T. 26 S., R. 14 E., Woodson County). Apparent dip about 20° E. E, Very thin to thin even bedding in spillway of Toronto Dam (near center sec. 31, T. 26 S., R. 14 E., Woodson County).

15 are in Douglas County and 1 each in Leavenworth and Franklin Counties. As nearly as I can determine, 7 of these localities^{1/} represent massive sandstones of the Ireland and 10 represent shales and siltstones of the upper part of the Robbins-Ireland Member. Sparse plant fossils have been reported from other Ireland exposures (Wagner and Harris, 1953; Ball and others, 1963; and numerous measured section descriptions in files of the State Geological Survey of Kansas).

Record of invertebrate fossils in the Ireland is indeed limited. Reworked marine fossils are known locally from conglomerate developed in the lower part of the Ireland. Holly C. Wagner^{2/} (written communication, 1964) has recorded brachiopods, pelecypods, gastropods, and crinoids from the Ireland in Wilson County, Kansas, and Wagner and Harris (1953) reported brachiopods and ?worm tracks from that county. Patterson (1933, p. 27) reported the ostracode ?Cavellina, from shale in the upper part of the Robbins-Ireland Shale near Lawrence, Kansas. Molds and casts of ?nuculid pelecypods from a single exposure of the Ireland in east-central Coffey County and of brachiopods and gastropods, including Pharkidonotus, from four localities in Chautauqua County were observed during the course of this study. Sparse pelecypods and common to abundant well-preserved casts and molds of brachiopods, especially Linoproductus oklahomae, are common locally in the Jonesburg Sandstone of northernmost Osage County, Oklahoma (e.g., selected section 59 in appendix). Goldman (1920, p. 329-330) found a greater variety of invertebrates in the Jonesburg part of the section than were observed during this study.

^{1/} Six localities in Douglas County and the Franklin County locality.

^{2/} Geologist, United States Geological Survey.

Attempts to trace the Ireland Sandstone Member accurately in the subsurface were unsuccessful. However, discussion of general aspects of the distribution of sandstone within the Lawrence Formation is meaningful. Where such sandstones are developed in outcrops, they are classed largely with the Ireland Member. Negligible amounts or no sandstone in the Lawrence Formation is indicated by mechanical and sample logs in the northwestern part of the study area and none was observed in or has been reported from Nebraska exposures. The area of essentially no sandstone is traversed by the northwestern two-thirds of Plate 2^{1/} (northwest of well 7), by Plate 3^{1/}, and by the northwestern one-half of Plate 4^{1/} (northwest of well 11). Except locally in the southernmost and southeasternmost marginal parts of the area of essential continuity of the Cass Limestone (Fig. 23), sandstones are either poorly developed or lacking in the Lawrence Formation. South and southeast of this area sandstones commonly aggregate an important part of the Lawrence Formation.

Summary. -- The Ireland Sandstone is predominantly quartzose sandstone and shale, forms the upper part of the shale-sandstone complex that includes also the Robbins Shale, and, where definable, ranges from approximately 30 to approximately 120 feet in thickness. Locally the basal contact is strikingly disconformable (e.g., in parts of Douglas and Franklin Counties, Kansas). Elsewhere transition from clayey shale of the underlying Robbins Shale through silty shale and silty shale and siltstone to sandstone of the Ireland is commonly gradational. Where such contact relationships obtain base of the Ireland is arbitrarily positioned at base of the first escarpment-forming sandstone above the Haskell Limestone.

^{1/} In pocket.

The member is defined by Robbins Shale top below and Amazonia Limestone base or base of the zone of limestone lenses tentatively correlated with the Amazonia above. Considered regionally, the Ireland grades laterally and vertically into finer-grained rocks to the northward and northwestward and bounding contacts do not represent single stratigraphic horizons. The term Ireland, either used singly or compounded by hyphenation where contacts are not discernible, is applicable to Missouri and Kansas exposures as far southwestward as northeastern Chautauqua County. Farther south the Ireland is represented in part by the Jonesburg Sandstone of Goldman (1920, p. 329-330).

As currently known, rock types developed within the Ireland are lithologically indistinguishable from those of the older Tonganoxie Sandstone Member of the Stranger Formation. Fossils of the member are poorly known. Only the flora collected from Douglas County exposures has been adequately studied (Cridland and others, 1963). Patterson (1933) recorded the only invertebrate microfossils known from the member. The only shale samples of either the Ireland Member or the upper part of the Robbins-Ireland Member that have been washed for microfossils are those studied by Patterson (op. cit.). Patterson studied samples from exposures in Douglas and Leavenworth Counties where the upper part of the Robbins-Ireland Member is poorly exposed. The number of samples washed by Patterson from this part of the section is not known.

Amazonia Limestone Member

Hinds and Greene (1915, p. 31) originally proposed the name Amazonia limestone bed and were the first to recognize that the Amazonia and Iatan were not the same limestone. Moore (1936, p. 158) assigned member rank to

the Amazonia and designated its type locality as Amazonia, in southern Andrew County, Missouri. Connotation of the Amazonia has remained unchanged, although various geologists have, from time to time, confused it with the Iatan. The bluff exposure overlooking the Chicago-Burlington-Quincy Railroad (SE cor. SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 59 N., R. 36 W.) at Amazonia is proposed as the standard reference section (Pl. 29).

Description of standard reference section. -- The Amazonia aggregates about a seven-foot thickness of mixed-fossil lime mudstone to wackestone. Lithology is extremely uniform. The rock is very light gray to light bluish gray and weathers light gray. Bedding is poorly developed and discontinuous and the member tends to weather into massive blocks, which break along joint surfaces. Locally in its upper foot, the ledge weathers into nearly continuous 1 to 3 inch thick beds. Fresh rock surfaces show sparse brachiopods, bryozoans, crinoids, and algae embedded in a dense matrix mottled with ferruginous material. Fossils form about 10 percent of the surface and algal remains appear to be the most abundant faunal element. Algal veinlets are neither as numerous nor as large as ones occurring in the Iatan Limestone. Hence, fresh and especially weathered surfaces of the Amazonia are distinctly different from surfaces of Iatan Limestone. Other criteria that serve to differentiate type Iatan Limestone from type Amazonia Limestone are the less distinct bedding of the latter and occurrence of fusulinids in the former.

As seen in thin section, medium to coarsely crystalline sparry calcite fossils are interspersed in an aphanocrystalline calcite ooze matrix. Microspar calcite occurs in small patches around the margins of some of the fossils, but there is no evidence of extensive recrystallization in

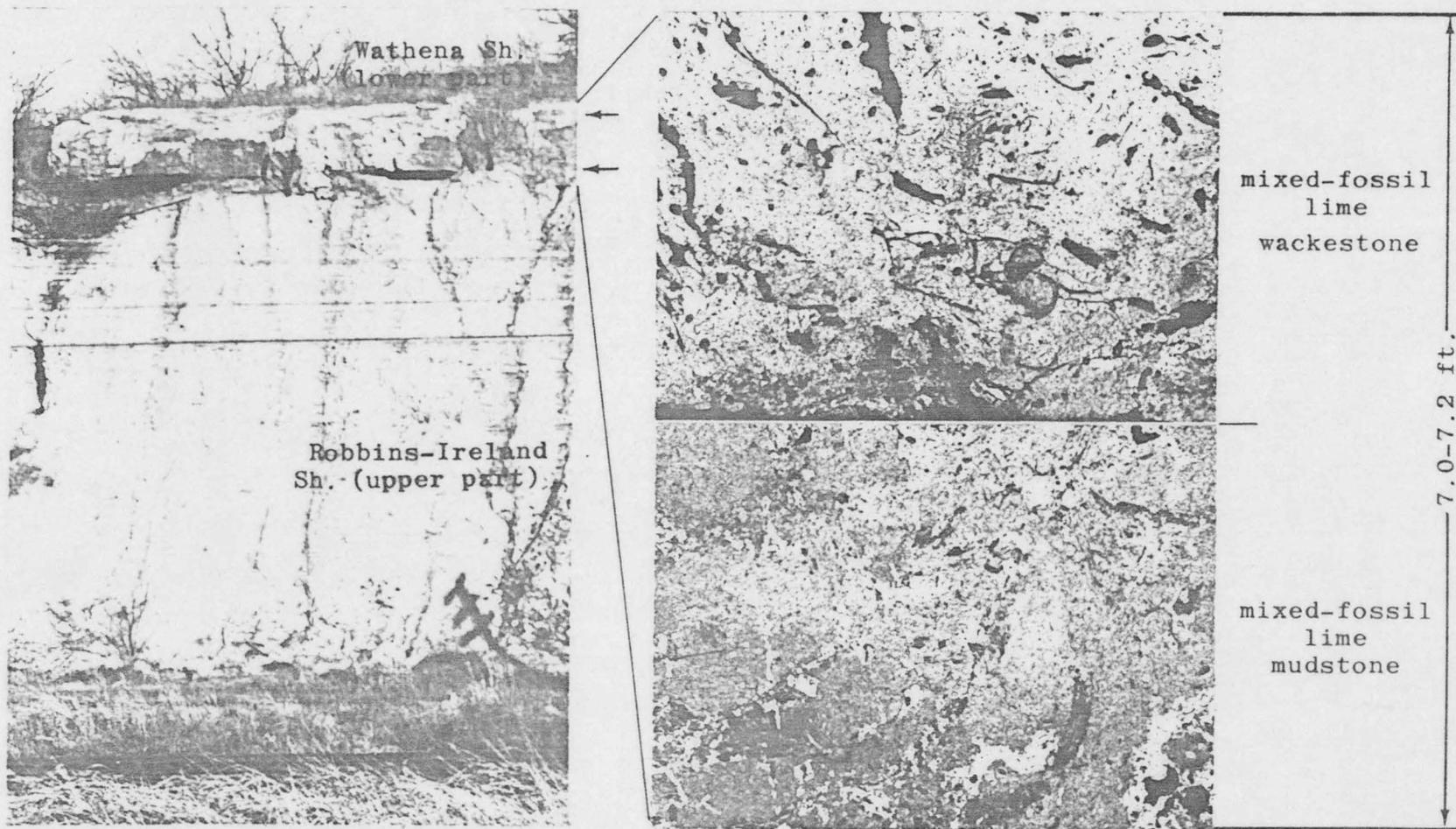


PLATE 29.-- Standard reference section of Amazonia Limestone. Railroad cutbank exposure at SE corner SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 59 N., R. 36 W., Andrew County, Missouri. Negative prints of thin sections (X3) on right. Arrows show exact positions of samples chosen as representative. Vertical surfaces, orientation as shown.

the matrix. Irregular blebs of ferruginous material appears to be associated with voids or fractures in the rock and coats calcite crystals rather than emphasizing grain boundaries.

Geographic, thickness, and facies ranges. -- The Amazonia Limestone extends from its type section northwestward approximately 1.5 miles where it passes beneath Missouri River alluvium. Southward the member is essentially continuous as far as southwestern Buchanan County, Missouri (SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 6, T. 55 N., R. 36 W.) and apparently wedges out a short distance southwest of this outcrop. No outcrops of the member northeast of the town of Amazonia, Missouri were located during this study. Extensive concealment by Pleistocene deposits makes tracing of units extremely difficult in this area. However, presence of the member is indicated in most subsurface records, of this part of the section in northwest Missouri (see Plate 2 in pocket). The Amazonia was not recognized in either Iowa or in Nebraska outcrops.

In Kansas, the Amazonia Limestone reappears from beneath Missouri River alluvium about 4 miles southwest of the type section at an exposure in northeastern Doniphan County (near NE corner sec. 28, T. 2 S., R. 22 E.). Numerous good exposures of the member are in the river bluffs and ravines of tributaries as far south as an outcrop in southeastern Doniphan County (near SW corner sec. 17, T. 4 S., R. 22 E.). The Amazonia apparently wedges out a short distance southwest of this exposure and is absent from outcrops in southeasternmost Doniphan County.

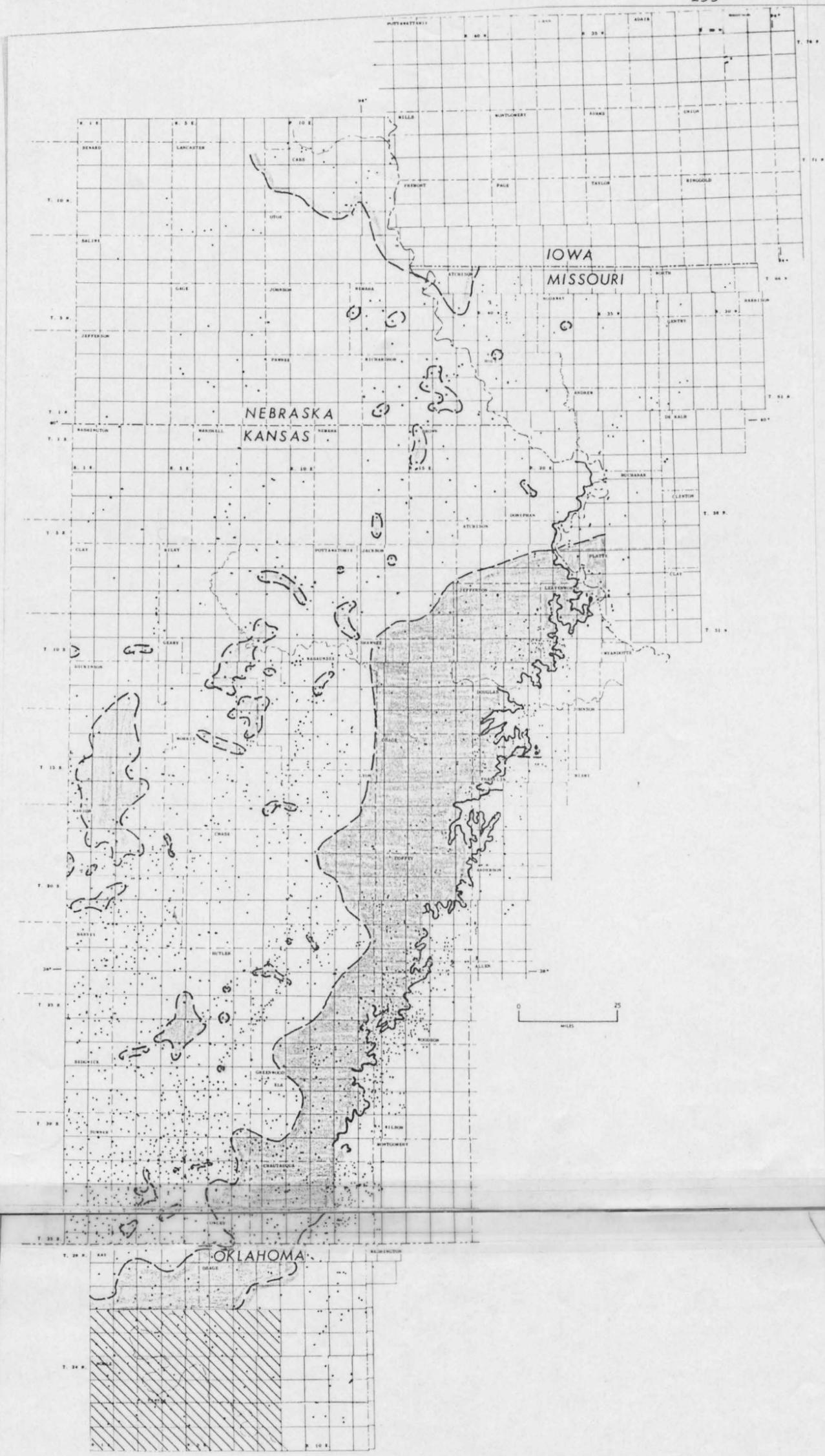
Argillaceous fossiliferous limestone or dolomitic siltstone (e.g., selected section 45 in appendix) lenses crop out in the approximate stratigraphic position of the Amazonia from Leavenworth County to Elk

County. Figure 11 shows the general stratigraphic relations of this zone of lenses. Bowsher and Jewett (1943, p. 35) proposed tentative correlation of the lenses with the Amazonia, a practice that has been followed by most geologists (Moore, 1949; Verville, 1958; and O'Connor, 1960). Sub-surface study, which resulted in the preliminary distribution map shown as Figure 24, corroborates this tentative correlation. The zone of fossiliferous, mainly limestone lenses^{1/} in the upper part of the Lawrence Formation is classed as the ?Amazonia Limestone in this report. Tentative correlation is applied from Leavenworth County to southeastern Elk County.

Outcrop thicknesses of the Amazonia Limestone range from a feather-edge to as much as about 14 feet in Missouri River bluff exposures in the southwesternmost Andrew County-northwesternmost Buchanan County area. Thickness of the lenses referred to the ?Amazonia Limestone ranges from a featheredge to as much as 9 feet (Verville, 1958, p. 26 and Fig. 6). The member may be as much as about 25 feet thick locally (Pl. 7, well 19, in pocket; log description 18 in appendix) in the subsurface of south-central Kansas.

Essentially a single facies, mixed-fossil mudstone to wackestone similar to that developed in the type section (Pl. 29), forms the Amazonia Limestone of northwestern Missouri and Doniphan County, Kansas exposures. This facies is poorly fossiliferous in greater part. Sparse to common fossil algae, brachiopods, crinoids, and bryozoans are generally found in the member, but in some exposures a diligent search is necessary to confirm

^{1/}These limestones are lenses as viewed in two dimensions. Amount of shallow subsurface control is insufficient to determine whether description as tongues would be preferable in some parts of the area of discontinuity and poor development (Fig. 24).



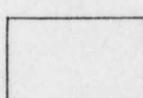
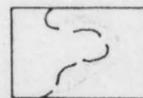
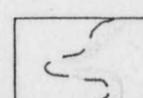
-  Area of general continuity.
-  Area of discontinuity.
-  Areas in which not identified and believed to be absent.
-  Limit of areas in which not identified and believed to be absent.
-  Correlation not established.
-  Area in which Toronto Limestone is absent.
-  Surface trace of Toronto Limestone base in Kansas approximates that of Amazonia Limestone, which was not mapped. Broken where breached by major drainage and not shown where discontinuous south of southeastern Elk County.

FIGURE 24.-- Distribution map of the Amazonia Limestone. The subsurface of southwestern Iowa was not studied. See Figure 1 for qualification of control points. Outcrops of the Amazonia or of the ?Amazonia have not been definitely identified south of Township 31 South in Kansas.

even this variety of forms. Fossils are abundant only locally (e.g., abandoned quarries in SW $\frac{1}{4}$ sec. 18 and NW $\frac{1}{4}$ sec. 19, T. 58 N., R. 35 W.; Andrew and Buchanan Counties, Missouri respectively) and there only in the upper 2 feet of the member, where productid brachiopods, especially Linoproductus, are most abundant. Bedding is characteristically indistinct and discontinuous and the member weathers as a single ledge, which displays massive splitting. Two joint sets extend from top to base of the Amazonia. Separation along joint surfaces into huge blocks, some as much as 20 feet across, is a striking aspect of the member. Moore (1949, p. 137) reported the slumping of these joint-bounded blocks, which are randomly arranged on slopes below the Amazonia escarpment. Amazonia slump blocks are especially well developed along Missouri River bluffs between Saint Joseph and Amazonia, Missouri, and in the bluffs of Township 3 South on the Kansas side of the river. Weathered surfaces commonly display a false brecciation in the form of close-fitted or dove-tailed pieces of limestone bounded by paper-thin argillaceous or ferruginous films (Pl. 30). Shades of gray constitute the characteristic colors of the Amazonia and weathering is generally to darker shades of gray.

Diverse facies are represented by the lenticular limestones of the ?Amazonia Limestone. Commonly the lenses are argillaceous and poorly fossiliferous. In some exposures the ?Amazonia is cross-stratified (O'Connor, 1960, p. 37 and Pl. 5B; Reynolds, 1957, p. 28 and Fig. 12) and contains coal stringers and shale pebbles as well as mollusks, brachiopods, and bryozoans. The dolomitic siltstone of some Douglas County, Kansas, outcrops contains only Lingula carbonaria and bottom markings. The diversity of rock types classed collectively as the ?Amazonia Limestone

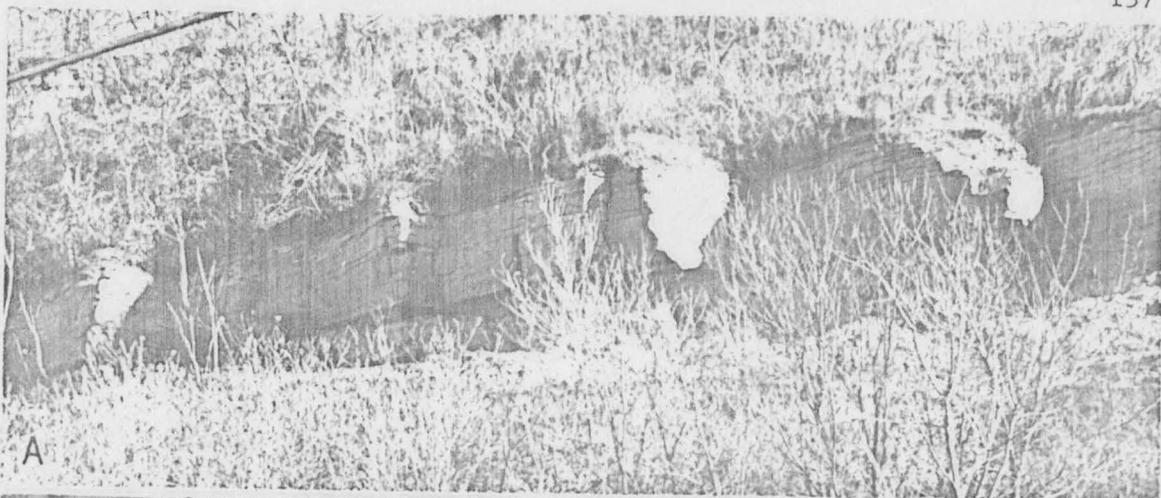


PLATE 30.-- Weathered surfaces of Amazonia Limestone. Missouri exposures. A, Poorly defined bedding near center north line sec. 29, T. 57 N., R. 35 W., Buchanan County. B, False brecciation in SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 30, T. 58 N., R. 35 W., Buchanan County.

in Wilson County are described by Wagner and Harris (1953). Extremely fossiliferous (mainly fusulinids) limestone forms the ?Amazonia Limestone in Elk County (Verville and others, 1958, p. 26 and Fig. 6) and is commonly a silty to sandy and friable rock. Lenticular limestones of the ?Amazonia crop out from as little as about 10 to as much as about 60 feet below the Toronto Limestone Member of the Oread Limestone.

Wathena Shale Member

The name Wathena^{1/} Shale is proposed for the strata bounded by Amazonia Limestone top below and base of the Toronto Limestone Member of the Oread Limestone above. As the uppermost member of the Lawrence Formation, distribution of the Wathena and unqualified areal usage of the name is the same as that of the Amazonia Limestone. Where the Amazonia Limestone is absent or cannot be identified, a significantly large area, and in the local areas of Toronto Limestone absence, compounding the term Wathena with the name of either the subjacent or superjacent unit by hyphenation is both definitive stratigraphically and convenient for writing purposes. An exposure in an abandoned quarry along the Missouri River bluffs about 0.6 mile south of Wathena (NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 33, T. 3 S., R. 22 E., Fig. 25) is the proposed type section.

Description of type section. -- About 23 feet of shale and mudstone in shades of gray, green and red form the Wathena Shale. Mudstone parts of the member generally lack obvious lamination but a few hand samples showed vague laminae. Sparse quartzose silt particles and medium silt- to very fine sand-size mica flakes are characteristic.

^{1/} Town located on U. S. Highway 36 in east-central Doniphan County, Kansas.

Exposure in abandoned quarry near center sec. 33,
T. 3 S., R. 22 E., Doniphan County, Kansas.

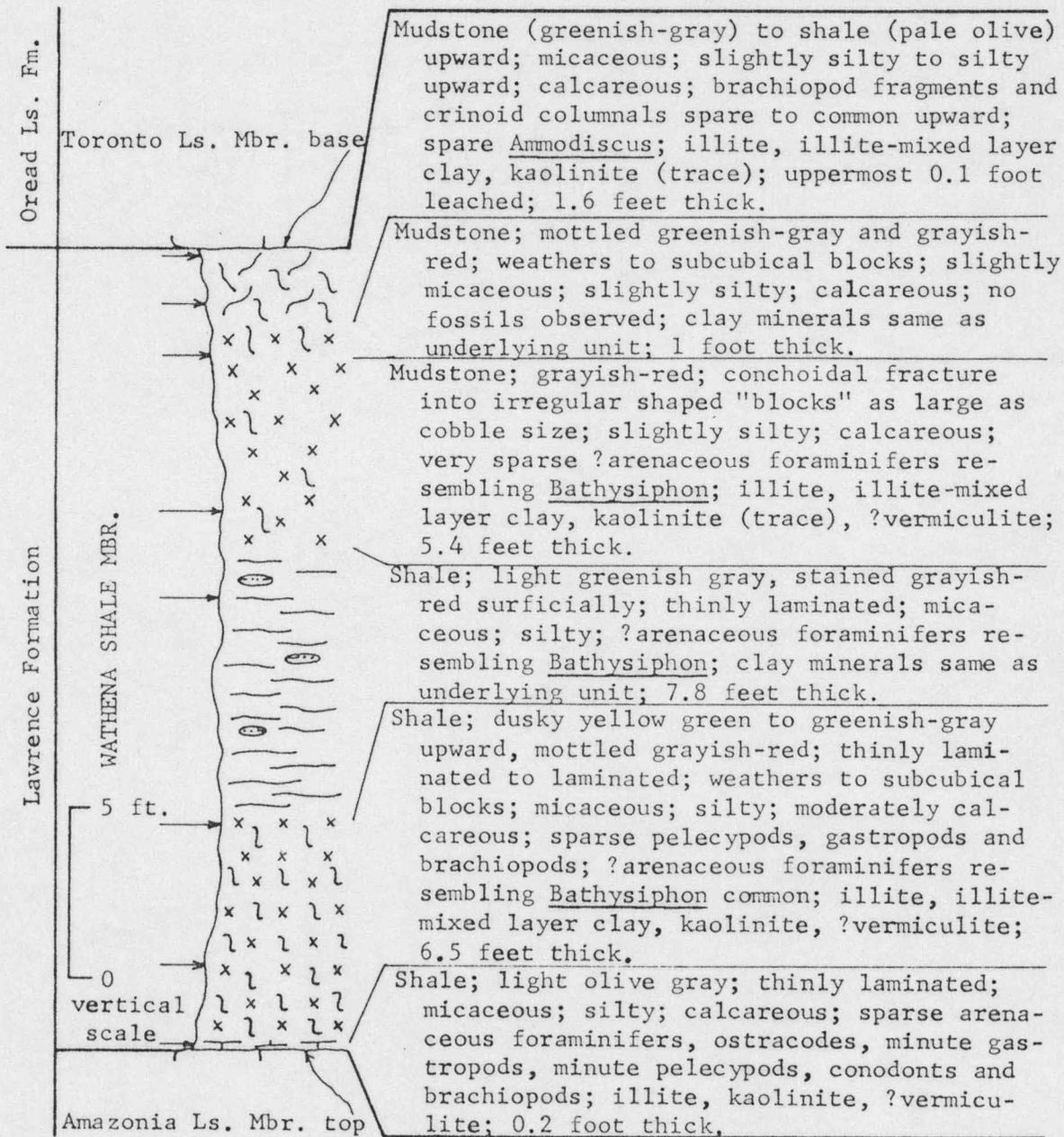


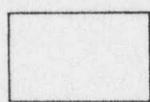
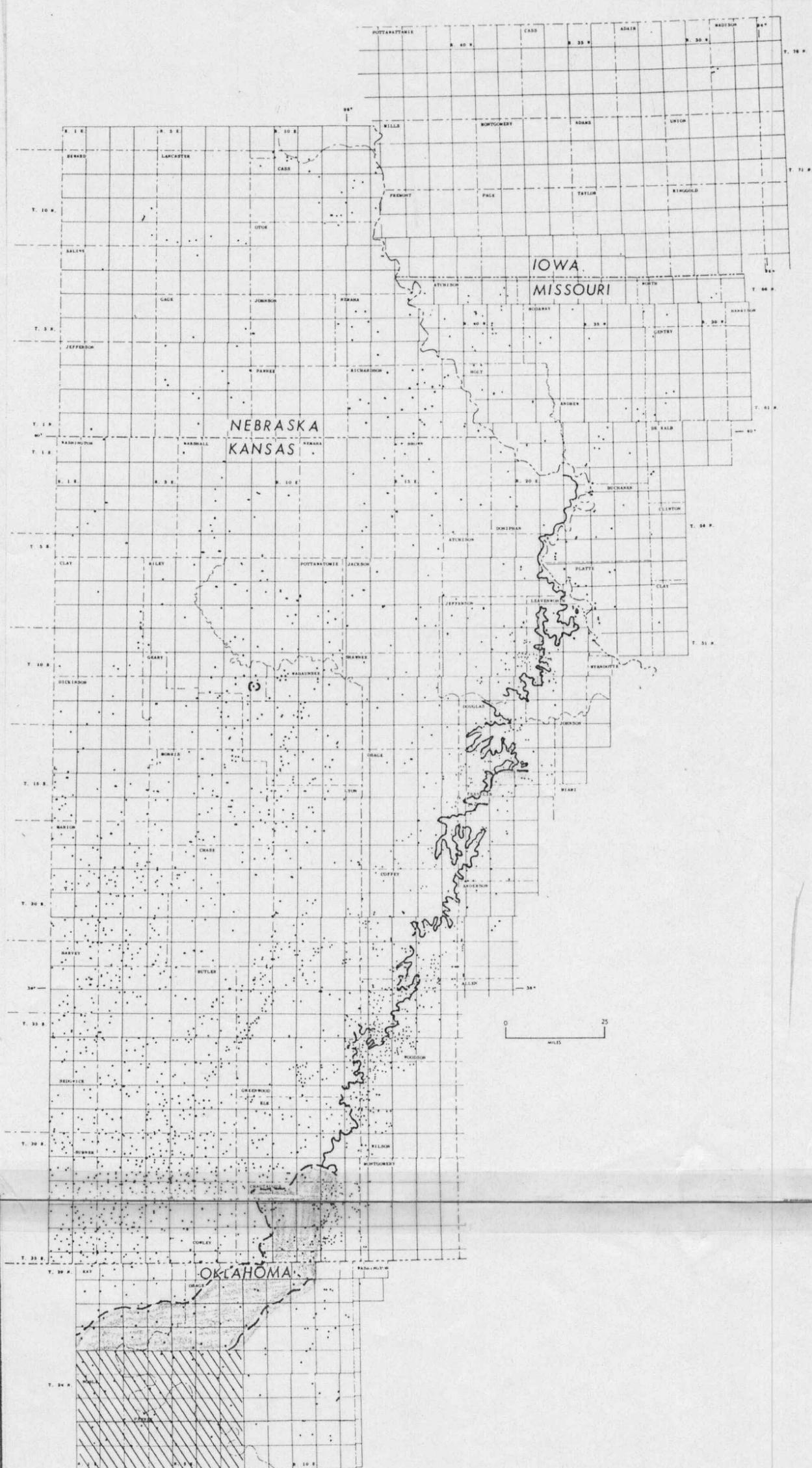
FIGURE 25.-- Type section of the Wathena Shale. Arrows indicate stratigraphic position of samples washed for fossils and analyzed for clay minerals. See selected section 54 in appendix for description of Amazonia Limestone and rocks of the Oread Formation.

Fauna of the Wathena is meager numerically and is not diversified. Arenaceous foraminifers, ostracodes, conodonts, and diminutive pelecypods, gastropods, and brachiopods are represented. Part of the grayish-red mudstone is apparently nonfossiliferous. Fossils are more abundant in the uppermost 1.6 feet than in other parts of the member.

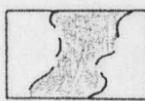
The clay-mineral assemblage comprises illite, kaolinite, ?vermiculite, and illite-mixed layer clay. Apparent decrease in kaolinite content above the base of the grayish red mudstone and lack of ?vermiculite in the uppermost 2 feet are noteworthy vertical variations in the clay mineralogy.

Contacts of the Wathena are gradational and apparently sharp at base and top respectively. Top contact characteristics have been partially obliterated by the leaching effect of ground-water movement.

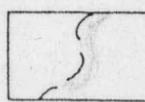
Geographic, thickness, and facies range. -- The Wathena Shale is generally continuous throughout the area of detailed study (Fig. 1). In south-central Douglas and northwestern Franklin Counties, Kansas, the overlying Toronto Limestone is absent and in this area (Fig. 26) the term Wathena is not applicable even though parts of the member are recognized locally. The Wathena Shale and the overlying Toronto Limestone were eroded from an area of negligible size including small parts of Andrew County, Missouri, and Doniphan County, Kansas (see discussion of disconformities in section on Historical Geology). The member is recognizable only locally, that is, where bounded above by the Toronto Limestone, in the southeastern Elk-Chautauqua Counties, Kansas, area (Fig. 26). Except in these limited areas, the term Wathena is applicable singly or compounded by hyphenation with the name of the next older recognizable member of the Lawrence Formation in Missouri and Kansas exposures. The Wathena was recognized in a



Area of general continuity.



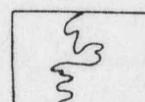
Area of discontinuity.



Limit of areas in which not identified and believed to be absent.



Correlation not established.



Approximate outcrop trace of Toronto Limestone. Broken where breached by major drainage.

FIGURE 26.-- Distribution map of Toronto Limestone. The subsurface of southwestern Iowa was not studied. See Figure 1 for qualification of control points. Toronto Limestone exposures have not been identified south of Township 28 North in Oklahoma.

single Oklahoma exposure, the only outcrop in which the Toronto Limestone was observed in that state (roadcut near center east line NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 12, T. 28 N., R. 9 E., north-central Osage County, Oklahoma). The member was not recognized definitely in Iowa exposures. Although bases of both the Little Pawnee (basal Robbins) Shale and the Toronto (Weepingwater) Limestone are definite in Nebraska exposures, it is entirely impractical to apply the term Robbins-Wathena Member in that state. The Haskell (Shoemaker) Limestone, Little Pawnee Shale, and Cass Limestone of Nebraska exposures weather as a unit, which is escarpment-forming and its base mappable where not covered by thick glacial drift. Consequently, the classification shown on Plate 1 is considered most applicable to Nebraska exposures. Usage of only one of the member names, that is, the Haskell Limestone, which are applied to subdivisions of the Lawrence Formation in the Missouri-Kansas area of outcrops, is recommended for Nebraska. The upper unnamed subdivision of the Lawrence Formation in Nebraska is, in part, correlative with the Wathena Shale.

Thickness of the Wathena ranges from about 10 (near center east line SW $\frac{1}{4}$ sec. 28, T. 23 S., R. 15 E., Woodson County, Kansas) to approximately 60 feet (near center sec. 23, T. 30 S., R. 12 E., Elk County, Kansas). Only the 20- to 55-foot thickness range for Missouri (4 measured sections) and Doniphan County, Kansas (2 measured sections), is based on measurements limited both above, Toronto Limestone base, and below, Amazonia Limestone top, by single stratigraphic markers. Tops of one or another of the lenticular limestones classed as the ?Amazonia Limestone limit the Wathena Shale below in outcrops between Leavenworth and Elk Counties, Kansas, and do not define a single stratigraphic horizon. Hence, the 10- to 60-foot

thickness range of the Wathena in the greater part of the Kansas outcrop area does not represent measurements between continuous key beds.

Wathena Shale thicknesses in the subsurface are generally within the 10- to 60-foot range measured on the surface. Within the area of essential continuity of the underlying Amazonia Limestone, Wathena thicknesses are generally less than 30 feet in that part of the area north of Township 30 South in Kansas and generally more than 30 feet southward. The member may be as much as approximately 90 feet thick in the subsurface of southern Kansas if my correlation of the Amazonia is correct that far south.

Shale and mudstone, as in the type section (Fig. 25), form the Wathena Shale of Missouri and Doniphan County, Kansas, exposures. The grayish red mudstone facies in the Wathena is in all Missouri and Doniphan County, Kansas, exposures observed, is essentially continuous as far southwest as Franklin County, Kansas, and is locally developed as far southwest as the Toronto Limestone member of the Oread Limestone was traced (near center east line NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 28 N., R. 9 E., north-central Osage County, Oklahoma). Grayish red mudstone is well developed in the upper unnamed shale in Nebraska exposures of the Lawrence Formation and is probably represented in Iowa exposures although top of the Lawrence was not definitely recognized in Iowa (see discussion in correlation part of section on Historical Geology). Red shale^{1/} or grayish red mudstone in the Wathena Shale or the upper part of the Lawrence Formation is surprisingly widespread, although not necessarily continuous, in the subsurface and is recorded on most sample logs in this part of the Douglas section (Fig. 27).

^{1/} Presence or lack of lamination cannot generally be ascertained from study of cuttings.

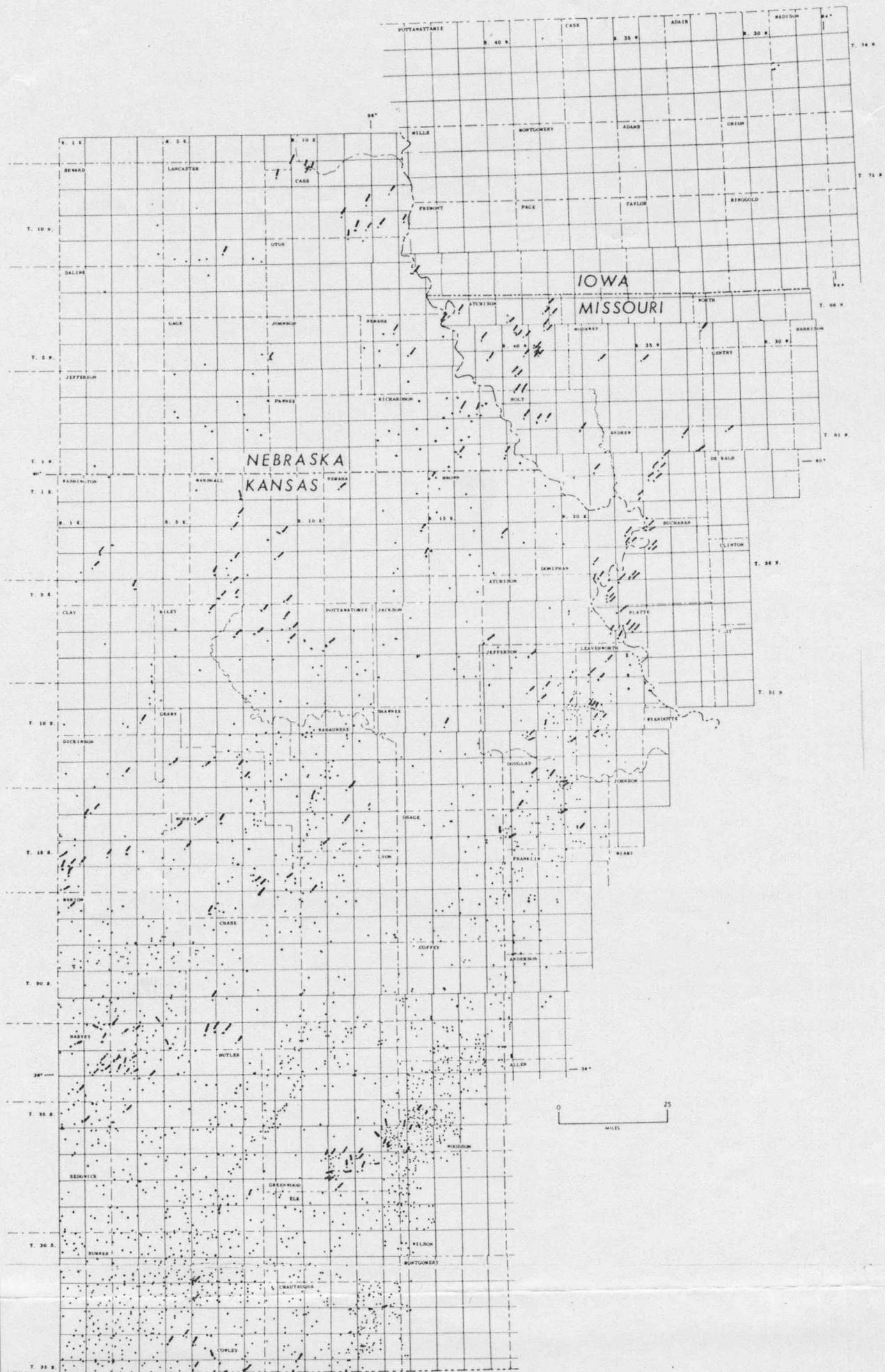


FIGURE 27.-- Plot of wells (complete) and outcrops (incomplete) showing widespread yet discontinuous extent of grayish-red mudstone in the Wathena Shale Member or in the upper part of the Ireland-Wathena Member of the Lawrence Formation. Presence of grayish-red mudstone indicated by short black dashes adjacent to control points. The subsurface of southwestern Iowa was not studied. See Figure 1 for qualification of control points. The small circles represent electric and radioactivity log control and have no significance regarding presence or absence of grayish-red mudstone.

Excepting the limestones, this grayish red mudstone or red shale development is the best stratigraphic marker within Douglas Group rocks.

The Upper Williamsburg coal bed is an excellent stratigraphic marker from Douglas County southwestward to Elk County, Kansas. This coal bed ranges from a smut to the maximum thickness of about 2 feet reported by Bowsher and Jewett (1943, p. 55), crops out in a position from immediately below the Toronto Limestone (Bowsher and Jewett, op. cit., p. 56) to directly above the ?Amazonia Limestone (Bowsher and Jewett, op. cit., p. 55) and about 30 feet below the Toronto Limestone, and invariably occurs above the grayish red mudstone facies where this rock type is developed in the Wathena. Although not perfectly continuous, the Upper Williamsburg is essentially so from north-central Douglas County (selected section 55 in appendix) to northeastern Elk County, Kansas (near NE corner sec. 12, T. 29 S., R. 12 E.). The Upper Williamsburg is the most widespread of Douglas Group coal beds. Detailed lithology of this coal bed was described by Bowsher and Jewett (op. cit., p. 56-57).

Detailed subsurface distribution of the Upper Williamsburg coal is not known. According to my interpretations, only 3 sample logs (Plate 9, well 50; Plate 7, well 15; and log 49 in appendix), about 34, 30, and 32 miles respectively west of the area of outcrop, record any coal within the Wathena Shale. These are the westernmost records of coal in the stratigraphic position of the Upper Williamsburg coal. Insofar as is presently known, the Upper Williamsburg is best developed between north-central Douglas and east-central Elk Counties, Kansas and does not extend in excess of approximately 35 miles downdip.

Quartzose siltstone and very fine- to fine-grained sandstone are locally developed in the Wathena Shale or in the upper part of the Lawrence Formation from southwesternmost Buchanan County, Missouri (e.g., selected section 17 in appendix) southwestward. However, no Wathena outcrops in which amount of siltstone and sandstone exceeds that of shale and mudstone were observed during this study. No siltstone or sandstone was seen in the Wathena north of southwesternmost Buchanan County in Missouri or in Doniphan County, Kansas, exposures. Neither siltstone nor sandstone have been reported or were observed in the upper unnamed shale of the Lawrence Formation in Nebraska outcrops.

Only samples from the type section (Fig. 25) and from 3 localities in Douglas County, Kansas (selected sections 45, 55, and 56 in appendix) have been analyzed for clay-mineral content. Preliminary study indicates that illite, kaolinite, ?vermiculite, and illite-mixed layer clay form the assemblage. Apparent^{1/} variation in kaolinite amount and absence of ?vermiculite in several samples are the only notable differences and neither difference appears to characterize a particular part of the member or to be associated with color or faunal variation in the member.

Megafauna of the Wathena Shale is either sparse or has not been reported in localities north of Woodson County, Kansas. From southwestern Woodson County (selected section 57 in appendix) southwestward, the uppermost 1 to 8 feet of the Wathena commonly contain abundant megafossils. Wagner and Harris (1953) described general aspects of this assemblage in Wilson County and Verville (1958, p. 26) did similarly for Elk County.

^{1/}Based on relative size of kaolinite peaks. No attempt was made to quantify by constituent percentages.

The most striking aspects of this accumulation of fossils are the general abundance of fusulinids and, locally in Elk and Chautauqua Counties, profuse numbers of pelecypods, mainly myalinids. Echinoderms, brachiopods, bryozoans, and corals are also represented and Wagner and Harris (op. cit.) reported the foraminifer, Tetrataxis, and the ostracode, Bairdia.

Arthur Troell^{1/} has studied this fossil assemblage extensively during preparation of his doctoral dissertation on the Toronto Limestone Member of the Oread Limestone. Observation of an apparently gradational Lawrence Formation-Oread Limestone contact in parts of Wilson County (Wagner and Harris, 1953); observations made during the course of this study in southwestern Woodson, Wilson, Elk, and Chautauqua Counties, Kansas; and more significantly the bed by bed disappearance of the Toronto Limestone, which has been worked out in detail by Mr. Troell in this area and has been studied by me with Mr. Troell, leave no doubt that the Wathena Shale and Toronto Limestone grade vertically and laterally into one another in southern Kansas (see discussion of rock-stratigraphic contacts in section on Historical Geology).

Microfauna of the Wathena Shale is poorly known. Few washings of the Wathena have been studied. Eight samples of the member yielded the fauna recorded on Figure 25. Patterson (1933, p. 27-28) washed a number^{2/} of shale samples from the Wathena in Leavenworth and Douglas Counties, Kansas. In greater part, exact stratigraphic placement of the fossils reported by Patterson from the upper 45 feet of the Lawrence Formation is unknown. Patterson's findings include fragments of pelecypods and

^{1/} Graduate student in Geology at Rice University.

^{2/} Number unknown.

brachiopod spines and the ostracodes Cavellina and Jonesina from this part of the section. Some of these fossils are from the Ireland part of the Robbins-Ireland Member of Douglas and Leavenworth Counties for Patterson stated (op. cit., p. 27):

Fossils come in just above the coal bed shown 40 feet below the top of the Lawrence Shale.

The coal referred to by Patterson is the Lower Williamsburg bed, a part of the Ireland Sandstone Member. The arenaceous foraminifer Hyperammina, holothurian spicules of Ancistrum, ostracodes comparable to Cytherella, and fresh water algae identified by M. K. Elias as Trochilicus were reported by Patterson from the red shale in the zone from 15 to 23 feet below top of the Lawrence Formation. The grayish red mudstone or shale is a part of the Wathena Shale. Not enough shale washings have been studied to determine whether or not the Wathena Shale is generally fossiliferous, as was inferred by Patterson (op. cit.) for Douglas and Leavenworth Counties, Kansas.

Shawnee Group

Oread Limestone

Toronto Limestone Member

The Toronto Limestone (Haworth, E., and Piatt, W. H. H., 1894, p. 117) bounds the Douglas Group above. Toronto, a town in southwestern Woodson County, Kansas, is the type locality but a type section has not been designated. A quarry exposure (NE cor. NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 25 S., R. 13 E., see Pl. 31) is proposed as the type section.

Description of type section. -- Four limestone and three shale units (Pl. 31) are described in ascending order. The three shale breaks are the

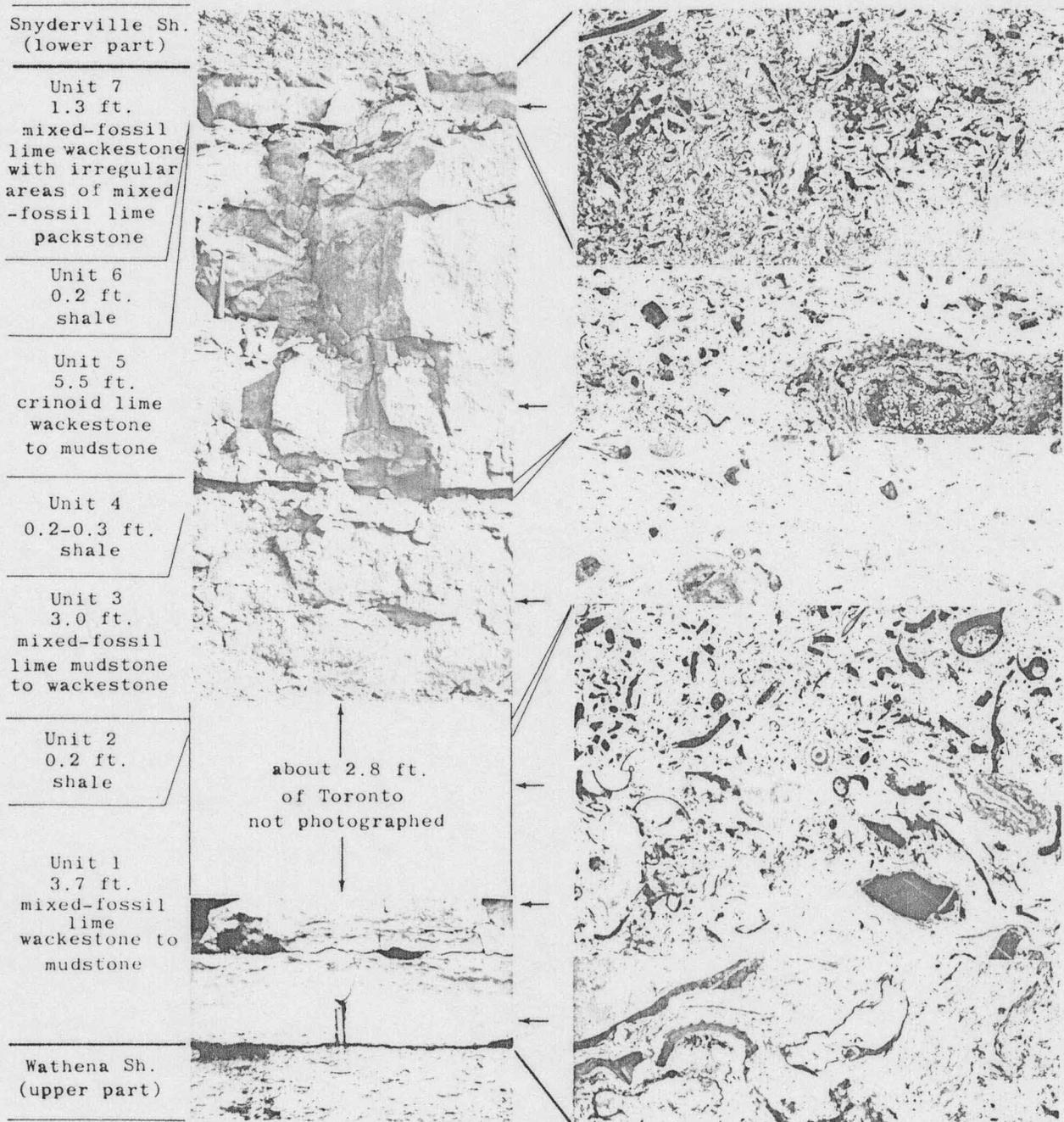


PLATE 31.-- Type section of Toronto Limestone. Quarry exposure at NE corner NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 25 S., R. 13 E., Woodson County, Kansas. Negative prints of thin sections (X2) on right. Arrows show exact positions of samples chosen as representative of footages indicated and described in text. Vertical surfaces, orientation as shown.

sole basis for unit differentiation. Textural differences in the limestone units are not pronounced and do not warrant further subdivision; seemingly there is as much textural variation laterally within a bed or even within individual thin sections as exists vertically between beds. Unit 1 aggregates 3.7 feet in thickness and includes relatively even to moderately irregular beds ranging from 0.5 foot to 1.7 feet thick. Fresh rock surfaces are light olive gray and weathering to shades of yellow and brown is characteristic. This unit is a mixed-fossil lime wackestone to mudstone. Grain percentage ranges from about 5 to about 30 percent. Skeletal grains include brachiopod, mainly productid; sparse fusulinid and other foraminifer; crinoid, bryozoan; gastropod; and algal remains. The algae, Osagia and Epimastopora and the foraminifer Triticites are noted. Grain coatings identified as the algal-foraminiferal consortium Osagia are common and characteristic. Another characteristic is the extensive recrystallization of skeletal structure to sparry calcite mosaics. One to two percent clay minerals are present in the basal and topmost parts of the unit. Lime mud is the dominant matrix material but presence of 5 percent or less irregular blebs of spar is common. Sparry calcite is seemingly concentrated in small parts of thin sections where fossil debris is relatively closely packed.

A greenish gray, calcareous, fossiliferous shale break or parting that is as much as 0.2 foot thick and weathers dark yellowish orange forms unit 2. The shale contains crinoid and brachiopod fragments. The basal contact of unit 2 is highly irregular relative to unit thickness and extends as much as 0.1 foot into unit 1. Unit 2 is probably discontinuous and is not apparent in many outcrops.

Mixed-fossil lime mudstone to wackestone forms unit 3, which is light gray to medium light gray in the central part, dark yellowish orange to moderate yellowish brown at base and top, and about 3 feet thick. The quarry faces show indistinct discontinuous beds ranging from 0.4 to 1 foot thick. Crinoid debris is the most conspicuous faunal element but brachiopod, gastropod, bryozoan, fusulinid, and other foraminifer remains are present. Discontinuous dark greenish gray clay laminae occur in a zone from about 1-2 feet above the base of the unit. The matrix consists of lime mud and 20-40 micron microspar in about equal proportions. Bounding contacts of unit 3 are gradational.

A greenish gray shale break that weathers dark yellowish orange and is 0.2 to 0.3 foot thick is designated unit 4. This shale break (locally a parting) is present stratigraphically near the middle of the member in many exposures. In the type section, the shale is calcareous and contains fragmented crinoid remains.

Unit 5 totals 5.5 feet thick and comprises indistinct discontinuous beds ranging from about 0.2 foot to 2 feet in apparent thickness. In many exposures in which weathering has accentuated the bedding, there are no single beds as much as 2 feet thick in this part of the member. Fresh rock surfaces are light brown. This unit is a crinoid lime wackestone to mudstone in which fragments of columnals and rarely of cups are conspicuous in the lower and upper parts and less so in the central part of the unit. Other skeletal grains include brachiopod, echinoid spine, bryozoan, sponge, and fusulinid remains. Fusulinids are common to abundant in the upper foot and extremely sparse in the rest of the unit. Osagia-like algal coatings on skeletal grains are common. The dominantly lime mud matrix shows extensive ferruginous stain.

A greenish gray, calcareous, fossiliferous shale break that weathers light brown and is 0.2 foot thick forms unit 6. This shale contains crinoid, brachiopod, bryozoan, and fusulinid remains.

The topmost unit (7, Pl. 31) is a single vertically-jointed bed devoid of shale breaks or partings and about 1.3 feet thick. In parts of the quarry, unit 7 shows a tendency to weather into platy "beds" in the upper 0.3 foot. Texturally the rock is a mixed-fossil lime mudstone to wackestone which contains irregular areas of mixed-fossil lime packstone. Patchy distribution of lime mud and spar and completely random orientation of long axes of lath-shaped grains suggests mixing of originally interbedded sand and mud. Sparry calcite is concentrated in areas in which packing of skeletal debris is relatively close. Grains, many of which are coated, include brachiopod, bryozoan, crinoid, sparse fusulinid and other foraminifer remains and lithiclasts.

This section is a particularly good type because by utilizing different parts of the quarry the entire member is well exposed and available for study. Contrast in bedding characteristics that results from difference in weathering time is shown by comparison of quarry faces with the road cut immediately north on U. S. Highway 54.

Geographic, thickness, and facies range. -- Distribution of the Toronto Limestone is shown on Figure 26. The Toronto is absent from a very small area^{1/}, including parts of Andrew County, Missouri and Doniphan County, Kansas, and from the area in south-central Douglas and northwestern Franklin Counties, Kansas. From southeastern Elk County, Kansas southwestward

^{1/} Not shown on Figure 26 but described in discussion of disconformities in section on Historical Geology.

across Chautauqua County to Township 28 North in Osage County, Oklahoma, the Toronto is thin and discontinuous. Southward the member was not observed in outcrop and is probably absent throughout much of the subsurface. Lukert (1949, Pl. 2) did not recognize the Toronto Limestone in the east ranges of Township 22 North in Noble, Pawnee, and Osage Counties, Oklahoma. The Toronto Limestone is probably absent in the Middle River area of Iowa (see discussion of correlations in section on Historical Geology). Elsewhere in the area of detailed study (Fig. 1) the Toronto is essentially continuous and like the older Haskell and South Bend Limestones is an exceptionally widespread marker unit.

Thickness of the member ranges from a featheredge to approximately 20 feet. Thinning to less than 1 foot in the Chautauqua County, Kansas, and northeastern Osage County, Oklahoma, area is the only thickness trend related to geography that was ascertained during this study.

During the course of this study, Mr. Arthur Troell^{1/} undertook an extraordinarily detailed surface study of the Toronto Limestone and has now completed this study. His report is in preparation and is to be published by the State Geological Survey of Kansas. Joint study with Mr. Troell of particular areas of Toronto outcrops was beneficial to this study. Only rock types developed in the lowermost part of the Toronto were studied in detail for this report. The basal 0.5 foot of the Toronto Limestone is a mixed-fossil lime wackestone to mudstone facies. Fresh rock surfaces are commonly light gray or light greenish gray whereas weathered samples show shades of either yellowish brown or yellowish

^{1/} Graduate student in geology at Rice University, Houston, Texas.

orange. This part of the member is deeply weathered in most outcrops. Fossil brachiopods, bryozoans, fusulinids, and crinoids, were noted in most exposures of the basal bed of the Toronto.

Interbedded limestone, in part nodular, and shale or mudstone form approximately the lower half of the Toronto (Weepingwater) Limestone of Nebraska exposures (Fig. 28 and selected section 1 in appendix). This argillaceous, abundantly fossiliferous facies is markedly different than the mixed-fossil lime wackestone to mudstone that forms the lower part of the Toronto in most Kansas exposures northeast of southwesternmost Woodson County and in Missouri exposures. Apparently this facies represents partial gradation of the lower part of the Toronto into shale in the area of Nebraska exposures but the limited lateral extent and small number of outcrops preclude verification of this.

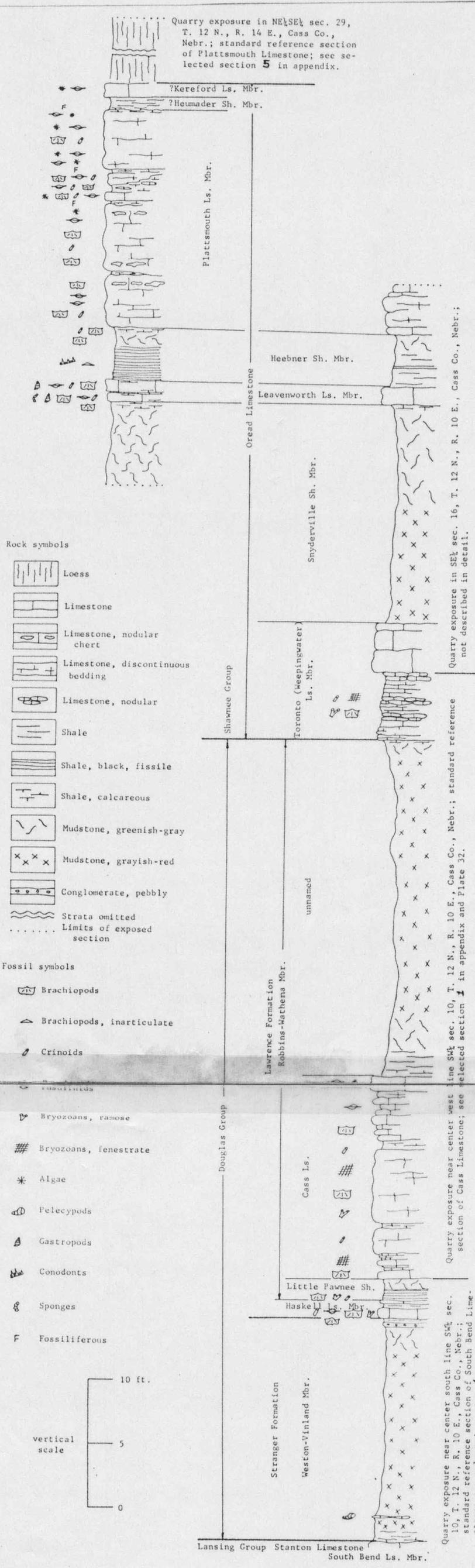


FIGURE 28.-- Correlation of Oread Limestone from near Plattsmouth to near South Bend, Cass County, Nebraska and illustration of Douglas Group rocks exposed in the latter area. See Condra and Scherer (1939, 1958) for cross sections of Pennsylvanian rocks exposed along the Platte River between Plattsmouth and South Bend.

HISTORICAL GEOLOGY

Correlations

Interstate and intrastate correlations considered problematical are described below.

Correlations form the direct or indirect basis for all interpretations (other than description) that result from a regional stratigraphic study. The painstaking effort of previous workers, who long since established many of the correlations restudied by me, is fully credited in this and other parts of the report.

Douglas Group between the Kansas-Missouri and Nebraska areas. -- The widespread near continuity of numerous thin stratigraphic units, a concept developed and documented mainly by those geologists cited on page is indeed real. No one familiar with the northern Midcontinent Pennsylvanian would seriously question this concept. Nonetheless, there are problems pertaining to exactly which units persist and what lateral variations obtain between Kansas and Missouri outcrops and those in Nebraska. Study of correlations to the Nebraska outcrop area involves utilization of both surface and subsurface data and comparison of sequences as well as individual stratigraphic units.

Shawnee Group rocks of Doniphan County, Kansas, were studied in a reconnaissance manner by C. K. Bayne^{1/} and I while mapping the county during the summer of 1961. W. D. Johnson^{2/} and I studied the upper part^{3/} of the

^{1/} Geologist, State Geological Survey of Kansas.

^{2/} Geologist, United States Geological Survey

^{3/} Ervine Creek Limestone Member of the Deer Creek Limestone to Coal Creek Limestone Member of the Topeka Limestone.

Shawnee Group during the Spring of 1962 in the excellent exposures between Sparks and Iowa Point in northwestern Doniphan County and compared this section to that exposed near Jones Point (NW $\frac{1}{4}$ sec. 21 and SE $\frac{1}{4}$ sec. 17, T. 10 N., R. 14 E., Cass County, Nebraska). The Jones Point section, which extends from the Plattsmouth Member of the Oread Limestone upward to the Coal Creek Member of the Topeka Limestone was described by Condra and Reed (1937, p. 25-28, divisions 1 to 6).

Several gross differences between Shawnee Group rocks as exposed in Doniphan County, Kansas, and the Jones Point section of southeastern Cass County, Nebraska, are noteworthy. The Kanwaka and the Calhoun Shale Formations display marked northward thinning. Northward thinning of the Tecumseh-Oskaloosa part of the section is less marked. Some of the shale members show inverse thickness relationships. For example, the Iowa Point Shale is the thickest and the Jones Point is the thinnest shale member of the Topeka Limestone near Iowa Point in Doniphan County and the reverse is true near Jones Point. Sandstone or siltstone forms a conspicuous part of the Kanwaka, the Tecumseh, and the Calhoun Shales locally in Doniphan County but was observed only in the Tecumseh-Oskaloosa Shale near Jones Point. The Haynes Limestone Member of the Deer Creek Limestone is not developed in Kansas (Moore, 1936, p. 187) or in Missouri (Howe and Koenig, 1961, p. 114) whereas the Ozawkie Limestone Member of the Deer Creek Limestone of Kansas and Missouri classification is not recognizable near Jones Point. The Ost Limestone of the Jones Point section was not recognized in Doniphan County exposures and the Clay Creek Limestone of Kansas and Nebraska outcrops was not definitely recognized near Jones Point. Shales of the Jones Point section apparently contain

more calcareous mudstone, argillaceous limestone, and invertebrate megafossils than do corresponding shale units in Kansas and Missouri. Grayish black fissile shale has not been reported from the upper part of Kansas and Missouri Kanwaka Shale exposures but is developed in the Jones Point section.

Parts of the Shawnee Group were traced northward toward Plattsmouth, Nebraska. Section from the Plattsmouth Limestone Member of the Oread Limestone to the Ervine Creek Limestone Member of the Deer Creek Limestone is well exposed at the Queen Hill quarry in east-central Cass County, Nebraska (NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 9, T. 11 N., R. 14 E.). About 3 miles farther north all members of the Oread Limestone except the lower part of the Snyderville Shale and the Toronto (Weepingwater) Limestone are exposed at the south end of the Heebner quarries (near center north line SE $\frac{1}{4}$ sec. 29, T. 12 N., R. 14 E.). Mr. Rudy Iverson^{1/} directed me to the best exposure of the Toronto (Weepingwater) Limestone observed near Plattsmouth (near center west line NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 7, T. 12 N., R. 14 E.). Figure 28 shows the correlation of the Oread Limestone from Missouri River bluff exposures near Plattsmouth westward to exposures along Platte River northwest of South Bend, Nebraska and relationship of the Oread to Douglas Group rocks exposed in the latter area.

Surface correlation of the Douglas Group into Nebraska was checked by subsurface study. Plate 2 extends from DeKalb County, Missouri to Cass County, Nebraska. Other geologists are credited for collection of much of the subsurface data. Sample log, core and outcrop descriptions are included in the appendix.

^{1/} Affiliated with the Chevrolet dealership in Plattsmouth, Nebraska.

Douglas Group from northwest of South Bend to northwest of Nehawka, Cass County, Nebraska. -- The diagrammatic cross section shown as Figure 29 represents this correlation. A standard reference section of the Cass Limestone of Condra (1927, p. 158) and the type section of the Shoemaker Limestone are described below.

Lawrence Formation-Cass Limestone Member. -- The name Cass (Condra, 1927, p. 41, 58, 158) was first applied to a ledge exposed in the Burlington quarries along the Platte River bluffs about $1\frac{1}{2}$ to 2 miles northwest of South Bend, Cass County, Nebraska. This unit was called a bed and as such does not represent an original designation of a formal stratigraphic unit. As indicated by the measured section description (op. cit., p. 158), the strata to which the name was applied from what was subsequently called the Haskell Limestone Member of the Cass Formation (Condra, 1949, p. 29). The latter usage of the term Cass represents its original designation as a formal stratigraphic unit. In this report redefinition of the Cass Limestone to conform to 1927 usage is suggested. So restricted the Cass Limestone is classed as a member of the Lawrence Formation. The quarry exposure in the $SE\frac{1}{4} NE\frac{1}{4} SE\frac{1}{4}$ sec. 9, T. 12 N., R. 10 E. (Cass County, Nebraska; quarry owned by Mr. Hopper) is proposed as a standard reference section.

Description of standard reference section. -- Nearly 15 feet of section is grouped arbitrarily into 3 units. The basal unit aggregates 10 feet in thickness. Individual beds range from about 0.1 foot to about 2 feet thick and color of fresh rock surfaces ranges from greenish gray to light brownish gray. Very thin shaly limestone and calcareous shale partings are distributed vertically as shown (Pl. 32). The shale is

180

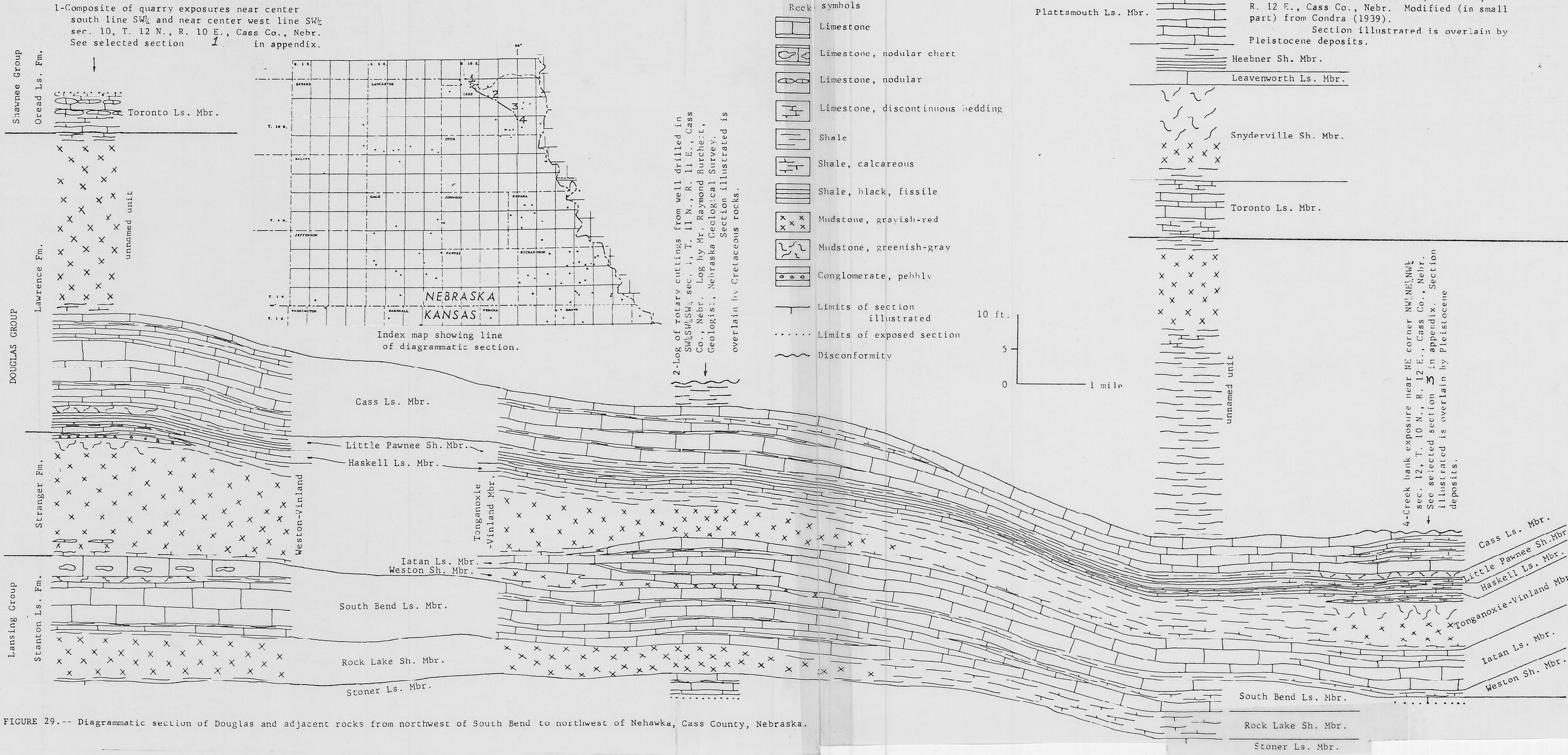


FIGURE 29.-- Diagrammatic section of Douglas and adjacent rocks from northwest of South Bend to northwest of Nehawka, Cass County, Nebraska.

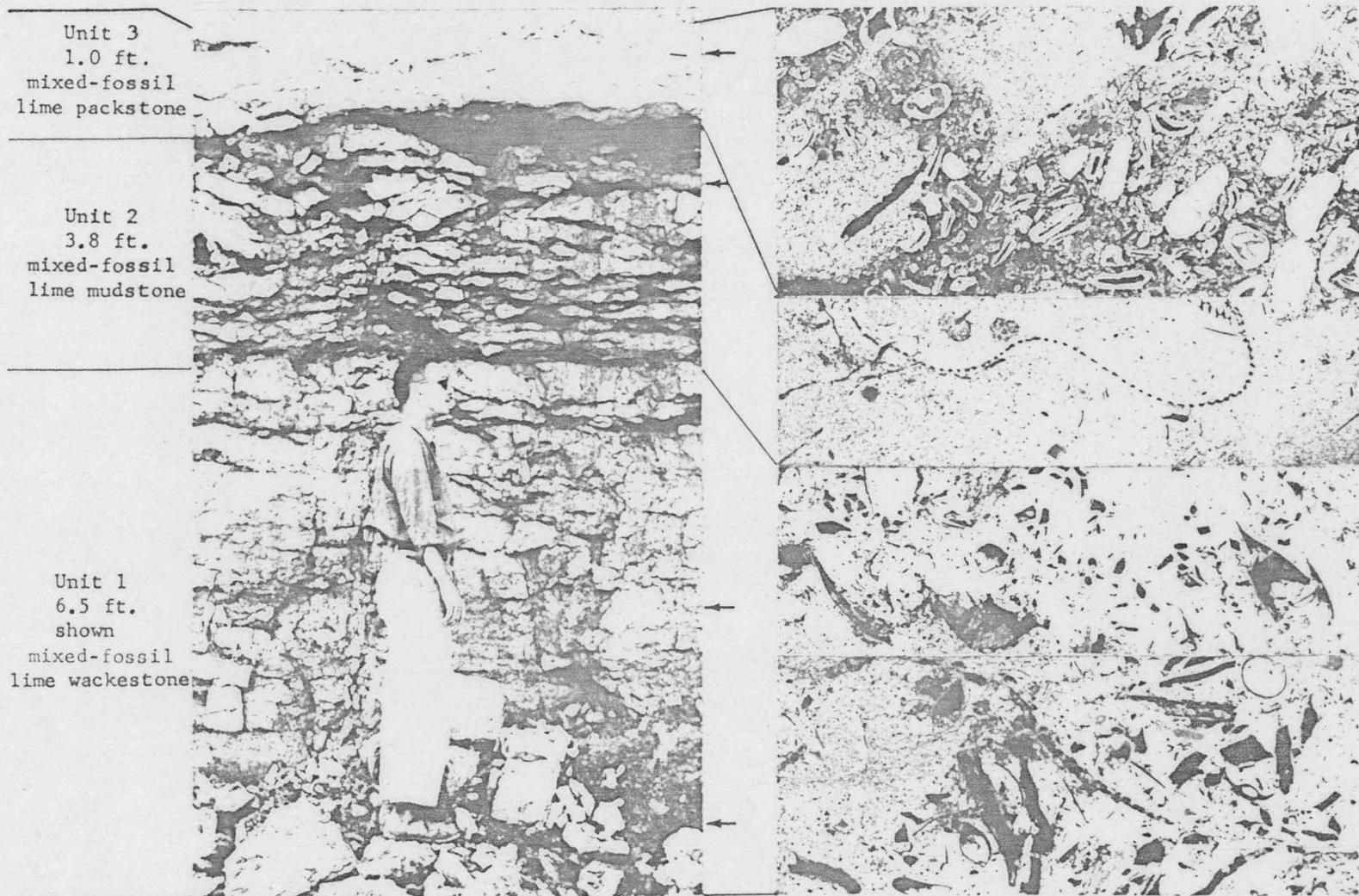


PLATE 32.-- Standard reference section of Cass Limestone. Quarry exposure in SE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 12 N., R. 10 E., Cass County, Nebraska. Negative prints of thin sections (X3.5) on right. Arrows show stratigraphic positions of samples chosen as representative of footages described in text. Vertical surfaces, orientation as shown.

greenish gray and contains brachiopod and crinoid remains. Mixed-fossil lime wackestone forms the unit. Brachiopod, bryozoan, crinoid, echinoid, and foraminifer remains constitute the fauna. Composita, Phricodothyris, Hustedia, Neospirifer, and marginiferids are present. Abundant spar stringers are sharply bounded and arranged with long dimension roughly parallel to stratification. Such shape and arrangement, sparse examples of incomplete recrystallization of shell structure, and sparse relict structures indicate that the majority of sparry calcite present represents recrystallized fossils. Nebulously shaped blebs of spar are common. Several examples of partially or wholly spar-filled brachiopod interiors are noted. Selective silicification of brachiopod interior spar and to a lesser extent of fossil hard parts is common in the basal 2 feet of the unit. About 1 percent clay minerals are distributed throughout the unit. Lime mud matrix amounts to about 70 percent.

Mixed-fossil lime mudstone comprises unit 2, which aggregates 3.8 feet in thickness and includes beds about 0.2 to 0.5 foot thick. Irregular and discontinuous laminae composed of clay minerals are distributed along the lime mudstone bedding surfaces. The rock is a uniform light olive gray with less than 10 percent included medium light gray (and white where silicified) skeletal remains. Brachiopods, bryozoans, and crinoids are the conspicuous faunal constituents. Sparse fusulinids are present in the lower half of the unit. Other grains include clay minerals in trace amounts and sparse irregular blebs of cryptocrystalline quartz.

Unit 3 consists of light olive gray, mixed-fossil lime packstone in which many of the skeletal grains are Osagia-coated. This unit is a single vertically-jointed bed devoid of shale breaks or partings and

about 1.1 feet thick. Grains are extensively abraded and randomly oriented relative to stratification. Brachiopods, crinoids, echinoids, bryozoans, and foraminifers, including sparse fusulinids, form the skeletal grains. Coatings of the algal-foraminiferal consortium Osagia as much as 1 millimeter thick are a conspicuous characteristic. Partial or complete obliteration of skeletal structure by recrystallization is common. Orientation of long axes of grains is random relative to stratification. Sparry calcite predominates over lime mud which shows patchy distribution.

Lawrence Formation-Haskell (Shoemaker) Limestone Member. -- Condra (1927, p. 35) named the Shoemaker Limestone for a unit exposed near the Shoemaker farm and Shoemaker Bridge about 3 miles northwest of Nehawka, Cass County, Nebraska. The section exposed in the south bank of the creek about 50 yards west of Shoemaker Bridge (NE cor. NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 12, T. 10 N., R. 12 E.) is considered the type section. Apparently the name was abandoned without mention or explanation (Condra and Reed, 1943, p. 49-50). Condra (1949, p. 29-30) realized that the Shoemaker Limestone as defined originally was stratigraphically equivalent to the Cass Limestone, chose to elevate rank of the Cass from member to formation, and revived the name Shoemaker Limestone in a redefined, restricted sense as the lower member of the Cass Limestone. Condra and Reed (1959, p. 49-50) abandoned the name Shoemaker. As defined in 1949 (op. cit.) the Shoemaker Limestone is stratigraphically equivalent to the Haskell Limestone of Kansas and Missouri.

Description of type section. -- The Shoemaker Limestone (Pl. 33, bounded by tools) comprises 2 limestone beds separated by a mudstone. Mixed-fossil lime mudstone forms the lower limestone (unit 1, Pl. 33),

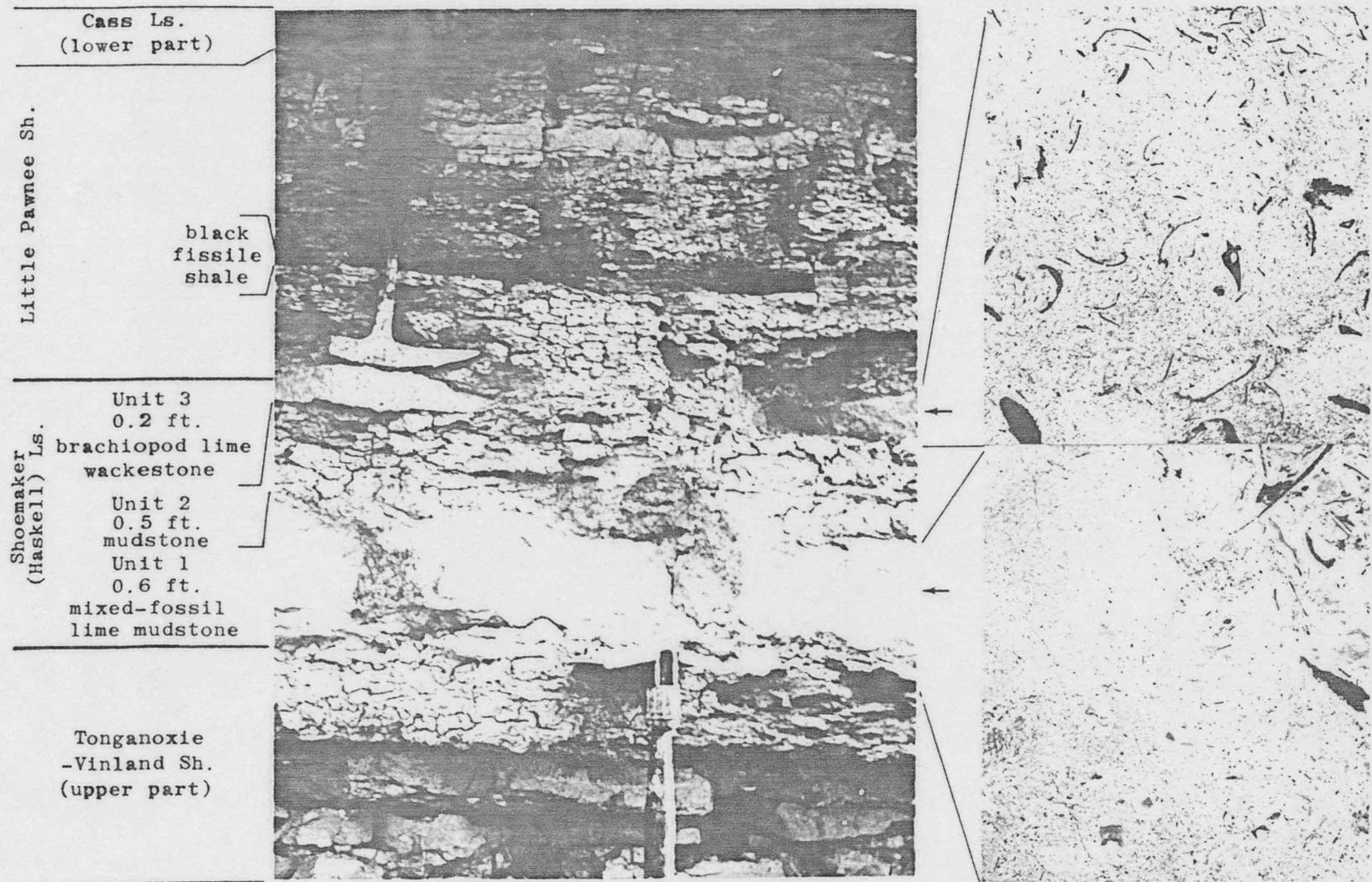


PLATE 33.-- Type section of Shoemaker Limestone. Streambank exposure at NE corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 12, T. 10 N., R. 12 E., Cass County, Nebraska. Negative prints of thin sections (X3) on right. Arrows show exact positions of samples chosen as representative of footages indicated and described in text. Vertical surfaces, orientation as shown.

which is a single, medium gray, 0.6 foot thick, vertically-jointed bed devoid of shale breaks or partings. Basal and top surfaces of the bed are hummocky. Skeletal grains include bryozoan, crinoid, brachiopod, echinoid, and pelecypod debris in order of apparent decreasing abundance. Other grains include 1 to 2 percent silt-size quartz particles and less than 5 percent clay minerals in the lowermost 0.2 foot and uppermost 0.2 foot of the unit. Lime mud greatly predominates over sparry calcite, which is restricted to recrystallized skeletal fragments and the few irregular patches of the rock in which fossil debris is closely packed. Contacts of this unit with adjacent strata are gradational.

Unit 2 is a light olive gray mudstone 0.5 foot thick. The mudstone is calcareous and contains sparse brachiopod and crinoid remains.

The upper limestone (unit 3, Pl. 33) is a brachiopod lime wackestone, which is medium gray, 0.2 foot thick, and vertically-jointed. Brachiopods are the dominant faunal constituent. Crurithyris planoconvexa is abundant throughout the rock and forms a crust at the top of the unit. Sparse bryozoan, gastropod, and crinoid debris is present. Lime mud forms nearly all the interstitial material; spar is virtually lacking except in recrystallized skeletal fragments. Contacts of the unit are gradational with adjacent strata.

The Cass and the Haskell (Shoemaker) Members are the only continuous limestones within the Douglas Group of Nebraska outcrop areas and, wherever observed, are separated by the Little Pawnee Shale, which contains a continuous black fissile shale marker. Details of the Haskell (Shoemaker) Limestone and Little Pawnee Shale parts of the sequence are nearly identical northwest of Nehawka and northwest of South Bend (Fig. 29).

Douglas Group subdivisions between northwest Missouri and south-central Cass County, Nebraska. -- Outcrops of Douglas Group rocks in northwest Missouri and those of south-central Cass County, Nebraska, are separated by about a 100-mile wide expanse of younger rocks (between section 1 and section 14, Plate 2 in pocket). Detailed shallow subsurface data are not plenteous along this traverse and some details of facies show marked lateral variation, for example; three-fold northwestward thinning of the Douglas Group; discontinuity of the Amazonia Limestone, the Cass Limestone, and the grayish red mudstone in the lower part of the Tonganoxie-Vinland Shale; and the development of different rock types within limestone members such as the Iatan (see Pl. 18 B and C). On the other hand, the Iatan and the Haskell Limestones are continuous, grayish red mudstone in the Wathena Shale is essentially continuous, and both the Amazonia Limestone and the black fissile shale just above the Haskell Limestone are well developed along this traverse.

Correspondence in over-all sequence of the Douglas Group and especially correspondence in details of the Haskell Limestone and adjacent beds (Pl. 34) led to correlation of the Haskell and Shoemaker Limestones and to correlation of the Iatan and Nehawka Limestones. The Cass Limestone of Nebraska is probably represented either in part or wholly by the limestones and interbedded shale developed locally in northwest Missouri exposures of the lower 30 feet of the Robbins-Ireland Member. However, the Cass Limestone is not continuous (Pl. 2) into Missouri and its recognition in Missouri outcrops cannot be established unequivocally.

The Iatan (Nehawka) Limestone in the subsurface of eastern Kansas and eastern Nebraska. -- Insofar as is known to me, Wallace Lee^{1/} first recognized the widespread extent of a 10- to 20-foot thick limestone close above Lansing Group top in the central Kansas subsurface. Mr. Lee has marked this unit with an X on many electric logs in the State Geological Survey of Kansas files. Lee (1956, p. 101) stated:

On the western flank of the Nemaha anticline as far south as Riley County two to five limestone beds 5 to 20 feet thick are interstratified with Douglas shale, which in this area is 75 to 90 feet thick. The most persistent of these limestones lies near the base of the Douglas group 5 to 20 feet above the South Bend limestone member of the Stanton formation. It is revealed by electric logs throughout much of the Salina basin where it is 10 to 20 feet thick, but it has not been reported in outcrops.

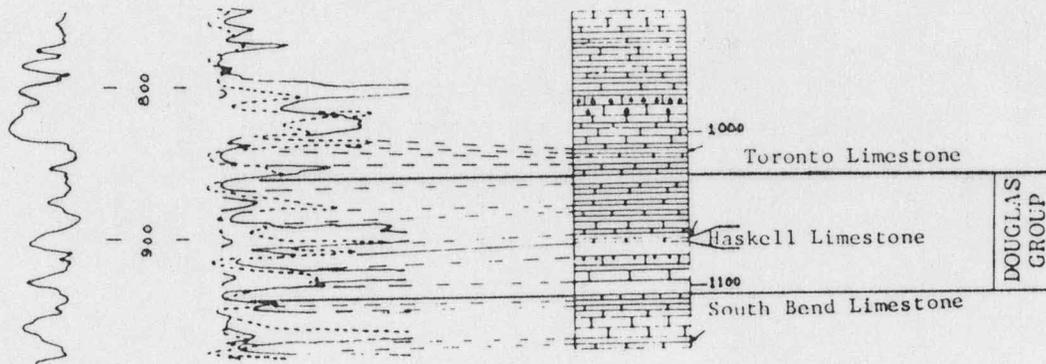
The persistent limestone recognized by Lee (op. cit.) 5 to 20 feet above the South Bend Limestone in the Salina Basin correlates with the Iatan Limestone as shown on Plate 4, wells 15 to 23 of Plate 5, and wells 17 to 25 of Plate 6 (in pocket). The Iatan Limestone extends farther southward into the northeastern part of the Sedgwick Basin, that is, that part of the area of general continuity (Fig. 13) from southern Marion County, Kansas southward.

Figure 30 shows the presence of a relatively high percentage of limestone within the Douglas Group, about 50 percent. Precise percentages are not important because no two geologists would agree exactly, but approximate extent of the shale-limestone facies of Douglas rocks (Fig. 12) is important. Throughout a considerable subsurface expanse including the northwestern part of the east ranges in Kansas and the western part of the

^{1/}Geologist of the United States Geological Survey until 1953 and of the State Geological Survey of Kansas until 1955.

George Johnston
 1 Floyd Brown
 NE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 21
 T. 4 S., R. 7 E.
 Marshall County
 Altitude 1132'

B.B. Blair
 1 Cox
 C SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 10
 T. 4 S., R. 7 E.
 Marshall County
 Altitude 1295'



EXPLANATION

SAMPLE LOG



Limestone



Limestone, cherty



Shale



Limestone, oolitic

ELECTRICAL LOG



Spontaneous-potential



Resistivity, normal

CORRELATION LINES

— Group boundary

— Formation boundary

- - - Member boundary

FIGURE 30 .-- Douglas Group rocks in area of shale-limestone facies (see Fig. 7). Electrical log on left. Log of cable tool cuttings on right; for detailed description see log 41 in appendix. Arrows to right of sample log indicate positions of black fissile shales referred to in text. Vertical scale shown by log depths in feet.

east ranges in Nebraska, the Douglas Group includes 33 or more percent limestone. All of the principal limestones except the Westphalia (i.e., the Iatan, the Haskell, and the Amazonia), which are known from various parts of the Kansas-Missouri outcrop belt, as well as the Cass Limestone are essentially continuous in the area of shale-limestone facies development (Fig. 12). Virtually no Douglas Group sandstone is known from this area and interbedded shales are relatively thin as compared to shale thicknesses developed in Kansas-Missouri outcrops (Fig. 11).

Several geologists have expressed to me reasons for classing the Iatan (Nehawka) Limestone with Lansing rocks in some parts of the Kansas and Nebraska subsurface. One reason is practicality in areas where extreme thinness^{1/} of the Weston Shale and generally similar electric log character of the Iatan and South Bend Limestones preclude certain recognition on mechanical logs. Thinness of the Weston, regardless of degree of lithologic difference or similarity between the Iatan and the South Bend, could preclude differentiation of these members by study of rotary cuttings. Another reason expressed was that where the Iatan of this report and the next older limestone show some correspondence in mechanical log character, or in sample descriptions, and are separated by a relatively thin shale unit, the two limestone units appear to be genetically related^{2/}.

I would not argue strongly with the first-mentioned reason, that of practicality. Different geologic projects have different objectives. It

^{1/}The Weston Shale is commonly about 1 foot thick near the type locality of the Nehawka Limestone (see selected section 3 in appendix).

^{2/}Genetically related units are parts of a larger natural unit; for example, parts of a cyclothem.

is rarely possible for geologists to justify the time necessary to attempt to trace individual members from their type areas into various areas of subsurface study.

The other reason, that of suspected genetic relationships, should not be involved in an attempt to apply rock-stratigraphic classification (see Moore, 1936, p. 21-22; American Commission on Stratigraphic Nomenclature, 1961, article 4c, p. 649; and Jewett, 1962). Recognition of so-called genetic relationships in study of surface outcrops is a purely subjective matter in most cases and use of such insight for application of classification in subsurface studies can only lead to confusion.

Douglas Group between Missouri and Nebraska outcrop areas and the Middle River area of Iowa. -- The northernmost Missouri exposures measured and described during this study are located in west-central DeKalb and southwestern Andrew Counties (Fig. 1). Several thin sections separated by areas covered with thick glacial drift were studied to the northeast in Missouri. However, I was entirely uncertain of stratigraphic identification north of the DeKalb-Gentry County line in Missouri. Therefore, approximately an 85-mile stretch of no surface control separates northeasternmost Missouri outcrops studied adequately from the exposures studied near Middle River in west-central Madison County, Iowa. Because of glacial cover, surface control will always be limited in this area. However, detailed study of all Kansas City Group to Shawnee Group exposures would result in a better understanding of detailed correlation from Missouri to Iowa exposures of Douglas and adjacent parts of the section.

About an 85-mile stretch in which no outcrops of Douglas or adjacent rocks were studied separates easternmost Nebraska exposures near Plattsmouth

from those studied near Middle River, Iowa. According to Hershey and others (1960, p. 23-24), no exposures of Douglas rocks are known in Iowa west of eastern Adair County. The best way to be sure of general surface correlations from Nebraska across southwest Iowa is to study lower Kansas City Group rocks, especially the Swope Limestone to Dennis Limestone part of the section. In southwest Iowa, the Bethany Falls and Winterset Limestone Members are both approximately 12 to 20 feet thick (see various parts of Hershey and others, 1960); the Galesburg Shale is relatively thin, generally from about 1 foot to 9 feet thick (Hershey and others, op. cit., p. 27-28); and both the Bethany Falls and Winterset consist of relatively high-calcium rock (personal communication, T. L. Welp^{1/}, 1959). Consequently, the Swope-to-Dennis sequence is as or more widely quarried than any other part of the Pennsylvanian of southwestern Iowa. If quarry exposures were not available for study, tracing of beds with any degree of surety from one to another of the few good natural exposures in southwest Iowa would not be possible. Uniform development is a striking aspect of the Bethany Falls-to-Winterset sequence across southwest Iowa. Other than gradual thickness variations, the only noteworthy lateral change observed during reconnaissance study of this part of the section was local absence of the Canville Limestone Member of the Dennis Limestone. Plate 35 shows a comparison of the Swope-Dennis sequence from southeastern Sarpy County, Nebraska to near Winterset, in central Madison County, Iowa. Condra and Scherer's report (1939, 1958) related the exposures shown as the western part of the reconnaissance cross section (Pl. 35) to the sections exposed near Plattsmouth and near South Bend, Nebraska, which were

^{1/}Chief geologist of Iowa State Highway Commission, Ames, Iowa.

discussed above. Welp and others (1957) reported the stratigraphic relationships of bedrock exposed in Madison and Adair Counties, Iowa.

Selected section 7 in the appendix records my correlation of "Douglas" and adjacent rocks of Madison County, Iowa. Of the correlations attempted in this report, I consider only those of the Leavenworth Limestone, the Heebner Shale, and the Plattsmouth Limestone reliable. These members display few marked differences between Cass County, Nebraska and Madison County, Iowa outcrops. The Leavenworth contains numerous specimens of ?Ottonosia at the latter locality, which were not observed in Nebraska exposures. No marked difference was observed in the Heebner Shale. The Plattsmouth Limestone contains more interbedded shale in the Iowa exposure.

None of the following limestone members; Toronto, Amazonia, Cass, Haskell, Westphalia, Iatan, South Bend, Stoner, Captain Creek, Spring Hill, or Merriam; were definitely recognized in Iowa exposures during this study. Many opinions have been given either in the literature or verbally as regards correlations of these units but few geologists agree. For example, the main ledge quarried in Schildberg's quarry (NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T. 75 N., R. 29 W.) is reported by Welp and others (1957) as the Argentine Limestone Member of the Wyandotte Limestone, is thought to be the Spring Hill Member of the Plattsburg Limestone by W. B. Howe^{1/} (personal communication with Mr. Welp and related to me, 1959), and is tentatively correlated with the Stoner Member of the Stanton Limestone by me. Any combination of two or possibly all three of these geologists are wrong. I did not attempt subsurface study in southwestern Iowa.

^{1/} Senior Geologist, Stratigraphy and Areal Geology Division, Missouri Geological Survey.

Douglas Group and adjacent rocks in southern Kansas and northernmost Oklahoma. -- Abrupt lateral changes in many parts of the Pennsylvanian section of southern Kansas and northernmost Oklahoma have been known for years. Moore and others (1937) reported the first comprehensive study of such changes. As regards the rocks discussed in this report, all limestone members that are essentially continuous along the greater part of the outcrop belt in Kansas reach featheredge thicknesses and are discontinuous in either Montgomery or Chautauqua Counties, Kansas. The distributions of the South Bend, Westphalia, Haskell, and Toronto Limestones in southern Kansas have been discussed above and are shown as Figures 8, 19, 21, and 26 respectively. All of these limestone members as well as the Leavenworth and Plattsmouth Members of the Oread Limestone wedge out in one or another part of the Osage County, Oklahoma outcrop area and have not been observed southward. Correlatives of Lansing rocks older than the South Bend were not recognized in Oklahoma. The other limestone members considered in this study, the Iatan and the Amazonia, wedge out in the shallow subsurface (Fig. 13 and Fig. 24 respectively). Within the area of study, the Iatan does not extend into Oklahoma and the Amazonia was not definitely recognized in Oklahoma outcrops.

Since Newell's 1933 study and that of Moore and others (op. cit.), all workers familiar with Lansing to Oread surface stratigraphy from central Kansas southward have realized that the lateral changes so characteristic of these rocks, especially in southernmost Kansas and northernmost Oklahoma, are primarily the result of facies change.

As traced southwestward across Kansas, marked change in Lansing facies is first apparent in central Anderson County outcrops (Fig. 7). An estimated

150-foot minimum thickness of Lansing rocks is exposed along Cedar Creek between Garnett and Mont Ida. The Merriam Limestone, Hickory Creek Shale, and part of the Spring Hill Limestone Member of the Plattsburg Limestone are well exposed about 3 miles northeast of Mont Ida (SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 4, T. 21 S., R. 14 E., Anderson Co., Kans.). About 0.5 mile south (near center east line sec. 9, T. 21 S., R. 19 E.), a 70-foot thick limestone section is exposed. A similar development exists near the center of section 9. I was unable to determine any member contacts in section 9 except in the exposures flanking Cedar Creek along the north section line. This thick limestone development probably is, in greater part, the Spring Hill Limestone, which is about 60 feet thick nearby (quarry near center north line SE $\frac{1}{4}$ sec. 34, T. 20 S., R. 19 E.). However, unless there are structural complications^{1/} of a magnitude not realized because of limited exposures, the upper part of the thick limestone development contains some Stanton Limestone. The Vilas Shale is either extremely thin or absent in this area. Top of the Captain Creek Limestone Member of the Stanton is exposed near water level of Cedar Creek at a point 0.5 mile southwest (near NE corner sec. 17, T. 21 S., R. 19 E.). Cedar Creek flows essentially along regional strike between this exposure of Captain Creek top and the outcrop of Merriam Limestone base about 40 feet above water level at a point 1 mile northeast.

Plate 36 shows the rock types developed in the Stoner Limestone east of Mont Ida (SE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 21 S., R. 19 E.). This exposure

^{1/} Exposures (near center sec. 17, T. 21 S., R. 19 E.) across a small rivulet tributary to Cedar Creek are one of relatively few places in eastern Kansas where strike and dip are obvious. There beds in the upper 10 to 15 feet of the Stoner Limestone strike N45°E and dip 5 to 6° SE.

contains the southernmost well-developed black fissile shale part of the Eudora Shale observed during this study. Southwestward this part of the Eudora is absent from most outcrops and interbedded fossiliferous shale and limestone is classed as the Eudora (Newell, 1933, p. 80; Eastwood, 1958).

Maurice Fishburn^{1/} and I measured an 85-foot thick limestone section exposed about 2.5 miles east of Mont Ida (SW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 21 S., R. 19 E.). Fishburn (1962, p. 76-86) described^{2/} and illustrated this locality and pointed out the difficulty encountered in an attempt to identify Lansing Group subdivisions. Since visiting the area with Mr. Fishburn, I have had opportunity to walk out Cedar Creek exposures across Township 21 South. Upper Lansing beds are well exposed at three localities in Township 21 South, Range 19 East (selected sections 32, 33, and 35 in appendix). As reported by Fishburn (op. cit.), the thick limestone development shown in his Figure 35B is, in greater part, referable to the Stanton Limestone. However, I believe that only the Captain Creek-Stoner part of the Stanton displays the facies described as reefoid^{3/} by Fishburn (op. cit.) in Anderson County exposures. There is no indication in

^{1/} Formerly a graduate student in geology at the University of Kansas.

^{2/} Mr. Fishburn's over-all discussion is excellent. However, this important exposure was carved by a north-flowing Cedar Creek tributary about 2.5 miles east of Mont Ida (SW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 21 S., R. 19 E.). The exposure is not in section 1 and is not along Cedar Creek as reported by Fishburn (op. cit.).

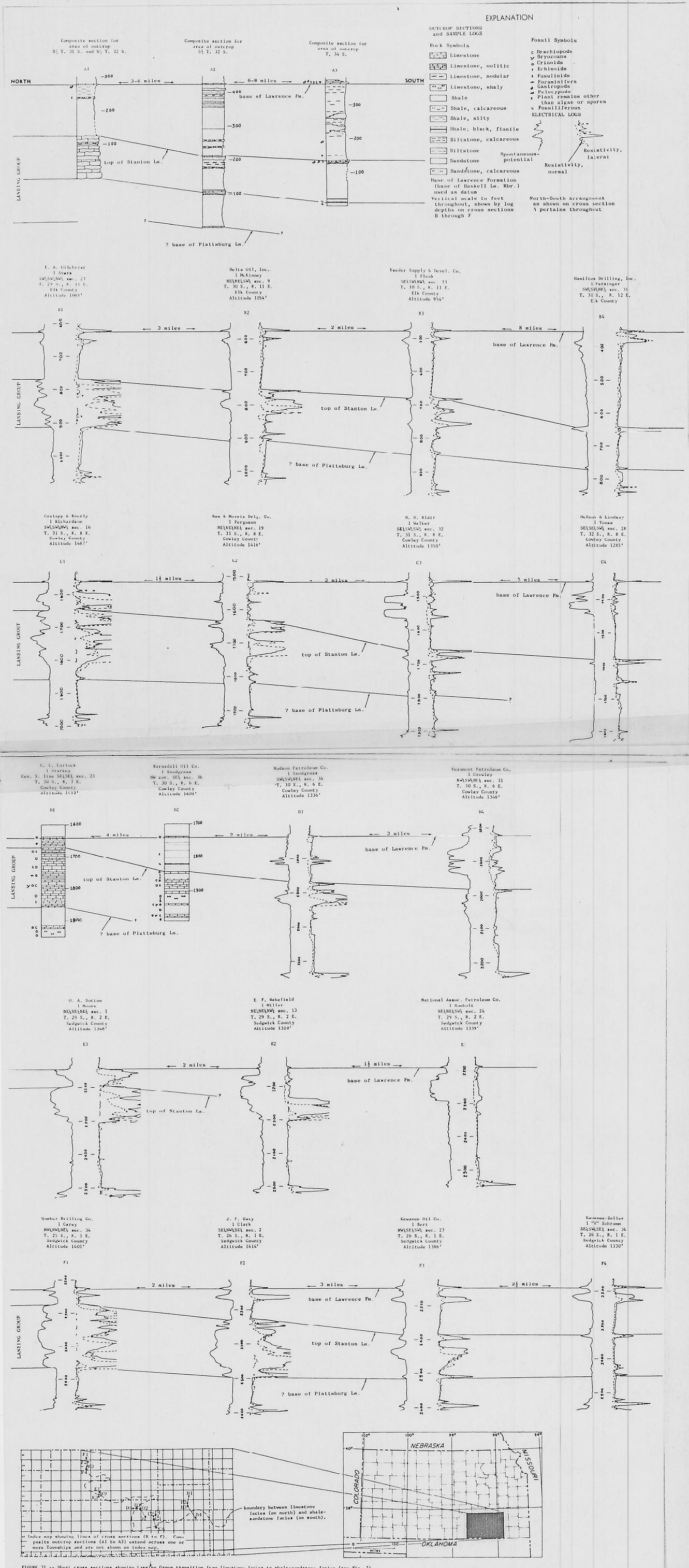
^{3/} This facies is relatively thick, in part devoid of bedding, sparsely fossiliferous, and contains abundant blebs and stringers of sparry calcite. Development of this rock type in central and southern Kansas Lansing Group outcrops has been well documented by a number of workers (Newell, 1933; Moore and others, 1937; Wagner and Harris, 1953; Wagner, 1954, 1961, 1962; Chelikowsky and Burgat, 1947; Wilson, 1957; Eastwood, 1958; Davis, 1959; Harbaugh, 1959, 1960, 1961, 1962; Lineback, 1961; Fishburn, 1962; and O'Connor, 1962.

Anderson County exposures that either the Rock Lake Shale or the South Bend Limestone Members of the Stanton Limestone display facies markedly different from northeastern Kansas exposures (see Fig. 9). The lower quartzose molluscan lime wackestone (Pl. 13) and the upper mixed-fossil lime wackestone (Pl. 14) of the South Bend persist across Anderson County. Newell (1933, p. 76-81) realized that the South Bend^{1/} was an excellent stratigraphic marker at least as far south as northern Allen County. Subsequent study has corroborated the general accuracy of Newell's work. Unfortunately Newell's 1933 study was never published; it is an invaluable aid to all students of the northern Midcontinent Pennsylvanian. Among many other good data, his report contains the most comprehensive statement currently available pertaining to lateral variations in Lansing faunal facies and points out that Lansing faunas northeast of approximately the latitude of Garnett, Kansas are as markedly different from Lansing faunas to the southwest as are other aspects of Lansing rocks.

So-called marine bank development (Harbaugh, 1959, 1960, 1961, 1962) in the Lansing is not unique to Wilson and Montgomery County exposures, as shown by Harbaugh (1962, p. 15, fig. 1 B), but characterizes also central and southwestern Anderson County, northwesternmost Allen County, and eastern Woodson County exposures of the Lansing. Also, Merriam (1962, p. 75) has reported a marine bank in the subsurface of south-central Butler County, and I believe that the so-called marine banks of the Lansing are but small parts of a much larger reefoid complex that will ultimately be known to extend throughout much of the area of limestone facies (Fig. 7). See also Plate 7 and wells 43 to 69, and 72 to 75

^{1/} Referred to as the Kaw limestone in Newell's report.

of Plate 9 (in pocket). Figure 31 shows the abrupt change from the limestone to shale-sandstone facies of the Lansing (Fig. 7). These short cross sections (Fig. 31, A to F) show the initial lateral change of the Lansing Group part of the section as developed in the east ranges of southern Kansas. All geologists familiar with surface stratigraphy of Lansing rocks have realized the marked facies changes in southern Kansas. Figure 31 (cross section A) shows such change for the Stanton Limestone and similar change in the Plattsburg Limestone farther north has long been realized (see Newell, 1933; Moore and others, 1937; and subsequent reports referred to on page 195). However, Winchell (1957) found that lateral changes in Lansing rocks of south-central Kansas were the result of pre-"Stalnaker", or pre-Tonganoxie according to Winchell, erosion and reported evidence for facies change. Consideration of both the facies change and disconformity possibilities is necessary in areas where faulting or some other structural complication is not believed to have been responsible for lateral changes in a stratigraphic unit. The question of facies change or erosion as the principal reason for lateral variations is a perennial one in Stratigraphy and has been argued for many different stratigraphic units in many different areas. Winchell (op. cit., p. 143, other parts of text, and Pl. 2B) argued that Lansing Group top had been removed by post-Missourian erosion throughout approximately 3,600 square miles in south-central Kansas. The east ranges part of this area covers approximately 1,700 square miles and was a part of this study. If Winchell's (op. cit.) hypothesis is valid, the initial lateral change would necessarily be the absence of uppermost Lansing beds as the result of erosion.



As regards the east ranges of south-central Kansas, the initial change in Lansing rocks is lateral transition from limestone to shale and occurs in the lower (older) part of the group (see Fig. 31, cross sections B, C, D, and F). The first marked changes from areas of thick Lansing limestones as traced southwestward, southward, southeastward, and eastward in outcrops affect those parts of the Lansing Group classed as the Plattsburg and Vilas Formations. For example, the total footage of limestone classed as Plattsburg diminishes from about 60 feet near Garnett (Lineback, 1961) southward and southeastward to about 5 feet in south-central Anderson County, Kansas (Fishburn, 1962). Southward and southwestward the Vilas Shale thickens gradually, but not uniformly, to such an extent^{1/} near Vilas in northeastern Wilson County that the Lansing Group is a shale-sandstone facies in southeasternmost Woodson and northeastern Wilson Counties (Fig. 7). Harbaugh (1959, p. 318-319, fig. 2) postulated lateral transition of the Spring Hill Limestone into adjacent shale units in the area of so-called marine bank development of the Plattsburg (Harbaugh, 1962, p. 15, fig. 1B). The upper formation of the Lansing, the Stanton Limestone, is generally not predominantly shale and sandstone in outcrops north of Township 32 South in Montgomery County, Kansas. Therefore, both on the surface and in the subsurface (Fig. 31), the initial change which results in the shale-sandstone facies (Fig. 7), affects Lansing rocks older than the Stanton Limestone and surface studies have never indicated post-depositional erosion as the principal cause. I disagree strongly with Winchell's (op. cit.) postulate in regard to Lansing rocks in the east ranges part of the south-central Kansas area.

^{1/}Slightly over 100 feet (Newell, 1933, p. 61-62).

Nonetheless, post-depositional erosion could have affected the Lansing locally in this area (e.g., see Fig. 31, cross section E).

Correlations attempted across the southern Kansas part of the area of detailed study (Fig. 1) are shown as Plates 7 and 8 and wells 68 to 92 of Plate 9 (in pocket). Excepting Heebner Shale base, only limestone member correlations are shown. I was unable to trace Douglas Group sandstones accurately in the subsurface.

The South Bend Limestone is at least in part correlative with the Birch Creek Limestone of Oklahoma terminology. Current usage and area of application of the term Birch Creek are discussed above (p. 33 and p. 55). Bowen's (1918, p. 17) type section was not located during this study, but an incomplete section at Forrest-Oyster ford along Birch Creek (SW corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T. 24 N., R. 10 E., Osage County, Oklahoma) was studied nearby and the complete exposure about 1.2 miles northeast of Bowen's type is described below (Pl. 37).

The Birch Creek Limestone in its type area is characteristically a dolostone or a partially dolomitized limestone. In the standard reference section (Pl. 37), the member aggregates 4.5 feet thick and comprises indistinct discontinuous beds ranging from 0.1 - 0.9 foot in thickness. Fresh rock surfaces are moderate yellowish brown in the basal foot and medium light gray mottled medium bluish gray above. Dolomitic fossiliferous siltstone in the basal 0.5 foot grades upward (and in places laterally) into silty to sandy, marine invertebrate-bearing crystalline dolostone. Subrounded to subangular, equant to elongate, medium silt- to very fine sand-size quartz particles amount to about 40-60 percent of the rock in the basal foot and to about 25-40 percent above. Sparse to common relic

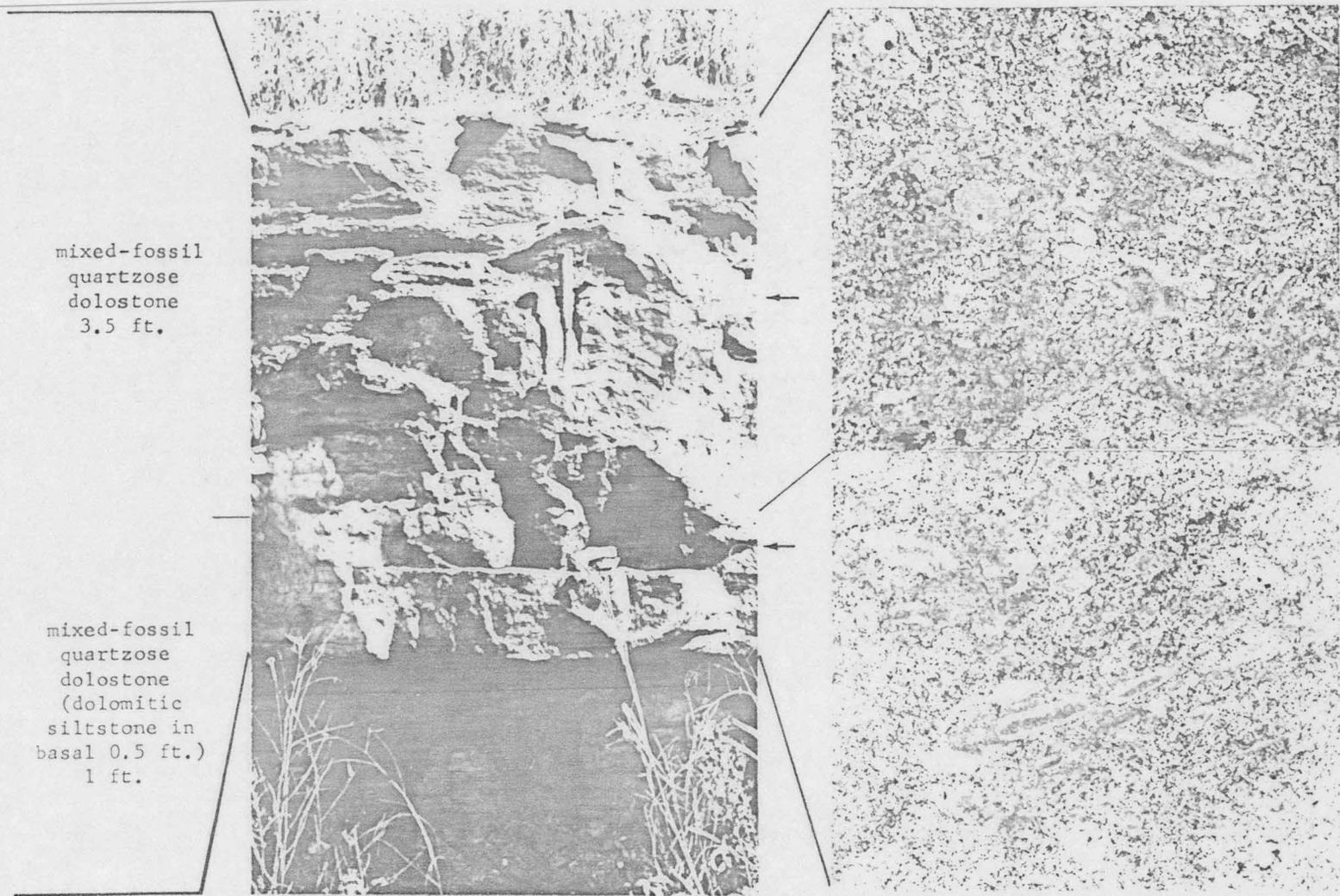


PLATE 37.-- Standard reference section of Birch Creek Limestone. Railroad cutbank exposure near center south line NE $\frac{1}{4}$ sec. 19, T. 24 N., R. 10 E., Osage County, Oklahoma. Negative prints of thin sections (X3.5) on right. Arrows show stratigraphic positions of samples chosen as representative of footages indicated. Vertical surfaces, orientation as shown.

fossils and inditifiable crinoid, gastropod, and brachiopod debris form about 5 percent of the rock. The dolomite matrix shows ferruginous stain, which is extensive in the basal foot of the member.

The Birch Creek displays variable facies in outcrops between its type area and southernmost definite South Bend outcrops (e.g., selected sections 66, 67, 68, and 71 in appendix) and is discontinuous. The probable application of the name Birch Creek to more than one limestone has already been discussed (p. 33). Nonetheless, there is no question of the approximate stratigraphic position of the limestone lenses to which the name Birch Creek is generally applied. Bowen (op. cit., p. 19) first suggested correlation of the Birch Creek with some part of the Stanton Limestone of southern Kansas. Moore and others (1937, p. 64, fig. 21) made this correlation. Oakes (1940) correlated the Birch Creek with the South Bend Member of the Stanton, as did Branson (1957). I regard the Birch Creek at least in part correlative with the South Bend.

The Bowring Limestone (Tanner, 1956, p. 43) was named after the town of Bowring (NE $\frac{1}{4}$ sec. 28, T. 28 N., R. 11 E.). Selected sections 60 and 61 (in appendix) record Bowring exposures in the type area and show stratigraphic relationships to beds below and above respectively. Selected section 60 (appendix) shows the stratigraphic position of the Bowring relative to the Leavenworth Limestone Member of the Oread Limestone. The southernmost Bowring exposure observed during this study is in the northernmost part of Township 27 North, Range 11 East (near center north line sec. 4), Osage County, Oklahoma. The member is not at all continuous north and east of this locality as shown by Tanner (1956, Pl. 1).

Detailed lithology of the Bowring is shown as parts E and F of Plate 20. The Bowring Limestone is in every respect the homotaxial correlative of the Westphalia Limestone (see Fig. 11). Branson (in Jewett and Muilenburg, 1957) first reported this correlation. A thin coal seam immediately below the Westphalia (Bowring) Limestone is known from a single Oklahoma exposure near Bowring (C. C. Branson, personal communication, 1962). I failed to locate this exposure but there is no reason why a southern correlative of the Upper Sibley bed of Kansas should not occur. The term Bowring, unlike the terms Birch Creek and Labadie, is unnecessary and its abandonment is recommended.

The Labadie Limestone (Bowen, 1918, p. 45) was named for Labadie Point, a spur along Sand Creek in the NE $\frac{1}{4}$ of sec. 9, T. 26 N., R. 10 E., Osage County, Oklahoma. A type section has not been designated. Near the center sec. 3, T. 26 N., R. 10 E. on U. S. Highway 60, the Labadie Limestone forms an excellent exposure, which is proposed as a standard reference section (Pl. 38).

The Labadie in the standard reference section and its type area is predominantly dolostone. Fresh rock surfaces are light gray or medium light gray and show commonly medium bluish gray overtones. Weathering to light brown or to dark yellowish orange is characteristic. Thickness of individual beds ranges from 0.2 to 0.7 foot and the member totals 13 feet thick. Bedding is relatively even to moderately wavy. Texturally the rock is a mixed-fossil crystalline dolostone. Uniformity of texture is interrupted only by a stromatolitic structure, possibly a fossil alga, about 0.5 to 1 foot below the top of the member. The stromatolite is not

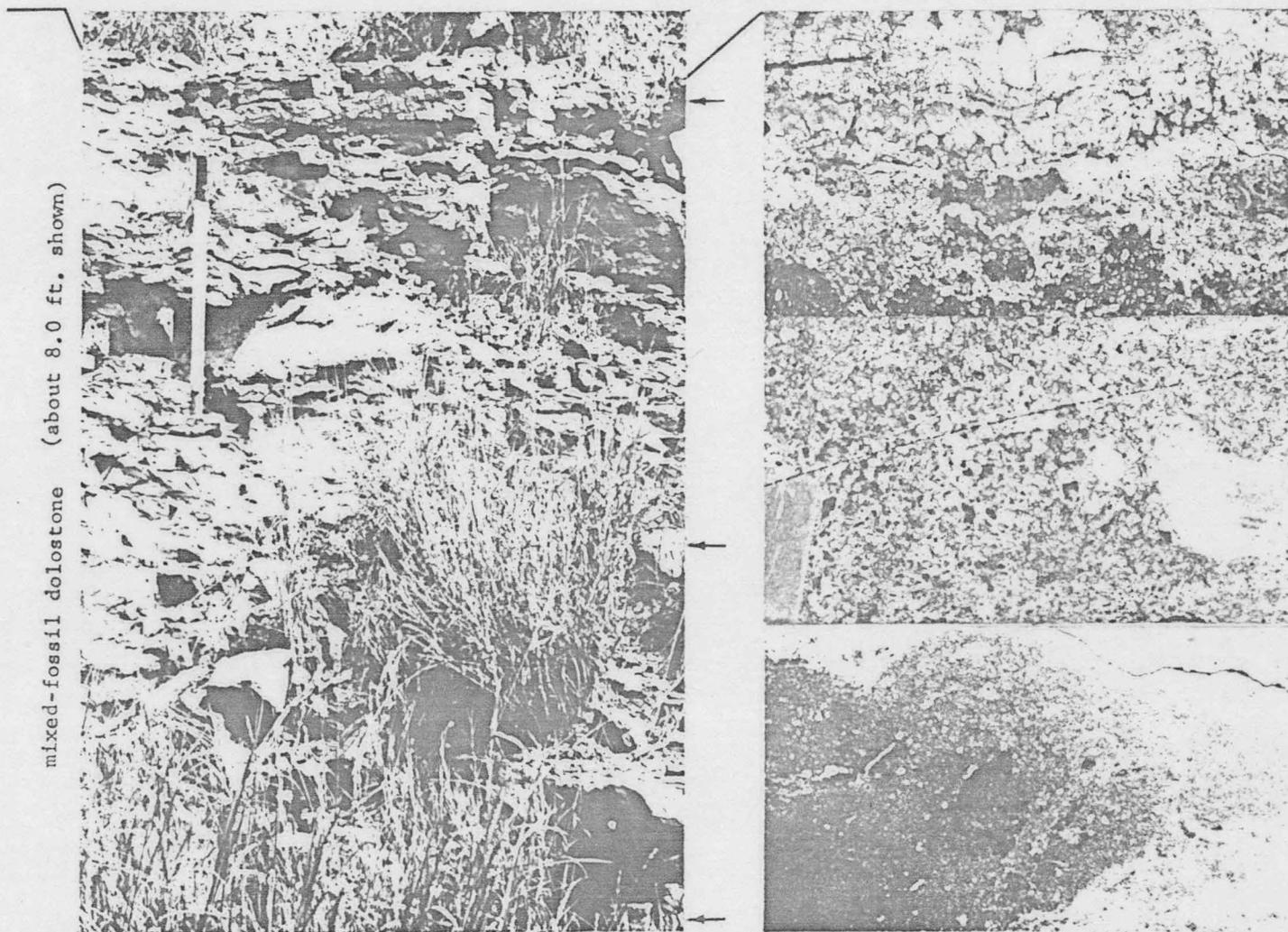


PLATE 38.-- Standard reference section of Labadie Limestone. Road cut exposure near center sec. 3, T. 26 N., R. 10 E., Osage County, Oklahoma. Negative prints of thin sections (X3.5) on right. Arrows show stratigraphic positions of samples chosen as representative. Vertical surfaces, orientation as shown.

present throughout the exposure, is about 1 centimeter thick, and has been partially silicified but has not been dolomitized. Definitely identifiable fossils include sparse brachiopod and crinoid remains throughout and extremely sparse fusulinids in the upper 2 feet. Clay-mineral laminae are well developed in the basal two feet and aggregate about 6 percent of the rock. In the remainder of the member argillaceous material is not concentrated in laminae but is present along dolomite grain boundaries in amounts ranging from traces to about 3 percent. Irregularly elliptical silica-lined vugs and amoeba-shaped blebs of silica are common. Most of the dolomite matrix consists of a very finely to medium crystalline grain mosaic but euhedral dolomite rhombs from one-tenth to 2.7 millimeters in long dimension are common to abundant in unevenly distributed areas of hand samples and thin sections.

Well-developed clay-mineral laminae in the basal part of the unit and the fossiliferous character of the uppermost part of the underlying shale indicate that the basal contact of the Labadie is gradational. The upper contact of the member is sharp.

Description of geographic, thickness, and facies range of the Labadie Limestone is included in discussion of the Haskell Limestone. Figure 11 relates stratigraphy of the Labadie Limestone to that of the Haskell Limestone of southern Kansas and Figure 32 shows development of the Labadie south from the standard reference section. The southernmost definite Labadie observed during this study is shown at the south end of the diagrammatic section (Fig. 32). There is no question that the Labadie Limestone is correlative with the Haskell Limestone but both names should be

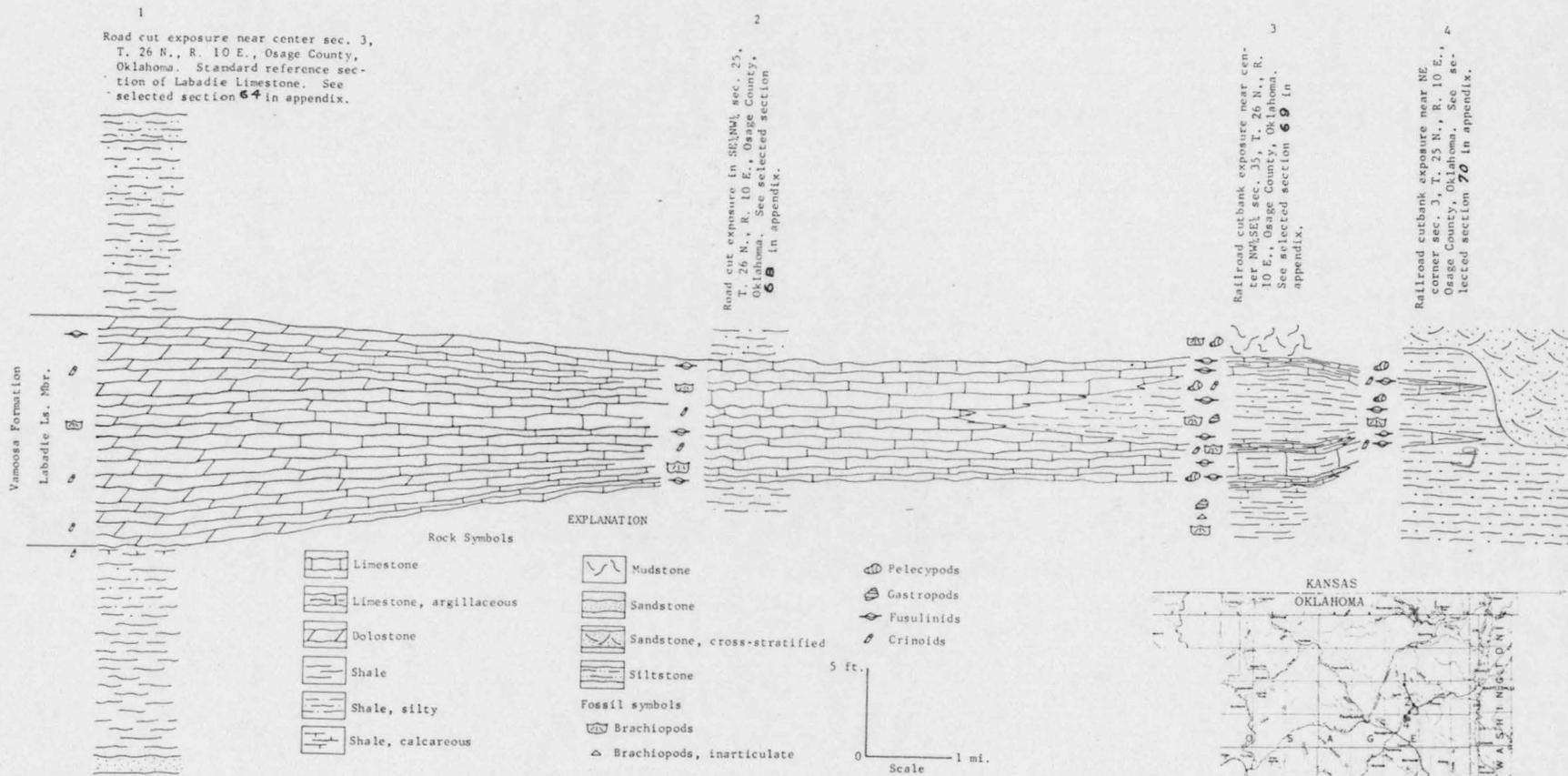


FIGURE 32.-- Diagrammatic section of the Labadie Limestone Member of the Vamoosa Formation from its type area to southernmost definite Labadie exposures.

retained because of significantly different facies development and long establishment in the literature. Moore (1948, 1949) reported correlation of the Labadie and Haskell Limestones as did Branson (1947) and the current study corroborates this correlation.

The name Wildhorse was proposed by Greene (1918, p. 121) for a prominent escarpment-forming limestone conspicuous in the western half of T. 22 N., R. 10 E., Osage County, Oklahoma. In current Oklahoma Geological Survey classification, the Wildhorse dolomite is considered a lenticular bed in the upper unnamed shale member of the Barnsdall Formation. Although not now a part of formal classification, the Wildhorse is an excellent stratigraphic marker from southern T. 23 N. to southernmost T. 22 N. in an area and in a part of the section in which any marker utilitarian for correlation and mapping purposes deserves a formal name. The road cut exposure in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 22 N., R. 10 E. and the quarry exposure in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 14, T. 22 N., R. 9 E. (Pl. 39) are used for reference.

Description of Wildhorse dolostone. -- Very light gray color with light bluish gray overtones on fresh rock surfaces and weathering to moderate yellowish brown are characteristic. Individual beds range from about 0.2 to 0.9 foot thick and the member totals approximately 17 feet and 24 to 25 feet in thickness respectively in the reference exposures cited above. All along the Wildhorse escarpment huge blocks (as much as 10 feet in length and width) part along vertical joints and creep down-slope. In the reference sections, the Wildhorse is a mixed-fossil dolostone. Identifiable remains of fusulinids, crinoids, brachiopods, and

mixed-fossil dolostone (about 17.0 ft. shown)

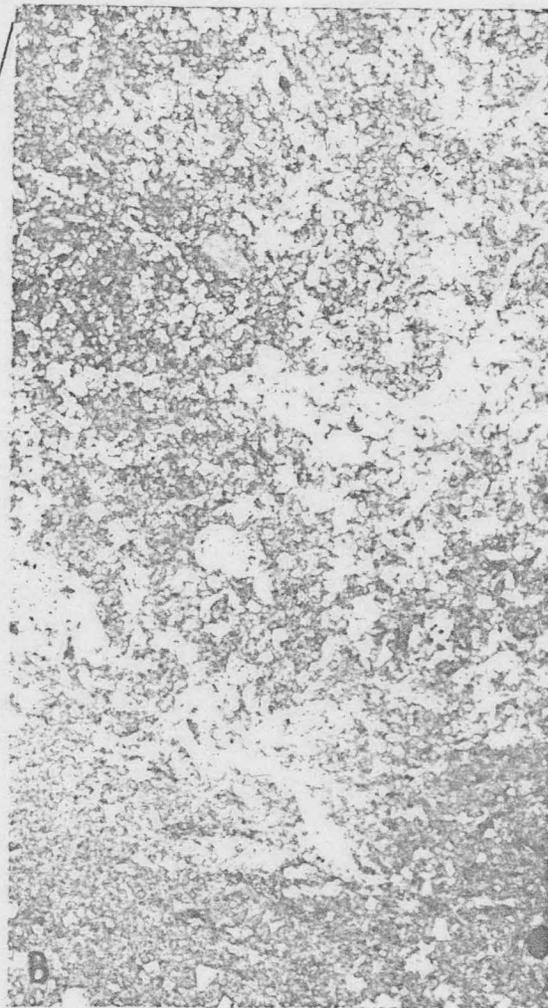


PLATE 39.-- Exposure and lithology of Wildhorse dolostone. A, Quarry exposure in SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 14, T. 22 N., R. 9 E., Osage County, Oklahoma. B, Negative print of thin section (X 4) of sample collected from 9.5 feet above base of Wildhorse in the road cut exposure in the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 14, T. 22 N., R. 9 E. Vertical surface, orientation as shown.

echinoids are included in a medium to coarsely crystalline dolomite mosaic. About 3 to 5 percent ferruginous material is concentrated along and emphasizes dolomite grain boundaries.

Description of geographic, thickness, and facies of the Wildhorse dolostone is included in discussion of the Haskell Limestone (p. 123). According to Beckwith (1928, p. 228), the most northerly outcrop of the Wildhorse is located in sec. 27, T. 23 N., R. 10 E., approximately 1 mile farther north than the unit was studied by me (near center west line SE $\frac{1}{4}$ sec. 34, T. 23 N., R. 10 E.). The southernmost exposure of the Labadie Limestone observed during this study (selected section 70 in appendix) is about 17 miles north of the northernmost known Wildhorse exposure. However, Bowen (1918, p. 18, 20) reported two fusulinid-bearing limestones from the predominantly shale section between the Bigheart Sandstone below and the Fourmile Sandstone above in Township 24 North, Range 10 East. I failed to locate exposures of these limestones but Beckwith (1928, p. 229) considered these limestones as probably correlative with the Labadie Limestone. Bowen's Figure 5D and 5A (1918, p. 18) show the southward convergence between the Bigheart Sandstone and the Birch Creek and Avant Limestones. Selected section 73 (in appendix) records the southward continuation of this convergence. Because of this convergence and because of the variable thicknesses of shales and sandstones between the Bigheart Sandstone and the Labadie Limestone, Beckwith's (op. cit., p. 229) suggested correlation of the Labadie with the Wildhorse is altogether reasonable. Reference sections of the two units (described above) show similar developments. Especially the molluscan zone developed in the shale unit below the Wildhorse (selected section 73 in appendix) has influenced

several geologists to attempt correlation of the Wildhorse dolostone with the Haskell Limestone of Kansas terminology. Both Moore and Newell suggested this correlation in unpublished field notes prepared during the early 1930s. Moore (1936, 1949) reported the probable correlation of the Haskell, Labadie, and Wildhorse units and observations by me corroborate this correlation.

Some geologists may be averse to grant the probable correlation of the Wildhorse dolostone with the Labadie (Haskell) Limestone since, in recent years, the Wildhorse has been reported as a lenticular unit in the upper unnamed shale member of the Barnsdall Formation, one formation removed^{1/} from the Labadie Limestone Member of the Vamoosa Formation. With the exception of Beckwith's 1928 report, no one except those attempting to trace limestones of the Kansas section southward has ever suggested correlation of the Wildhorse with the Labadie (Haskell) Limestone. Those working northward in this part of the Oklahoma section are forced to attempt some correlations on the basis of tracing so-called sandstone "bases" in shale-sandstone complexes. These complexes are characterized by erosional overlap and facies changes, both of which are confusing.

I believe the so-called Okesa Sandstone shown by Oakes (1952, p. 90, fig. 11) in Townships 22 and 23 North is wholly or partly the Bigheart Sandstone. Approximate trace of the "base" of sandstones called Bigheart prior to 1928 is shown by Beckwith (op. cit., geologic map), who considered the Bigheart sandstones as older than the Wildhorse. In description

^{1/}The Tallant Formation separates the Barnsdall and Vamoosa Formations in Oklahoma classification.

of the Bigheart, Beckwith (op. cit., p. 231-232) stated:

In the areas where best developed, Tps. 23-24-25 N., Rs. 10-11 E., it forms several prominent benches that be used locally for mapping of geologic structure, as in the north-central part of T. 25 N., R. 11 E., south and west across the north-west part of T. 24 N., R. 11 E., the east side of T. 23 N., R. 10 E. In the southeastern part of T. 23 N., R. 10 E., it splits into several rather short massive lenticular beds separated by shale of varying thickness. In places there are six or more of these short lenses, present in one vertical section of the group^{1/}. None of these short sandstone beds can be traced more than a few miles, many of them only one or two miles. This multiplicity of sandstone beds in the Bigheart group continues across the east half of Tps. 21-22 N., R. 10 E. It is impossible to trace any of these beds more than a few miles along the strike. Only the more important ones are shown on the map and no attempt has been made to name them. They are all grouped as Bigheart sandstones. For mapping of structure the top or bottom of the group is the only safe datum plane to use, even locally.

Even though the Bigheart displays complex lateral development and even though neither its top nor base represents a single stratigraphic horizon, I do not believe there is any reasonable doubt that the bulk of the member can be traced more or less continuously from its type area to the exposure about 12 miles south (selected section 73 in appendix). Nonetheless, the Okesa Sandstone may be represented in the basal part of the unit called Bigheart in this measured section description.

Clark (1918, p. 95) noted a 50-foot convergence between the Buck Point and Okesa Sandstones toward the southwest across T. 26 N., R. 11 E. Since Beckwith's 1928 report, the so-called Buck Point has been known to be a part of the Bigheart Sandstone. Hopkins (1918, p. 77) reported southward convergence between the Okesa and Torpedo Sandstones across T. 25 N., R. 11 E. and (ibid) stated:

. . . on the line between Tps. 25 and 24 N., R. 11 E., it replaces most of the underlying shale and locally rests on the Torpedo sandstone.

^{1/}The word group refers to the group of sandstones in the Bigheart Sandstone member.

Southward convergence between the Bigheart Sandstone and successively older marker limestones, the Birch Creek and the Avant, from T. 24 N. to T. 22 N., has already been discussed. Therefore, all the principal named sandstones between the shale above the Bigheart and the shale above the Avant Limestone converge in the area between Townships 26 and 22 North. The bulk of the Bigheart Sandstone can be traced more or less continuously from its type area into this exposure regardless of the fact that exact placement of its base and top is purely subjective. The Bigheart Sandstone is definitely older than the Wildhorse dolostone. I could not accurately trace either the Okesa Sandstone or the Torpedo Sandstone from their type areas into the exposure recorded as selected section 73 (in appendix). Distances of approximately 25 and 28 miles respectively are involved.

Lenticular limestone in the Lawrence Formation. -- A prominent limestone cropping out in the vicinity of Hale (eastern Chautauqua County, Kansas) is illustrated as Plate 40. In its outcrop area, this unit ranges stratigraphically from about 65-80 feet above the Haskell Limestone and from about 100-130 feet below the Toronto Limestone.

This limestone lens is well exposed in an abandoned quarry in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 31, T. 32 S., R. 13 E. (Pl. 40) where it aggregates a 14 feet thickness of medium light gray wavy-bedded limestone. Individual beds range from 0.1 to 0.6 foot thick. Texturally the rock is predominantly a mixed-fossil lime wackestone. Some hand samples contain less than 10 percent grains and therefore are classed as mixed-fossil lime mudstone. Variation in grain percentage is apparently as great laterally within a bed as vertically between beds. Skeletal grains include sparse to common

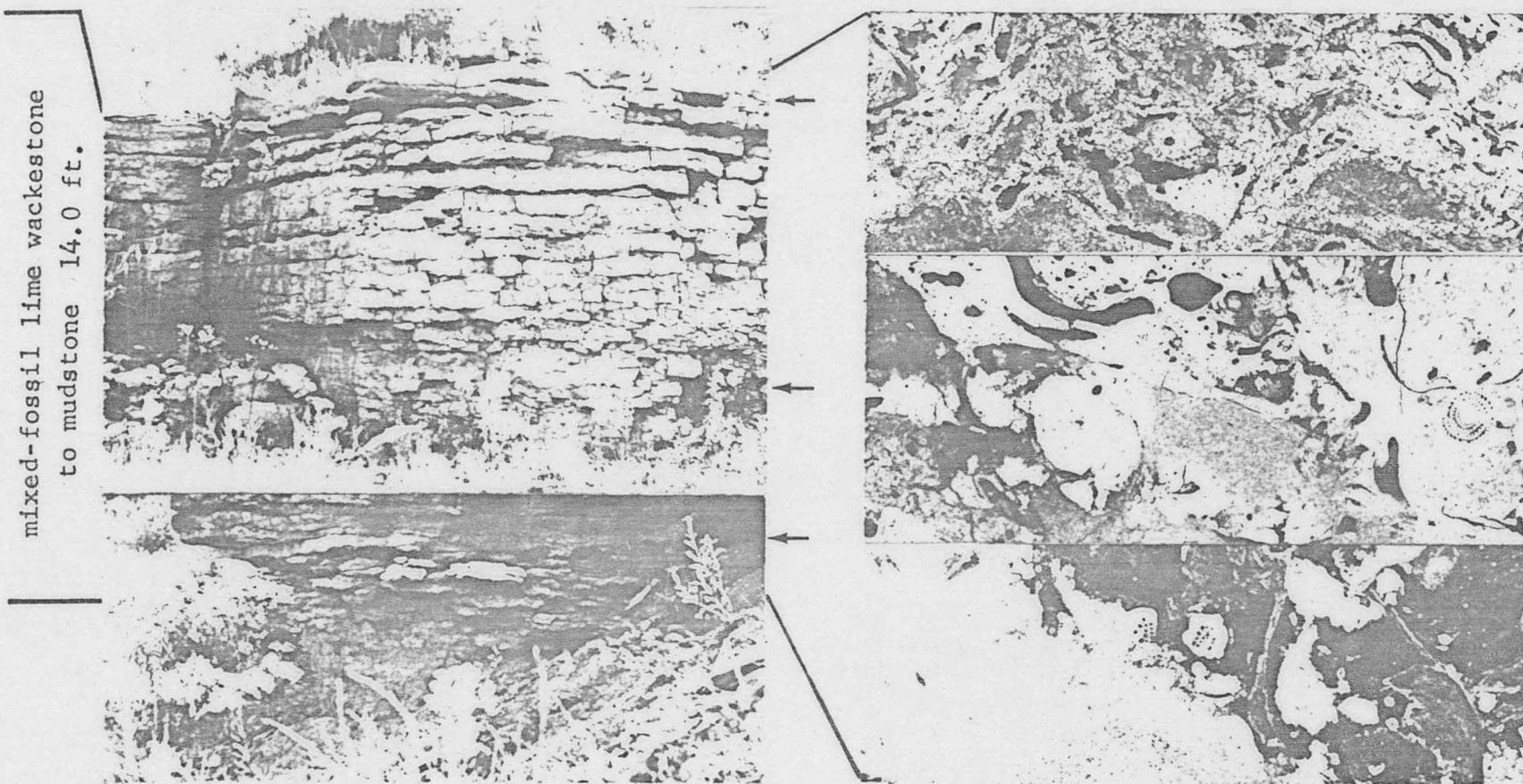


PLATE 40.--Reference section of lenticular limestone in the Lawrence Formation in southern Kansas. Quarry exposure in SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 31, T. 32 S., R. 13 E., Chautauqua County, Kansas. Negative prints of thin sections (X3) on right. Arrows show exact position of samples chosen as representative. Vertical surfaces, orientation as shown.

crinoid, echinoid, fusulinid, other foraminifer, bryozoan, brachiopod, and ostracode remains. Thin sections show the following effects of recrystallization: spar stringers transecting allochems; irregularly bounded lime mud blebs in spar mosaics; areas of lime mud to microspar to sparry calcite gradation; skeletal grains in which structure has been partially or completely obliterated by recrystallization to spar; and, in one thin section, sparse patches of dolomite in the lime mud matrix.

The lenticular limestone in eastern Chautauqua County, Kansas outcrops of the Lawrence Formation may be stratigraphically equivalent to the Amazonia Limestone. However, until and if, a much greater amount of detailed subsurface control is available, one or several possible three-dimensional relationships of this limestone lens cannot be established.

A limestone lens prominent in the northwest quarter of T. 27 N., R. 10 E., Osage County, Oklahoma has been correlated with the Labadie Limestone by W. F. Tanner (1956a, geologic map in pocket). I believe that this limestone is younger than the Labadie Limestone; is correlative with the limestone lens of Chautauqua County, Kansas exposures of the Lawrence Formation; and is not an inlier as mapped by Tanner (op. cit.). The principal area of outcrop of this limestone in Osage County, Oklahoma is in sections 4, 8, 9, 16, and 17, T. 27 N., R. 10 E. A quarry exposure (near center east line NW $\frac{1}{4}$ sec. 17) shows 25 feet of wavy-bedded limestone and dolostone in beds ranging from 0.2 to 0.7 foot thick. Presence of dolostone affords a convenient basis for differentiation into three units. Unit 1 (Pl. 41) aggregates about 11 feet of mixed-fossil lime mudstone (locally wackestone). Color of fresh rock surfaces ranges from very light gray to greenish gray. Skeletal grains include brachiopod,

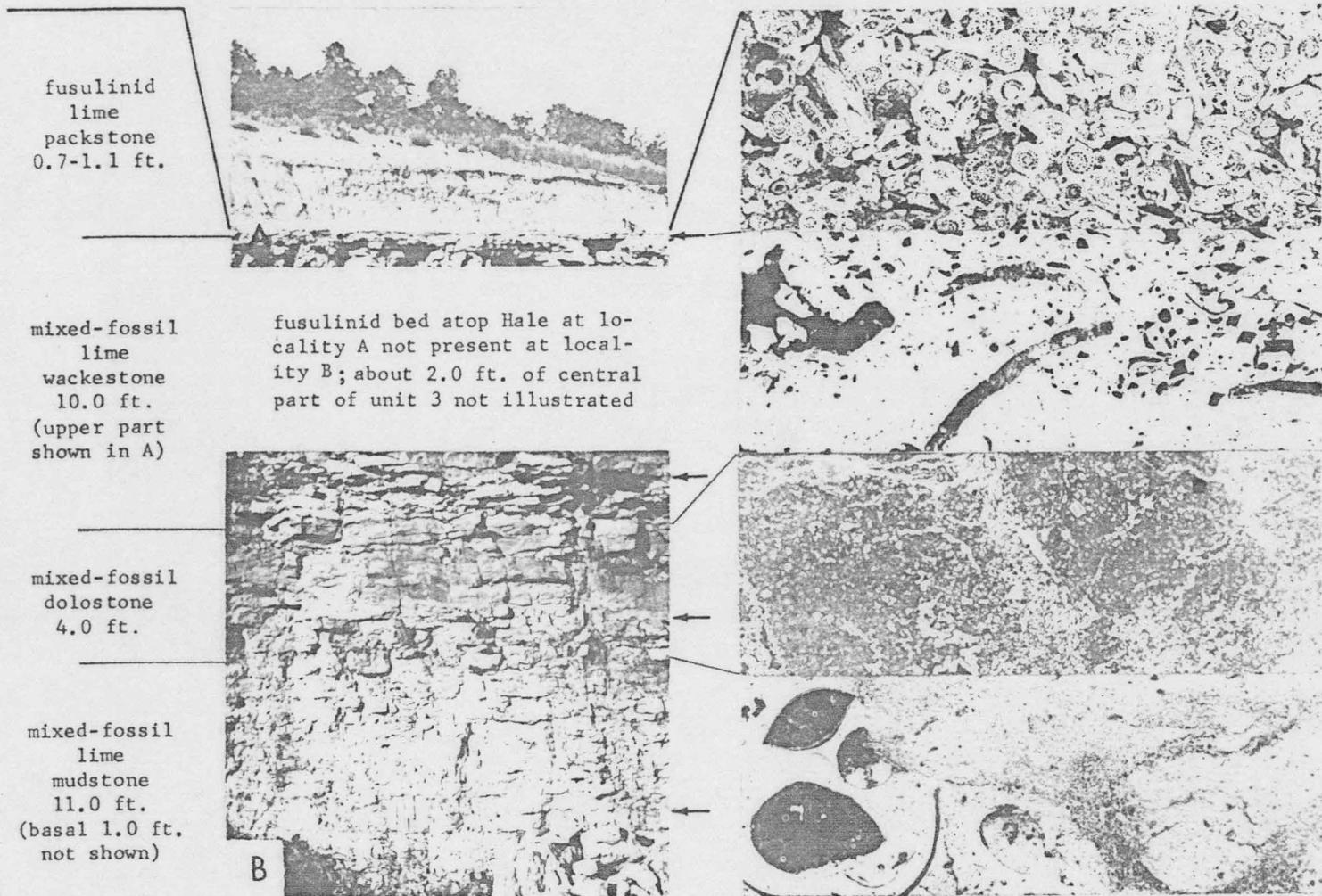


PLATE 41.--Lenticular limestone in the Lawrence Formation in Osage County, Oklahoma. A, Quarry exposure near SW corner NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 27 N., R. 10 E. Note orientation of fusulinids in packstone bed at top of the quarry face. B, Quarry exposure near center east line NW $\frac{1}{4}$ sec. 17, T. 27 N., R. 10 E. Negative prints of thin sections (X3.5) on right. Arrows indicate stratigraphic position of samples selected as representative of footages indicated and described in text. Vertical surfaces, orientation as shown.

crinoid, bryozoan, and foraminifer remains. The brachiopods Composita magna and Dielasma bovidens and the coral Syringopora are present.

Medium to coarsely crystalline mixed-fossil dolostone forms unit 2. Skeletal grains include recognizable brachiopod and crinoid fragments. Fresh medium bluish gray rock surfaces weather moderate yellowish brown. Dolomite rhomb boundaries are accentuated by concentration of ferruginous material. Unit 2 is about 4 feet thick and bounding contacts are gradational.

Unit 3 is a light olive gray mixed-fossil lime wackestone, which contains crinoid, brachiopod, bryozoan, echinoid, and foraminifer remains and aggregates about 10 feet in thickness. Dusky yellow clay-mineral laminae are common in the upper 2 feet of the unit. Effects of recrystallization are evident in thin section. Spar stringers transecting allochems, lime mud blebs included in sparry calcite mosaics, and areas of lime mud to microspar to coarse spar gradation are common. In the basal foot of the unit, less than 5 percent irregularly bounded patches of dolomite is present.

The fusulinid bed atop the limestone section shown in Plate 41A is tentatively correlated with a similar facies developed in Chautauqua County, Kansas and possibly correlates with the ?Amazonia Limestone of Elk County, Kansas outcrops. This bed is composed of transported constituents and its base is locally disconformable.

Occurrence of the Oread Limestone in northern Oklahoma has been known since the Osage Reservation was studied by numerous United States Geological Survey personnel (White and others, 1922). The first comprehensive documentation of correlation of Pennsylvanian rocks across the

Kansas-Oklahoma line was published by Moore and others (1937) and resulted in definite recognition of the Leavenworth Limestone, Heebner Shale, and Plattsmouth Limestone Members of the Oread Limestone in Oklahoma. Prior to this, only statements to the effect that the Leavenworth Limestone was recognized in Oklahoma had appeared in the literature. In addition to the already recognized occurrences, Cooley (1952) identified the Toronto and Snyderville Members of the Oread in a single Oklahoma exposure. Carter (1954) recognized only the Leavenworth, Heebner, and Plattsmouth Members in Osage County, Oklahoma exposures. As reported by Cooley (1952), the Toronto, Snyderville, Leavenworth, Heebner, and Plattsmouth Members of the Oread Limestone crop out in northernmost Oklahoma (Pl. 42).

All members of the Oread display facies change in either southern Kansas (Toronto and Snyderville) or northernmost Oklahoma (Leavenworth, Heebner, and Plattsmouth). Facies change of both the Toronto and Plattsmouth Limestones is marked whereas that of the Leavenworth Limestone is less marked. Facies change of both the Heebner and Snyderville Shales is marked. Principal southeastward, southward, and southwestward changes in Oread rocks include: several-fold thickening and associated variation in rock types, as well as development of erosion surfaces within the shale members; thinning of the limestone members; increased clay or silt content in the limestone members, especially marked in the Toronto and progressively less so in the Plattsmouth and Leavenworth Members; discontinuity of the limestone members; and finally complete wedge out of the limestone members.

The southernmost exposures in which the various limestones of the Oread were observed in Oklahoma are indicated on Plate 42. There are no reports of either Toronto or Plattsmouth exposures farther south. The southernmost exposure of the Leavenworth Limestone observed during this study is near the center NW $\frac{1}{4}$ sec. 18, T. 27 N., R. 10 E. (Pl. 42). However, White and others (1922) reported the middle Oread as far south as the southern part of Township 24 North, Range 9 East as shown on the geologic map that Beckwith (1928) compiled. The main concern of the United States Geological Survey personnel assigned for work in the Osage Reservation, White and others (op. cit.), was structural mapping. Where limestone markers were absent, other resistant beds or otherwise distinctive horizons were utilized to extend the approximate trace of marker units. Consequently, the middle Oread as applied by various authors does not everywhere represent the Leavenworth Limestone. I believe the so-called middle Oread of Townships 27 to 29 North generally represents the Leavenworth but probably does not represent the Leavenworth south of Pawhuska in the greater part of Township 25 North and Township 24 North. Carter (op. cit.) reported a probable Leavenworth outcrop in the southeast corner sec. 25, T. 27 N., R. 9 E., which comprised a 0.2-foot thick shaly limestone. R. C. Moore (personal communication, 1961) has identified the Leavenworth as far south as Pawhuska. Tanner (1956, p. 52) reported the Leavenworth in Township 26 North, Range 9 East but I consider this report doubtful. Tanner (op. cit., p. 54) stated:

The calcareous shale zone thought to represent the Middle Oread in the southern part of the area has been mapped more on stratigraphic position than on field recognition. For example (Beckwith, 1928; Shannon, 1954) have drawn the Middle Oread through the

railroad cut in sections 20 and 29, T. 26 N., R. 9 E. No doubt the horizon is present there . . . However, no limestone is present, other than the many thin silty limestones which occur practically everywhere that the "lagoonal" gray shale facies of this report occurs.

Shannon (1954, p. 14) reported the Oread in a railroad cut in the southwest corner of sec. 23, T. 26 N., R. 9 E., and explained (op. cit., p. 13) that his Oread was the Leavenworth Member. However, there is no fossiliferous limestone whatsoever in this railroad cut. In fact there is not even any limestone. Quartzose siltstones are the only resistant beds exposed there. No reported evidence that the Leavenworth passes laterally into nonfossiliferous quartzose siltstone is known and the Leavenworth cannot be recognized in this railroad cut. Mr. Arthur Troell^{1/} and Mr. Donald Toomey^{2/} are preparing detailed stratigraphic reports on the Toronto and Leavenworth Limestones respectively. These reports are designed for forthcoming publication by the State Geological Survey of Kansas and contain much more data pertaining to the surface stratigraphy of the Toronto and Leavenworth Members than are included herein.

Douglas Group and adjacent rocks between Osage County, Oklahoma and the Arbuckle Mountains region. -- As regards the rocks studied, all of the reliable key beds, the limestone and dolostone members, wedge out in Osage County, Oklahoma outcrops. Southward the section between the Avant (Iola) Limestone and the Lecompton^{3/} Limestone comprises a shale-sandstone-conglomerate complex to which northern Midcontinent classification is not at all applicable. Map contacts in this part of the section and area

^{1/} Graduate student in geology at Rice University, Houston, Texas.

^{2/} Geologist for Shell Development Company, Houston, Texas.

^{3/} Correlations agreed upon by both Oklahoma and Kansas geologists (see Moore, 1948 and Branson, 1957).

represent so-called sandstone bases. The unreliability as stratigraphic datums of such map contacts extended over appreciable distances has been stressed above (p. 30 to p. 36). The shale-sandstone-conglomerate complex (Fig. 11) in which facies changes are abrupt and erosional surfaces multiple precludes precise correlation of this part of northern and central Midcontinent classifications. The cumulative effects of erosion have resulted in a progressively more imperfect geologic record from Osage County, Oklahoma southward to the Arbuckle Mountains region.

This imperfection of record is documented on the Geologic Map of Oklahoma (Miser and others, 1954). The southward tapering of the Avant (Iola) -Lecompton part of the section is mapped as far south as south-central Creek County, Oklahoma. Southward the Avant (Iola) Limestone cannot be identified, whereas the Lecompton Limestone has been mapped to the North Canadian River. In the absence of the Avant (Iola) Limestone, the Dewey (\approx Drum) Formation is the next older reliable marker unit across Okfuskee County, Oklahoma. The Dewey-Lecompton part of the section records the continuation of over-all southward thinning to the North Canadian River. A reliable marker unit, the Belle City (selected section 77 in appendix), is well developed in the southern Seminole-northernmost Pontotoc Counties, Oklahoma area.

According to Tanner (1956, p. 79) the Belle City Formation is truncated by the Ada Formation about 2 miles north of Ada, Oklahoma. Limestone conglomerates of the Ada have been traced northward as far as central Seminole County, Oklahoma and thence grade northward into chert conglomerates, and finally into shale (Tanner, op. cit., p. 100). Whereas the

southern termination of the Belle City Limestone is probably the result of erosional truncation, I believe that the southward regional facies change and wedge out of the Lecompton^{1/} results from the influence of and swamping by northward influx of terrigenous detritus.

The map contact at the base of the Ada Formation where it crosses the trace of the Lecompton Limestone at North Canadian River (Miser and others, 1954) records only the loss of Lecompton trace within a shale section and not erosional truncation of the Lecompton. The southward facies changes and wedge-outs of all the post-Belle City, pre-Lecompton limestones^{2/} record nondeposition of these carbonates in areas between the Arbuckle Mountains region and their respective southern limits. Therefore, the progressive southward thinning of the Belle City (≈ Dewey, ≈ Drum) - Lecompton part of the section (Miser and others, 1954) is the result in part, of nondeposition of carbonates and, in greater part, of disconformities within the shale-sandstone-conglomerate parts of the section. That disconformities in this part of the section are both more numerous and physically more prominent southward across Creek, Okfuskee, Seminole, and Pontotoc Counties, Oklahoma has been well documented by the work of geologists cited above (p. 12 to p. 16) and by Ries (1954), Tanner (1956) and Oakes (1959). I believe that increments of the Arbuckle Orogeny collectively spanned a large part of the post-Belle City, pre-Lecompton interval. The culmination of this orogeny is

^{1/}Classed as a member of the Pawhuska Formation in Oklahoma nomenclature and as a formation of the Shawnee Group in northern Midcontinent classification.

^{2/}Lansing, Douglas, and Oread limestones of this report as well as the Avant (Iola) Limestone (see Oakes, 1959, p. 33).

probably post-dated by unconformities at the base of the Ada Formation and at the base of the Vamoosa Formation in their respective type areas as concluded by Ham (1954, p. 2042). However, marked imperfections in the geologic record between the Arbuckle Mountains region and Osage County, Oklahoma preclude precise correlation of the base of the Vamoosa Formation in its type area and northern Midcontinent exposures. The acme of Arbuckle Orogeny cannot be more precisely related to northern Midcontinent classification.

The basis for surface to subsurface correlations attempted in this report is shown as Plates 2 to 9 (in pocket). Outcrop sections and sample log descriptions are included in the appendix.

Conclusions regarding correlations are summarized in Table 3. Abandonment of 5 stratigraphic names, Nehawka, Bowring, Shoemaker, Middle Oread, and Upper Oread is recommended.

Sedimentational Framework

Broader aspects of the sedimentational framework that prevailed during deposition of sediments that now form the Douglas Group within the study area are shown on Figure 12. Within the area of study, part of a single sedimentary basin^{1/} existed during Douglas sedimentation. Insofar as I know, there is no convincing evidence that the named structural basins^{1/} of the area were expressed topographically while Douglas sediments were forming. Lee (1956, p. 102) referred to a thinning of the Douglas Group^{2/} from 185 to 150 feet in a 2.5-mile distance as abrupt and as

^{1/}The intended connotation of sedimentary as opposed to structural basins is the same as that of Dallmus (1958, p. 884), who referred to structural basins as dynamic basins.

^{2/}Of former classification.

| IOWA (Adair and Madison Counties) | | NEBRASKA | MISSOURI | KANSAS | OKLAHOMA Osage County | Southward |
|--------------------------------------|----------------------|-----------------------|---------------------|----------------------|--------------------------|-----------|
| Shawnee Grp. Oread Ls. Fm. | Plattsmouth Ls. Mbr. | | | | | |
| | Heebner Sh. Mbr. | | | | | |
| | Leavenworth Ls. Mbr. | | | | | |
| | | Snyderville Sh. Mbr. | | | | 3/ |
| | | Weepingwater Ls. Mbr. | Toronto Ls. Mbr. | | | 4/ |
| | | | Wathena Sh. Mbr. 6/ | | | 8/ |
| | | | Amazonia Ls. Mbr. | | | 2/ |
| | | | | Ireland Ss. Mbr. | | |
| | | | | Robbins Sh. Mbr. 10/ | | |
| | | | | | | 8/ |
| Lansing Grp. Stanton? Ls. Fm. | | | | | | |
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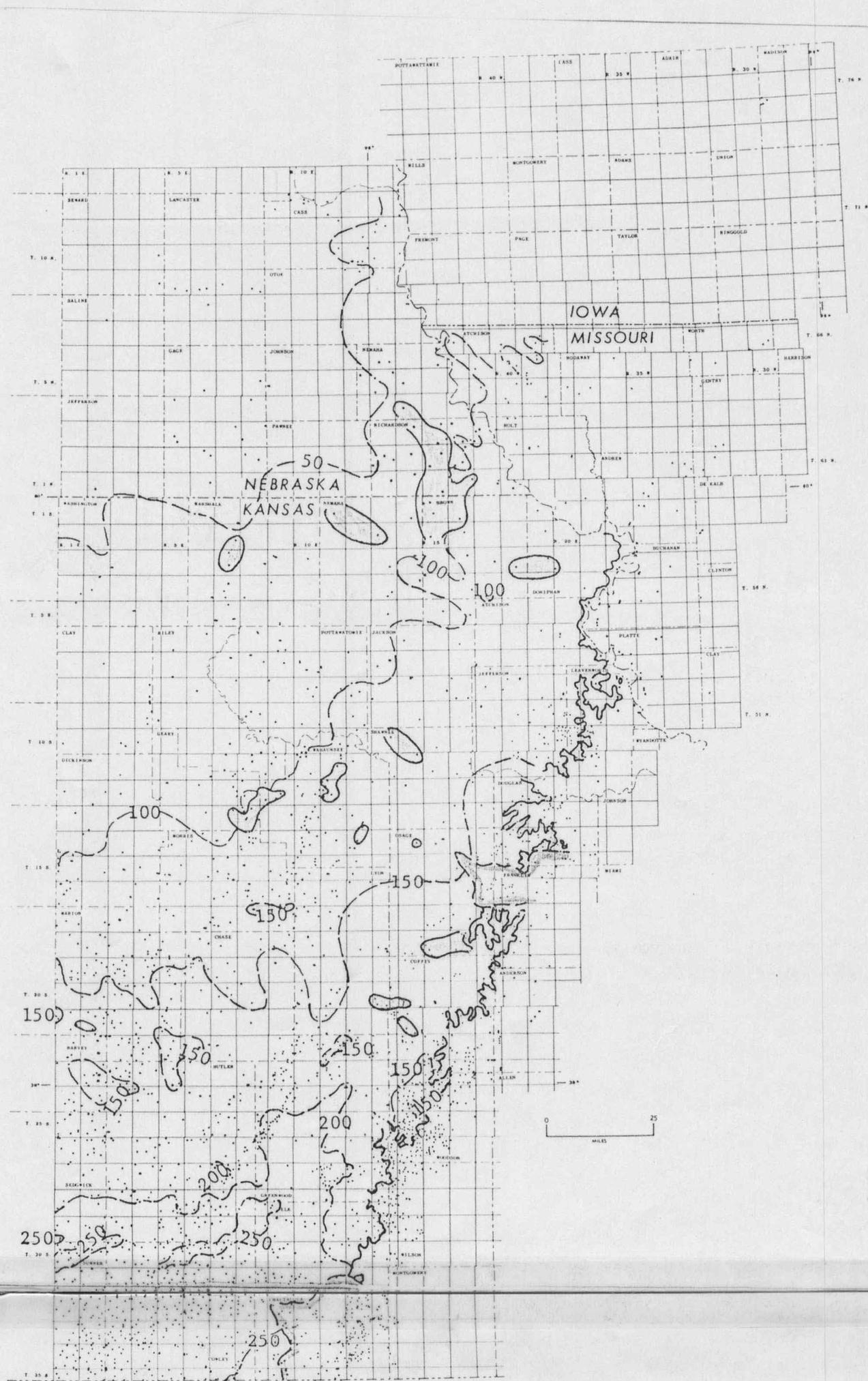
- 1/ The South Bend, Iatan, Haskell, Cass, Amazonia, and Toronto Limestones extend into southwestern Iowa. However, the writer did not study the southwestern Iowa subsurface and did not definitely recognize any of these limestones in Adair and Madison Counties, Iowa outcrops.
- 2/ Recognition of correlations into Oklahoma is important but does not imply that the northern Midcontinent terminology shown should necessarily be incorporated in Oklahoma's formal stratigraphic nomenclature.
- 3/ Observed in a single exposure.
- 4/ Observed in a single exposure.
- 5/ Subsurface only.
- 6/ New name.
- 7/ Subsurface only.
- 8/ Correlation based largely on stratigraphic position relative to non-contiguous key beds and not upon either continuity or homotaxis (strict sense).
- 9/ Sandstone names were applied by the writer only within respective type areas.
- 10/ Whether the Robbins Shale contains all, or most, of the Cass Limestone of Nebraska terminology is a moot question (see p. 179 to p. 186).
- 11/ Approximate correlation (see p. 186).
- 12/ Not recommended for formal usage in Missouri.
- 13/ Not recommended for formal usage in Missouri.
- 14/ Abandonment of term Shoemaker recommended.
- 15/ Abandonment of term Bowring recommended.
- 16/ Abandonment of term Nehawka recommended.
- 17/ Correlation not established.

TABLE 3.-- Summary of correlations. Dashed lines imply recognition of the various stratigraphic units within the states indicated.

indicative of deformation along the east flank of the Nemaha anticline. Lee (ibid.) recognized continued westward and northwestward thinning toward what was described as the deepest part of the Salina Basin and proceeded to explain the thin section in the deepest part of the basin as follows:

The data seem to indicate that there was uplift west of the east flank of the Nemaha anticline but little or no arching of the crest, and at the same time a regional tilt toward the southeast, hence, less shale deposition on the rising area toward the northwest.

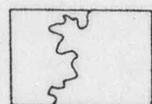
It seems probable that the magnitude of thickness variation cited by Lee (op. cit.) is minor and need not signify corresponding structural movements. Such thickness variations are common to very Missourian-Virgilian shale or shale-sandstone unit of a thickness comparable to the Douglas Group. However, the over-all, although not perfectly uniform, northwestward thinning discussed by Lee (op. cit.) is significant because northward and northwestward thinning (e.g., Fig. 18 and Fig. 33) is characteristic of all terrigenous detritus formations of at least the Kansas City Group-Shawnee Group part of the northern Midcontinent Pennsylvanian. As regards the Douglas Group, such thinning has already been discussed (p. 69). Plates 2, 4, and 5 (in pocket) extend from the Forest City Basin to the Salina Basin. Plate 3 is within the Salina Basin. Plate 6 extends from the Bourbon arch to the Sedgwick Basin. Plates 7 and 8 are within the Cherokee Basin but extend on the west to more comprehensive cross sections by W. L. Adkison (1963, and Subsurface cross section of Paleozoic rocks from Cowley County to Comanche County, Kansas, in preparation). Plate 9 extends from the Forest City Basin to the Cherokee Basin and Figure 11 extends across the Forest City and Cherokee Basins to the McAlester Basin.



Areas in which formation base was not identified.



Areas in which top or both base and top of the formation were either not identified or were extremely discontinuous.



Approximate surface trace of Toronto Limestone base (bounds Lawrence Formation above). Broken where breached by major drainage.

FIGURE 33.-- Lawrence Formation thickness (in feet) map. See Figure 1 for qualification of control points.

These cross sections do not indicate that the Nemaha Anticline or the Bourbon Arch displayed sufficient relief during Douglas sedimentation to divide the area of study into parts of separate sedimentary basins. Excepting the regional northward and northwestward convergence, the magnitude of thickness variations is such that they need not signify anything more than local irregularities of sedimentation and compaction.

Were the sites of sediment accumulation maxima conditioned more by configuration of the Douglas sedimentary basin or by proximity to terrigenous detritus source areas and the cumulative effects of differential subsidence since initiation of Douglas sedimentation? Do Douglas Group rocks thicken or thin toward the center of the Douglas sedimentary basin? Data presented or referred to in the following discussion indicate that sites of Douglas sediment maxima were controlled primarily by proximity to terrigenous detritus source areas and that Douglas Group rocks thicken toward the southern and southeastern margins of the Douglas sedimentary basin.

The remarkable continuity of the various limestones^{1/} considered in this report (see distribution maps in section on Stratigraphy) seems to preclude the existence of any large areas of intrabasinal erosion during accumulation of Douglas sediments in the northern and northwestern parts of the study area. The near lack of quartzose sandstone in that part of the area in which the Douglas Group is less than 100 feet thick (Fig. 10) suggests that only negligible amounts of terrigenous detritus larger than

^{1/} The Westphalia Limestone is the only exception to this generalization and there was probably some intrabasinal erosion during Westphalia deposition (see discussion of disconformities below).

silt size reached the northwestern part of the study area. Unless one postulates northeast to southwest, north to south, and northwest to southeast bypassing of quartz sand of a volume and to a completeness both beyond reason, the predominant source areas for Douglas quartz sands must have been located to the south and southeast. Potential ultimate or immediate source areas could have been located in the central parts or on the flanks of uplifts in the southern and southeastern parts of the study area (Fig. 1) or to the south and southeast outside the study area. That the acme of Arbuckle Orogeny can be dated within the time interval recorded by post-Bell City Limestone, pre-Lecompton Limestone part of the section has already been discussed (p. 221) and there can be no doubt that these mountain-making movements resulted in development of the terranes from which the greatest amount of terrigenous clastics supplied to late Missourian-early Virgilian seas of the northern Midcontinent was derived. This concept has been long-established by the work of those geologists cited in Table 2 (p. 12). Southward and southeastward thickening and coarsening of Douglas terrigenous detritus indicate that the Arbuckle Mountains and Ozark Dome regions were of primary and secondary importance respectively as source areas. Sandstones of the Douglas Group are subgraywackes and there is no indication that either igneous or metamorphic areas were important immediate source terranes. The writer believes that Douglas quartz sands were derived mainly from pre-Douglas Pennsylvanian terranes exposed on the northern flanks of the Arbuckles and the western flanks of the Ozark Dome.

The record is clear as regards the Arbuckles. Gilluly (1949, p. 569) noted that while a basin was still drowned its borders were the places

most vulnerable to erosion and loss of record. Dunbar and Rodgers (1956, p. 67) pointed out:

The zone where land and sea meet is an area of maximum geographic complexity, where different kinds of processes operate. Deposits in this zone show the imprint of these different processes, commonly as a confusing mixture of the criteria ordinarily supposed to indicate marine or non-marine deposition. But if they are rightly interpreted, such deposits can provide a maximum of paleogeographic information.

The zone described by Dunbar and Rodgers and more commonly the zone immediately seaward are zones in which carbonate sediments undergo maximum facies change and wedge out whereas carbonates deposited in the central parts of basins generally display much greater uniformity over a larger area. Therefore, basin marginal areas are generally areas of both maximum erosion and maximum facies change. The area of maximum erosion may be offset landward from the area of maximum facies change but, as a rule, there would be some geographic overlap. The discussions of Stratigraphy and Correlations establish that, as pertains to the rocks and area studied, southernmost Kansas and Oklahoma form the area of maximum erosion and most imperfect record and southern Kansas and northernmost Oklahoma the area of maximum facies change.

I believe that the southernmost shoreline present within the study area during Douglas sedimentation was located somewhere between Osage County, Oklahoma, where the southernmost carbonates of the Douglas and adjacent parts of the section were recognized, and the Arbuckle Mountains region. The numerous disconformities in Oklahoma north of the Arbuckles and the conglomerate sequence (Ham, 1954) structurally preserved within the Arbuckles are clear testimony to the importance of the Arbuckle

Mountains region and the northern flanks of this region as a source area during a major part of Late Pennsylvanian (including Douglas) deposition.

Importance of the Ozark Dome and peripheral areas as a source of Douglas sediment is not so clear. At their closest point, about a 70-mile wide expanse of older rocks separates the eastern limit of Douglas outcrops from the arbitrarily drawn boundary of the Ozark Uplift (Fig. 12). No suggestion that the Ozark Uplift was as important a source area as the Arbuckle Mountains region is intended. Nonetheless, it seems probable that some Douglas sediments were derived from the western flanks of the Ozark Uplift.

Antiquity of the Ozark Dome has long been known (Moore, 1936, p. 1795) and it is not merely a structure that came into being as a result of post-Pennsylvanian deformation. Keller and others (1954) reported evidence that the Ozark Dome was emergent during a part of post-Mississippian, pre-Marmaton time. Karst topography developed on the pre-Cheltenham terrane of Mississippian carbonates corroborates this contention. Keller (1956, p. 2707) thought the diaspore and flint clays of the Cheltenham formed in a non-marine environment relatively far from the sea and that the Cheltenham fire clays graded northwestward into typically marine illitic shale. Howe (1956) reported on the Cherokee rocks of southeastern Kansas and adjacent areas of outcrops. He (op. cit., p. 23) wrote:

The three major types of dark shale . . . all seem to be variants of a lagoonal or near-shore environment, differing from that of coal only by presence of sea water having moderate depth.

If, in fact, Cherokee coals are non-marine deposits, as inferred by Howe (op. cit.) -- and no one has suggested otherwise - a large expanse comprising

the Ozark Dome and northwest, west, and southwest peripheral areas was emergent at various times during Cherokee sedimentation. Jewett (1945, p. 11) thought that some of the Marmaton sediments were derived from the Ozark Uplift area. No one has yet concluded that the Ozark Uplift area was an important source of Pleasanton sediments. Moore (1949, p. 79-80) suggested that the large amount of sandstone, quantitatively as great or greater than limestone, in the southeastern Kansas part of the Kansas City Group outcrop area seems to be correlated with uplift in the area of the Chautauqua Arch, a pre-Mississippian westward trending extension of the Ozark Uplift in southern Kansas and northern Oklahoma.

Hence, there is every reason to believe that the Ozark Uplift was emergent at various times or possibly during the greater part of pre-Lansing Pennsylvanian time. During this time the Ozark region was the source of at least some of the northern Midcontinent middle and late Pennsylvanian terrigenous detritus.

The importance of a southern source for terrigenous detritus parts of the Lansing Group has long been known. Moore (1931, p. 250) wrote:

In southern Kansas and extending into northern Oklahoma there is a very abrupt change from lime and shale to sandstone, and in Osage County, Oklahoma, much or all of the Lansing consists of sandstone.

Figure 31 shows that the initial part of the change discussed by Moore (op. cit.) is from limestone to shale. Sandstone at least 40 feet thick comprises a part of the Lansing in Montgomery County, Kansas outcrops (see p. 49). The sandstone just below the uppermost limestone of the Lansing (Pl. 8 in pocket) and probably also the Torpedo Sandstone of Oklahoma classification are correlative with parts of the Lansing Group.

The shale-sandstone facies of the Lansing is not confined to the southern margin but also occurs along a part of the eastern margin of the limestone facies (Fig. 7). Arenaceous limestone or quartzose sandstone is characteristic of Missouri and Kansas South Bend Limestone outcrops but is not widespread to the northwest (see p. 67 and Fig. 9).

A fossil assemblage comprising vertebrates, invertebrates, and terrestrial plants is well known from Lansing rocks exposed near Garnett in Anderson County, Kansas (Moore and others, 1936; Peabody, 1952, 1957, 1958; Eaton and Stewart, 1960; and Cridland and Morris, 1963). Peabody (1952) thought that the Rock Lake Shale Member (Stanton Limestone; Lansing Group) at the Garnett locality represented a lagoonal deposit into which a terrestrial reptile was rafted by stream action. Eaton and Stewart (*op. cit.*) thought that the fishlike amphibian they studied lived in the shallow, weedy margins of lagoons and that the Rock Lake Shale was a deposit of alternately marine and freshwater lagoon conditions. On the basis of plant studies, Cridland and Morris (*op. cit.*) corroborated the conclusions of the above-mentioned vertebrate paleontologists.

The presence of both terrestrial and marine fossils in the same deposit is significant. Such a site of deposition could have been: (1) a marine environment into which remains of non-marine plants and animals were transported; (2) a non-marine environment into which remains of marine animals were transported; or (3) a mixed environment the deposits of which might contain indigenous as well as transported marine and non-marine fossils. In terms of current knowledge, the latter condition seems most probable. The Rock Lake Shale of east-central Kansas exposures

displays variable facies (Fig. 9 and Ball, 1959) contains appreciable amounts of quartzose sandstone, and is bounded below and at least locally above by disconformity (see discussion of disconformities below). In contrast, the Rock Lake Shale from Leavenworth County, Kansas, northeastward into Missouri is relatively uniform lithologically, contains only minor amounts of quartzose sandstone, and, if disconformities bound the member in this area they are certainly obscure. The Rock Lake Shale of Nebraska exposures (selected sections 1, 2, and 4 in appendix) is uniform lithologically, contains no quartzose sandstone, and is not associated with disconformities. The logs of cable tool cuttings utilized in this study, although too few to be considered conclusive, indicate that the heterogeneous character of the Rock Lake Shale of east-central Kansas outcrops does not extend any great distance northwestward into the subsurface. Seemingly, the Rock Lake Shale of east-central Kansas represents the deposits of a mixed environment that separated the terrestrial environment^{1/} of Petrolacosaurus kansensis and of the plants^{2/} to the southeast from a uniform marine environment to the northwest. Pre-Lansing Pennsylvanian terranes exposed on the western and northwestern flanks of the Ozark Uplift probably supplied some of the quartz sand incorporated in east-central Kansas, northeastern Kansas, and northwestern Missouri outcrops of the Rock Lake Shale and South Bend Limestone parts of the Lansing.

The probability that the Ozark Uplift was source of Douglas terrigenous detritus secondary only to the Arbuckle Mountains region is indicated

^{1/} Described by Peabody (1952).

^{2/} Described by Cridland and Morris (op. cit.).

by the distribution of some of the Douglas limestones, by the general distribution and thickness variation of Douglas sandstones and shales, and by the general distribution of Douglas coals. Distribution and general composition of some of the shale faunas are also significant.

All of the named limestones considered in this study wedge out southward. All of the limestone members, except the Westphalia, are essentially continuous in the northwestern part of the study area, that is, the area in which the Douglas Group ranges from 50 to 100 feet thick (Fig. 10). Three of the limestones, the Iatan (Fig. 13), the Cass (Fig. 23), and the Amazonia (Fig. 24), display as marked lateral change southeastward as southward within the study area. The other limestones, including the South Bend, Westphalia, Haskell, and Toronto, first become regionally discontinuous in southernmost Kansas (Montgomery and Chautauqua Counties). The areas of regional discontinuity^{1/} of all the limestone members are clearly associated with areas of facies change and are not simply a matter of post-depositional erosion. Both contemporaneous and post-depositional erosion (see discussion of disconformities) are clearly associated with the areas of facies change as is to be expected in sedimentary basin-marginal areas. If the southeastern margins of the areas of regional discontinuity of the South Bend, Westphalia, Haskell, and Toronto Limestones projected northeastward beyond the eastern limits of their respective present crop lines, which, of course, cannot be demonstrated, a southeasterly located land area during deposition of these limestones would be as probable as during deposition of the Iatan, Cass,

^{1/} Areas colored blue on distribution maps in section on Stratigraphy.

and Amazonia Limestones. Facies of the Haskell Limestone and adjacent parts of the Douglas Group are remarkably persistent in Nebraska outcrops (see Fig. 28 and Fig. 29 and p. 131 to 132) and apparently also throughout the area in which the Cass Limestone is essentially continuous (see Plates 2, 3, and 4 in pocket and Fig. 23). This sequence as exposed in Nebraska and northwestern Missouri is compared on Plate 34 (pocket). Figure 30 shows the Haskell Limestone and adjacent parts of the section as developed in Marshall County, Kansas. Southeastward thickening and coarsening as well as marked differences in facies in this part of the section are considered indicative of the influence a southeasterly source area.

Considering the entire Douglas Group, the southeastward thickening and coarsening of the terrigenous detritus parts of the section as well as the northwestward convergence of the limestones (Plates 2 and 4 in pocket) are seemingly in part the consequence of a southeasterly source area. Contrast of the Douglas Group between the northwestern part of the study area^{1/} and the Missouri-northern Kansas part of the principal outcrop area^{2/} to the southeast is not as marked as the southward change shown by comparison of Plates 3 and 8 (in pocket) but the southeasterly changes are appreciable.

Douglas Group coals are best developed in the Kansas part of the area of principal outcrop (Fig. 11), are poorly developed in Missouri outcrops, and are nearly lacking from Nebraska^{3/} and Iowa^{4/} outcrops. The sample logs

^{1/} Exemplified by Plate 3 in pocket.

^{2/} See Figure 11.

^{3/} One coal bed has been reported from southern Cass County, Nebraska outcrops of the Douglas (Plate 3, section 1) and no coals are known from Platte River valley exposures of the Douglas.

^{4/} True regardless of the imprecision of correlations into Iowa (p. 190).

utilized in this study indicate that Douglas coals are generally absent north of Township 25 South in Kansas and northwest of approximately a 40-mile wide area bounded on the southeast by Missouri and Kansas outcrops. Admittedly, the sample logs are too sparsely distributed (Fig. 1) to give more than a general indication of coal distribution. Nonetheless, general restriction of Douglas coals to the Kansas part of the study area south of Township 25 South (see Plate 8 in pocket) and to the surface and shallow subsurface northward (see logs of cable-tool cuttings in appendix) is apparent. The landscape upon which the vegetation grew was probably located southeast of the study area (see discussion of coals below). Regardless of whether the predominance of Douglas coals record deposition in a mixed environment or a non-marine environment, the general assumption that most coals record basin-marginal deposition is applicable to Douglas coals.

Facies changes of the Oread limestones (Pl. 42 in pocket), thickening and coarsening of the Oread shale members, and associated erosion surfaces in southern Kansas and northernmost Oklahoma indicate persistence of the southern source area that was marginal to the Douglas sedimentary basin.

Several areas of facies change in and erosion of Oread rocks farther north may indicate the influence of a southeasterly source area but this possibility is not corroborated by a regional southeastward thickening of the Oread shale members. The Plattsmouth Limestone Member of the Oread is represented largely, and locally entirely, by abundantly fossiliferous shale in west-central Woodson County, Kansas. Facies variations and disconformity within the Toronto-Snyderville part of the Oread Limestone

in the southern Douglas-northern Franklin Counties, Kansas area has long been known and has been described most recently by O'Connor (1960) and Ball and others (1963). In a part of the Andrew County, Missouri-Doniphan County, Kansas area, the limits of which are as yet too imperfectly known (see discussion of disconformities) to show on Figure 26, the Toronto Limestone was removed by erosion prior to deposition of the Leavenworth Limestone sediments. If Newell's interpretation (1942, p. 16-19) of the probable ecologic significance of Paleozoic Mytilacea is correct, and there is no reason to believe otherwise, the presence of abundant myalinids in some Andrew County, Missouri, exposures of the Snyderville Shale may record shore zone conditions in that area during Snyderville deposition. Characteristics of the limestone conglomerate developed in Andrew County exposures from which the Toronto Limestone was eroded (see Fig. 35 and discussion on p. 290) indicate that the Snyderville disconformity may represent shore zone erosion.

The Ouachita Mountains region was possibly an important source terrane for some of the coarse constituents of the Vamoosa Formation in Creek - Pontotoc Counties, Oklahoma outcrops. The banded chert fragments (Pl. 43F) were probably derived from either the Arkansas Novaculite or the Woodford Chert. Geologists who have studied these stratigraphic units and have looked at these banded chert fragments regard the Arkansas Novaculite as the more probable source (G. F. Stewart^{1/}, personal communication, 1963, and W. E. Ham, in Tanner, 1956b, p. 94).

It seems probable that a southern source of terrigenous detritus, the Arbuckle Mountains region, and a southeastern source of secondary

^{1/}Geologist, State Geological Survey of Kansas.

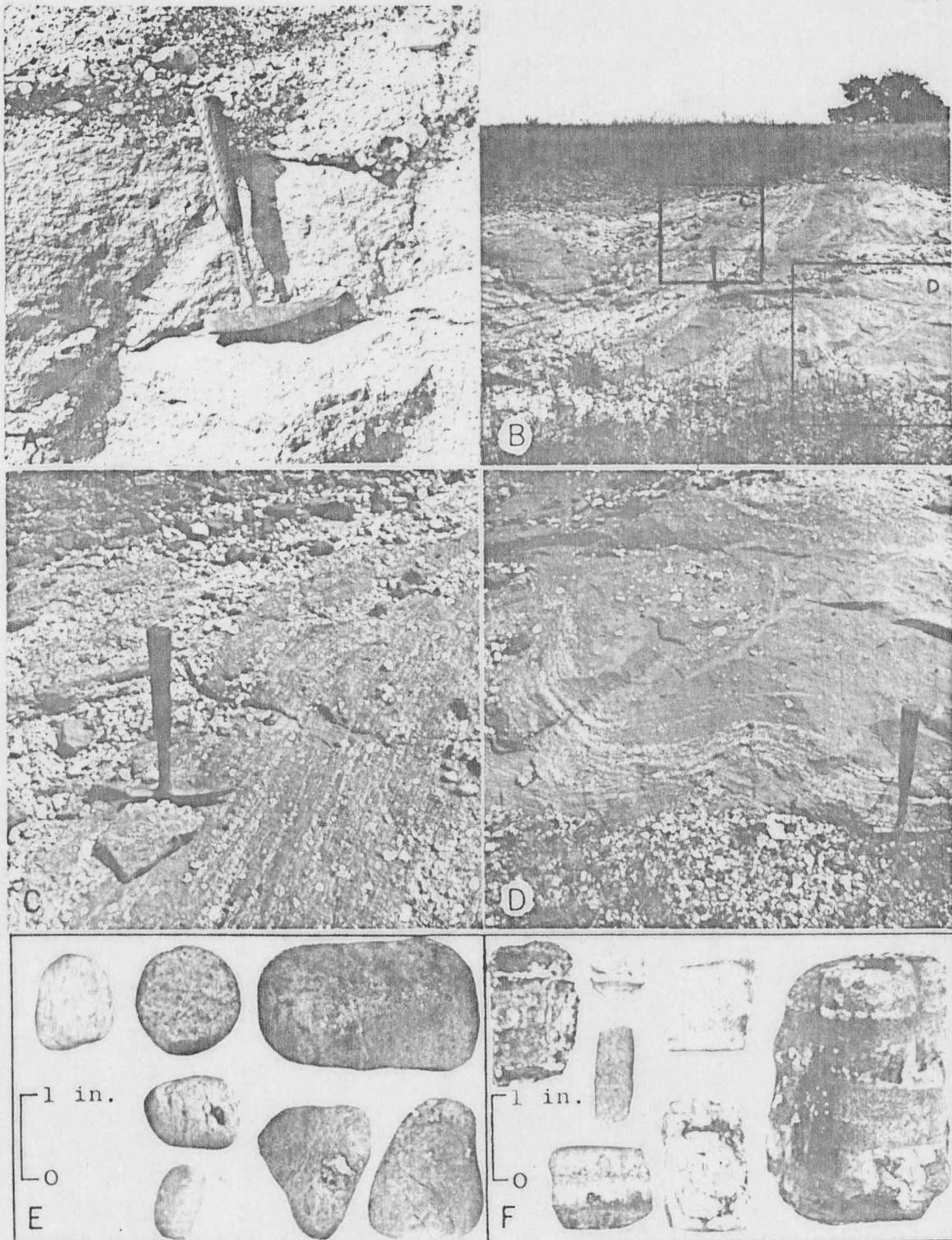


PLATE 43.-- Some aspects of Vamoosa Formation chert conglomerates. Okfuskee County, Oklahoma outcrops. A, Close-up of Boley Conglomerate Member (in part) near Boley (near center south line sec. 21, T. 12 N., R. 8 E.). B, contorted bedding in chert conglomerate near center NE $\frac{1}{4}$ sec. 29, T. 12 N., R. 8 E. C and D, Close-ups of areas indicated in B. E, Size and shape variation of Boley Conglomerate chert fragments, same locality as A. F, Banded chert fragments from Boley Conglomerate, same locality as A.

importance, the Ozark Uplift, obtained during Lansing sedimentation and persisted during Douglas deposition. At least the southern source area persisted during Oread deposition. The Douglas sedimentary basin was seemingly a single basin and marginal areas other than the southern and southeastern ones were source areas of primarily clay-size materials deposited in the Nebraska and Iowa areas. No important intrabasinal sources of terrigenous clastics were indicated by this study nor have been demonstrated by previous studies of Douglas rocks. Sources of the transported constituents of Douglas Group limestones were intrabasinal.

The strikingly uniform development^{1/} of the Douglas Group in the northwestern part of the study area is regarded as indicative of an area of relatively uniform sedimentation on relatively featureless surfaces relatively distant from the southern and southeastern shores of the Douglas sedimentary basin. Absence of the Iatan (Nehawka) Limestone in the north-central part of the Nebraska area (Fig. 13), absence of the Amazonia Limestone in the northeastern part of the Nebraska area (Fig. 24) and the wholesale differences in limestones of the Douglas and adjacent parts of the section in southwestern Iowa exposures (p. 192 and selected section 7 in appendix) may indicate proximity to northeastern margins of the Douglas sedimentary basin. However, until appreciably more subsurface study in southwestern Iowa and appreciably more surface work in northernmost Missouri and southernmost Iowa has been completed, this possibility cannot be corroborated and exactly which of the Douglas limestones are exposed in Madison and Adair Counties, Iowa will not be known.

^{1/}Exemplified by Plate 3 (in pocket), which extends an airline distance of about 75 miles and shows Douglas Group thicknesses within an approximately 50- to 62-foot range and the northwestern parts of Plates 2 and 4.

Conflicting opinions regarding the provenance of the northern Mid-continent Pennsylvanian terrigenous detritus. -- Mudge (1956) reported on sandstones and channels in the Upper Pennsylvanian and Lower Permian of Kansas and de-emphasized the importance of a single unconformity as a systemic boundary. This was an important contribution that seems to harmonize with the facts as currently known. In discussion of sources of fill material, Mudge (1956, p. 675-676) stated:

Moore (1931, p. 255) suggested that the source area of the channel and sheet sandstones and sandstone lenses was on the south and southwest. Although locally some clastics probably were contributed from these directions, the chief source area appears more likely to have been at the north and northwest.

An important matter of record is that Moore was not clearly represented by the reference quoted above. Moore (1931, p. 255) wrote:

The facts that the amount of clastic sediments increases regularly to the south as the rocks are traced from Nebraska to Oklahoma and that a distinctly greater proportion of sand occurs in the section southward, imply that the main source of sediments in the Pennsylvanian of the western interior basin lies to the south and perhaps the southeast.

Mudge's study (op. cit.) covered the upper part of the Wabaunsee Group in Kansas and is hardly basis for questioning Moore's statement, which applies to the regional aspect of eight groups of Pennsylvanian rocks. Hayes (1953, p. 1545-1546) referred to Mudge (op. cit.) and Wheeler and Murray (1957) as advocates of a northern source whereas Moore (op. cit.) and Weller (in Wheeler and Murray, op. cit.) advocated a southern source. Hayes (op. cit., p. 1546) stated:

On the basis of the evidence presented by Mudge and Wheeler and Murray, and of the cross-bedding data of this study, the writer thinks that most of the Pennsylvanian sands of the Western Interior (Mid-Continent) basin were carried across a shelf extending southwesterly into the basin (Fig. 1), although some of the sands were derived from local sources.

Hayes (op. cit.) studied the lower part of the Cherokee group in a five-county area in west-central Missouri and took a total of 117 azimuths of paleocurrent directions from 30 stations. Is the amount of data presented by Hayes sufficient to justify a conclusion regarding most of the Pennsylvanian sands of the Western Interior (Mid-Continent) region?

The northerly and northwesterly source areas of primary importance visualized by Mudge (op. cit.) and Hayes (op. cit.) may be real as regards particular areas and particular parts of the northern Midcontinent Pennsylvanian section but are certainly not valid generalizations applicable to the entire Pennsylvanian section of this area. As regards the area and rocks studied, the conclusion made by Moore 32 years ago (quoted above) is correct. I doubt that any geologist who visited Nebraska and Iowa exposures of the Kansas City Group-Shawnee Group part of the Pennsylvanian, as well as Kansas and northernmost Oklahoma exposures, would argue strongly for a northwesterly, northerly, or northeasterly source area that was of primary importance during deposition of Kansas City-Shawnee sediments in the northern Midcontinent. In Nebraska and Iowa, the Kansas City-Shawnee part of the section is much thinner than in northern Oklahoma-Kansas outcrops and contains only negligible amounts of sandstone and coal. If the geologist was even casually acquainted with this part of section in the subsurface of the Kansas and Nebraska east ranges he would promptly dismiss the idea that northwesterly, northerly, or northeasterly source areas were of major importance during this part of the Pennsylvanian and within the area of this study.

Rock-Stratigraphic Unit Contacts

Abruptness or gradation of lithologic change vertically is inherent in any stratigraphic section. Possibly for this reason and excepting obviously unconformable contacts, the significance of lithologic boundaries in a vertical sequence has received little specific attention in the literature. Pertinent discussion of the importance of contact relationships is given by Dunbar and Rodgers (1957, p. 126) and by Moore (1957, p. 82-83). These authors suggest the possible but not proven existence of a hiatus where an abrupt lithologic change is noted in the field. The obscure hiatus may be the result of erosion (paraconformity) or of non-deposition (diastem). Apparently abrupt lithologic changes are prevalent in the rock succession described in this report.

South Bend Limestone contacts. -- The basal contact of the South Bend Limestone is relatively gradational in the northern part of the outcrop area and relatively sharp in the southern part. Presence of gradational rock types has led to differences in opinion concerning arbitrary placement of the South Bend Limestone base. As much as 0.2 foot of soft, argillaceous fossiliferous siltstone, sandstone, or arenaceous limestone that readily disintegrates when exposed to weathering processes commonly forms the basal part of the member. Even though the weathered contact may appear sharp, examination of relatively unweathered blocks overturned in newly opened quarries or slumped from new road cuts reveals the gradational nature of this contact. The vertical lithologic sequence characteristic of the South Bend and lithologies overlying the basal contact are illustrated (Pl. 44).

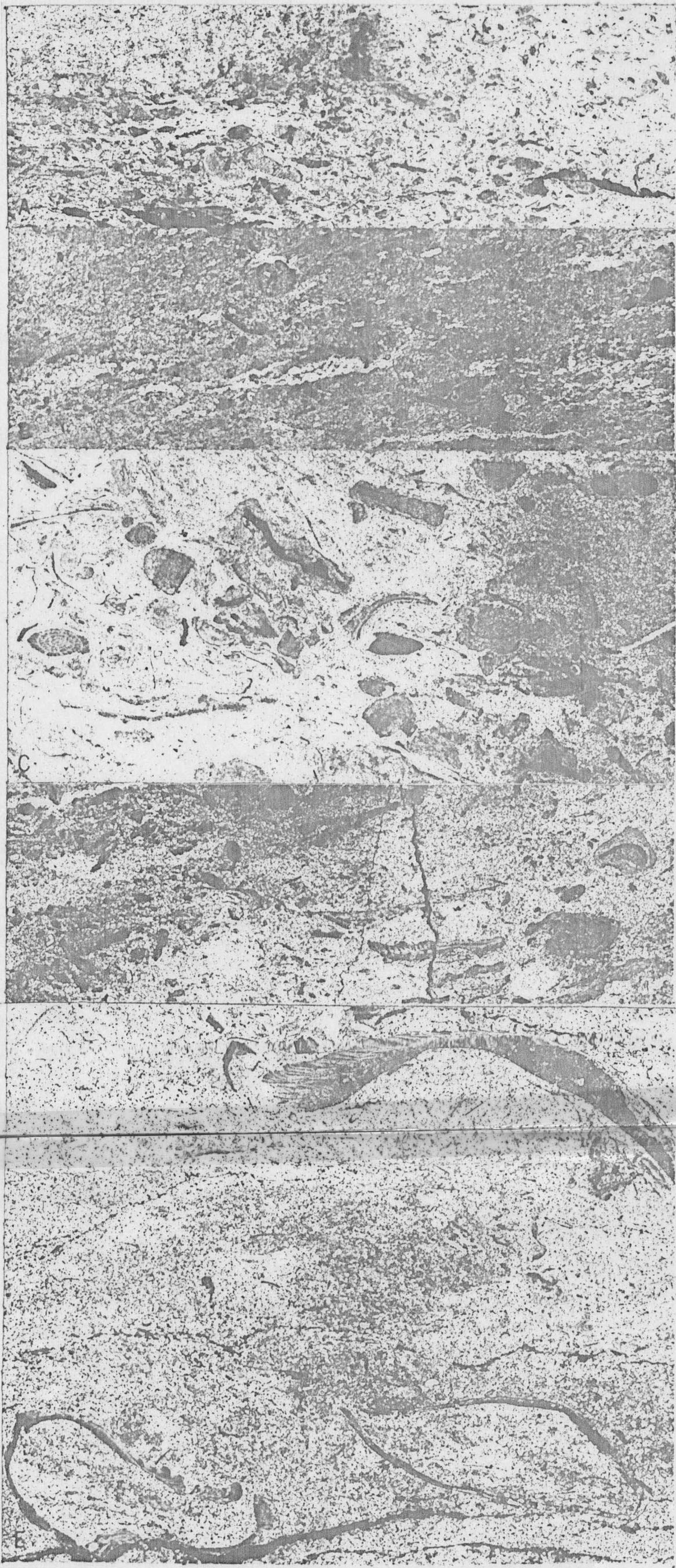


PLATE 44.-- General sequence of rock types that form the South Bend Limestone in Missouri, northern Kansas, and southernmost Kansas exposures. Samples from face of abandoned quarry in NW $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 52 N., R. 35 W., Platte County, Missouri. Negative peel prints (X4) are arranged in stratigraphic order, E to A from base to top of member. Vertical surfaces, orientation as shown. Note quartz silt particles (black) in E and the *Osagia*-coated grains and fusulinids in C and D. See also Plates 13 and 14 and Figure 9.

In the southern part of the outcrop area (Fig. 9 and Pl. 45C to F), the member is generally bounded below by a relatively sharp contact and locally overlies a disconformity. Cross-stratification or conglomerate in the basal bed and an irregular base overlying a scoured or channeled surface are not uncommon (e.g., Fig. 9, sections 5 to 11, and selected sections 37, 38, and 39 in appendix). The erosional contact may appear gradational because of reworking.

Weathering processes accentuate the apparent sharpness of the South Bend Limestone-Weston Shale contact. Because of disintegration upon weathering and colluvial cover, natural exposures rarely afford the opportunity to study this contact closely. Where exposed in quarry faces or on floors of quarries, the uppermost 0.1 to 0.2 foot is very argillaceous and the vertical transition from limestone to shale is more gradational than is apparent. Argillaceous laminae are generally abundant at the top of the South Bend. In the northern part of the outcrop area, frequency of clay-mineral laminae and discontinuous partings range from sparse to common to abundant upward through an approximately one-half foot thick gradational zone, whereas in the southern part of the area the gradational zone is much thinner and only locally exceeds two-tenths foot in thickness.

Locally in Anderson County, Kansas, and in all outcrops of the South Bend studied northeastward, the upper bed is a mixed-fossil lime wackestone in which most of the skeletal grains are extensively abraded. Osagia-coated grains are common and characteristic. Locally the author has had opportunity to study relatively large upper surface areas of the South Bend uncovered during quarrying operations. Comminuted skeletal debris

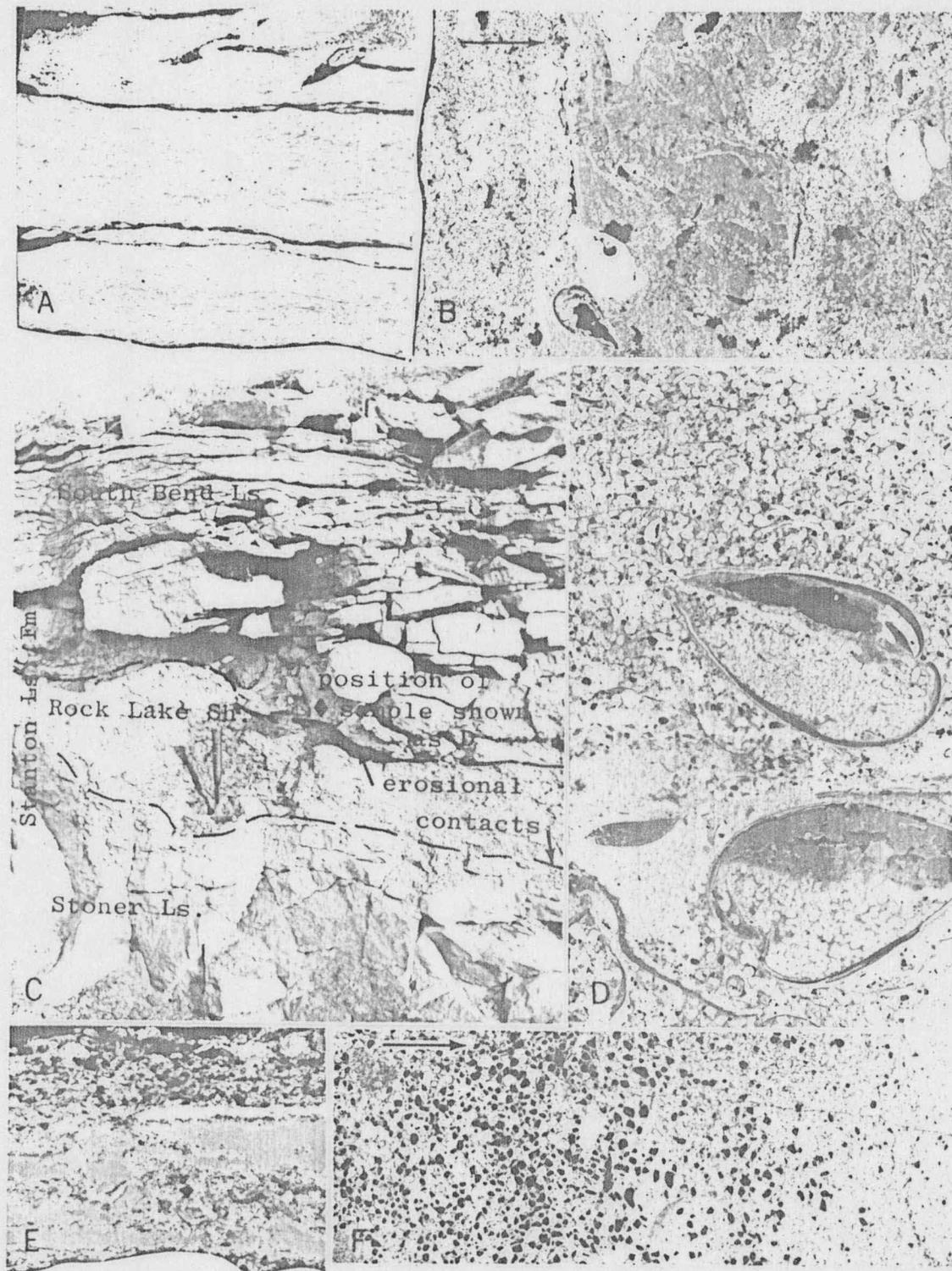


PLATE 16.-- Some aspects of South Bend Limestone basal contact. Kansas samples (A, B, D, and E) of lowermost South Bend and outcrop (C). A, Sample (X2.0) taken near center south line sec. 24, T. 13 S., R. 21 E., Johnson County. B, Sample (X1.3) taken near NE corner sec. 19, T. 21 S., R. 19 E., Anderson County. C, Outcrop near NW corner SW $\frac{1}{4}$ sec. 30, T. 21 S., R. 19 E., Anderson County. D, Sample (X4.0) taken at same locality as C. E, Sample (X1.2) taken in SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 30, T. 22 S., R. 19 E., Anderson County. F, Sample (X4.0) taken near NE corner sec. 26, T. 34 S., R. 13 E., Chautauqua County. Negative peel prints (A, B, and E) and negative prints of thin sections (D and F). Orientation as shown or as indicated by arrows.

mixed with well-preserved, complete or nearly complete fossils are distributed unevenly over the surface. This feature may indicate a smothered bottom (Shrock, 1948, p. 307) condition in which the bottom fauna and the skeletal material fragmented by current and scavenger action underwent relatively rapid burial. Megafauna dominated by arenaceous foraminifers is known to exist in exposures from which samples of this part of the Weston have been washed.

Iatan Limestone contacts. -- Where well exposed, calcareous fossiliferous shale or shaly limestone in the uppermost 2 to 5 feet of the Weston Shale is succeeded by argillaceous basal Iatan Limestone (Pl. 46A). Commonly the clayey material in the limestone is not arranged in inter-laminate fashion but wholly or partially encloses irregular subrounded to subangular areas of mixed-fossil lime mudstone to wackestone, which are closely fitted.

Locally, the gradational zone at the base of the Iatan is no more than 0.5 foot thick and the lowermost 0.2 foot of the member is an argillaceous to silty mixed-fossil lime packstone. Many of the echinoderm fragments and some of the brachiopod fragments are subrounded to subangular. Orientation of lamellar skeletal grains is essentially random.

The upper contact of the Iatan is characteristically sharp and bounding rock types are not gradational. Several limestone types form the topmost bed. (Pl. 18 and Pl. 46B). No example of gradual increase in clay-mineral or silt content from base to top of the bed was observed and abrupt change from limestone to silty shale in the lower part of the Tonganoxie Sandstone was noted in all exposures studied.

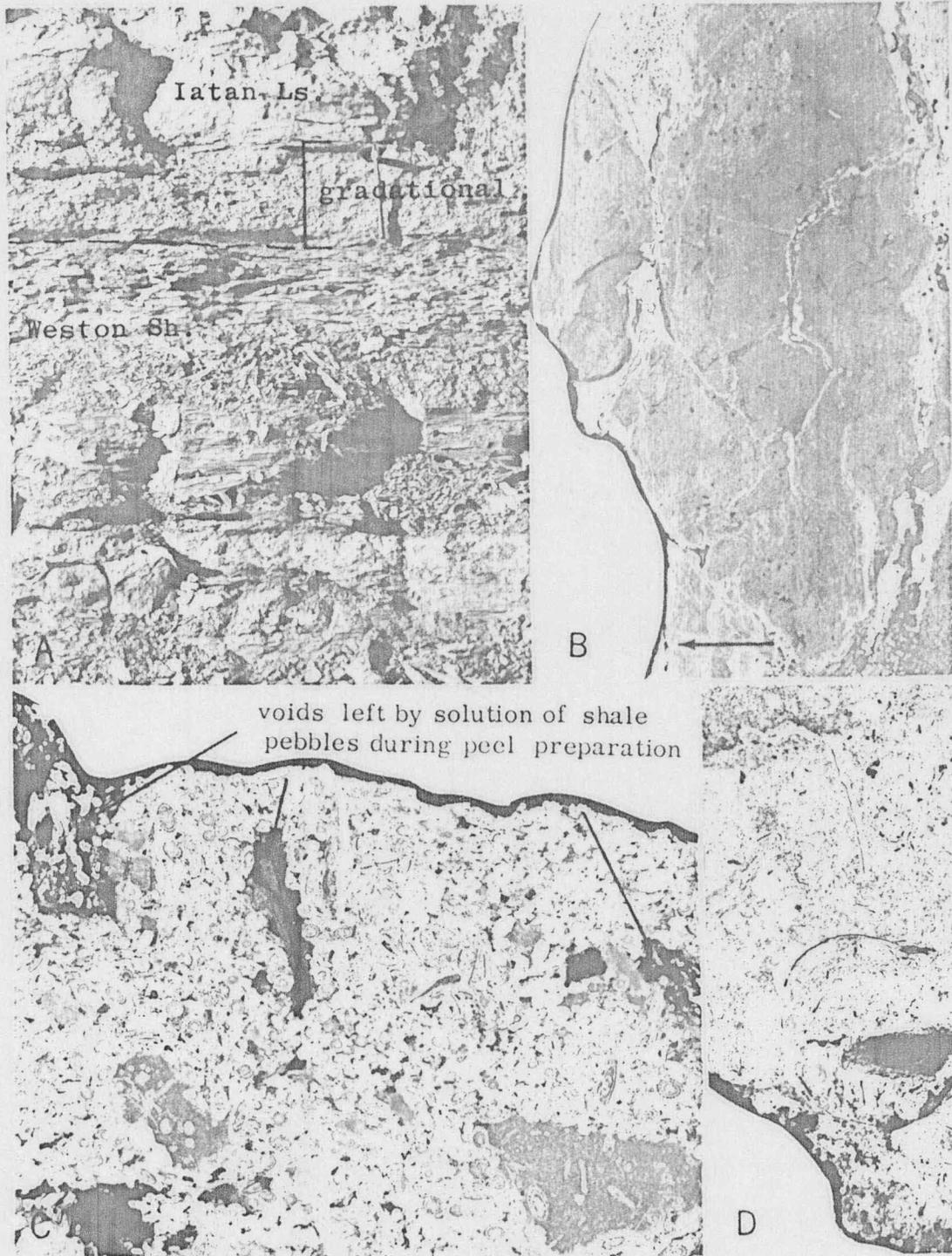


PLATE 46.-- Contacts of the Iatan and Westphalia Limestones, Missouri outcrop (A) and sample (B), Kansas samples (C and D). A, Outcrop near center NE $\frac{1}{4}$ sec. 36, T. 53 N., R. 35 W., Platte County. B, Sample of uppermost Iatan Limestone (X2.0) taken near center east line sec. 24, T. 53 N., R. 36 W., Platte County. C, Sample of uppermost Westphalia Limestone (X1.6) taken near center west line NE $\frac{1}{4}$ sec. 12, T. 21 S., R. 17 E., Anderson County. D, Sample of lowermost Westphalia Limestone (X1.6) taken near center sec. 10, T. 33 S., R. 13 E., Chautauqua County. Negative peel prints. Orientation as shown or as indicated by arrow.

Westphalia Limestone contacts. -- Contacts of the Westphalia are difficult to study because of recessive weathering of the arenaceous and argillaceous, commonly conglomeratic rock. The basal and uppermost parts of the member are especially impure and readily disintegrate to rubble upon weathering. Where obtainable, samples of rock types adjacent to the contacts were taken, some of which are illustrated (Pl. 46C and D). Although apparent gradation of rock types across both contacts of the Westphalia was noted repeatedly, only about six cases of clearly indigenous invertebrate fossils in the silty and sandy shales immediately above and below the member were observed. The basal contact of the algal-fusulinid packstone or osagite facies (Pl. 20) is within a gradational zone, which ranges from about 0.2- to 0.5-foot thick. Either silty to sandy shale or very fine-grained quartzose sandstone (uppermost Tonganoxie) grades upward into silty to sandy limestone. Extensive abrasion of and current lineation displayed by the arrangement of both skeletal and nonskeletal grains, many of which are Osagia-coated, indicate that the member consists largely of reworked debris. Locally, the Westphalia is partially or wholly conglomeratic.

The ostracode coaly lime mudstone facies of the Westphalia (Pl. 21) is either a caprock on the upper Sibley coal or overlies carbonaceous silty shale and the basal contact is gradational in both cases. In most cases the coal within the Westphalia consists of finely disseminated particles concentrated along laminae but at one locality (SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 8 S., R. 22 E.) apparent intercalation of coal and limestone was observed.

Throughout the outcrop area, the upper contact of the Westphalia is relatively sharp, although weathering of the impure limestone results in an apparently gradational relationship. The only indication of gradational rock types associated with this contact is the local development of a thin (less than 0.1 foot) rind of fusulinids in an argillaceous to silty matrix that may represent infiltrating of clay and silt.

Haskell Limestone contacts. -- The basal contact of the Haskell Limestone is within a gradational zone, which is as much as 1 foot thick in southern Leavenworth County, Douglas County, and northern Franklin County, Kansas. Silty to sandy calcareous shale; calcareous mudstone; argillaceous to silty limestone; micaceous, calcareous, quartzose, siltstone; or micaceous, calcareous, very fine-grained quartzose sandstone of the uppermost Vinland Shale is succeeded by argillaceous silty to sandy limestone or limy siltstone to sandstone that forms the basal part of the Haskell Limestone. Gradation of rock types across this contact is well exemplified in the Haskell type section (Pl. 24). Other examples of basal contact lithology are shown on Plate 47. The uppermost Vinland is commonly fossiliferous and locally replete with invertebrate remains, especially those of mollusks. Transition from a dominantly molluscan to a dominantly brachiopodal fauna in the lowermost part of the Haskell Limestone is characteristic. Because of the gradational nature of the rocks bounding the Vinland-Haskell contact, geologists, including the author, have been unavoidably inconsistent in the arbitrary placement of this boundary.

In sections studied southwest of northern Franklin County, Kansas, the Vinland-Haskell contact is generally gradational but the gradation is restricted to a zone not more than 0.5 foot thick. Limy fossiliferous

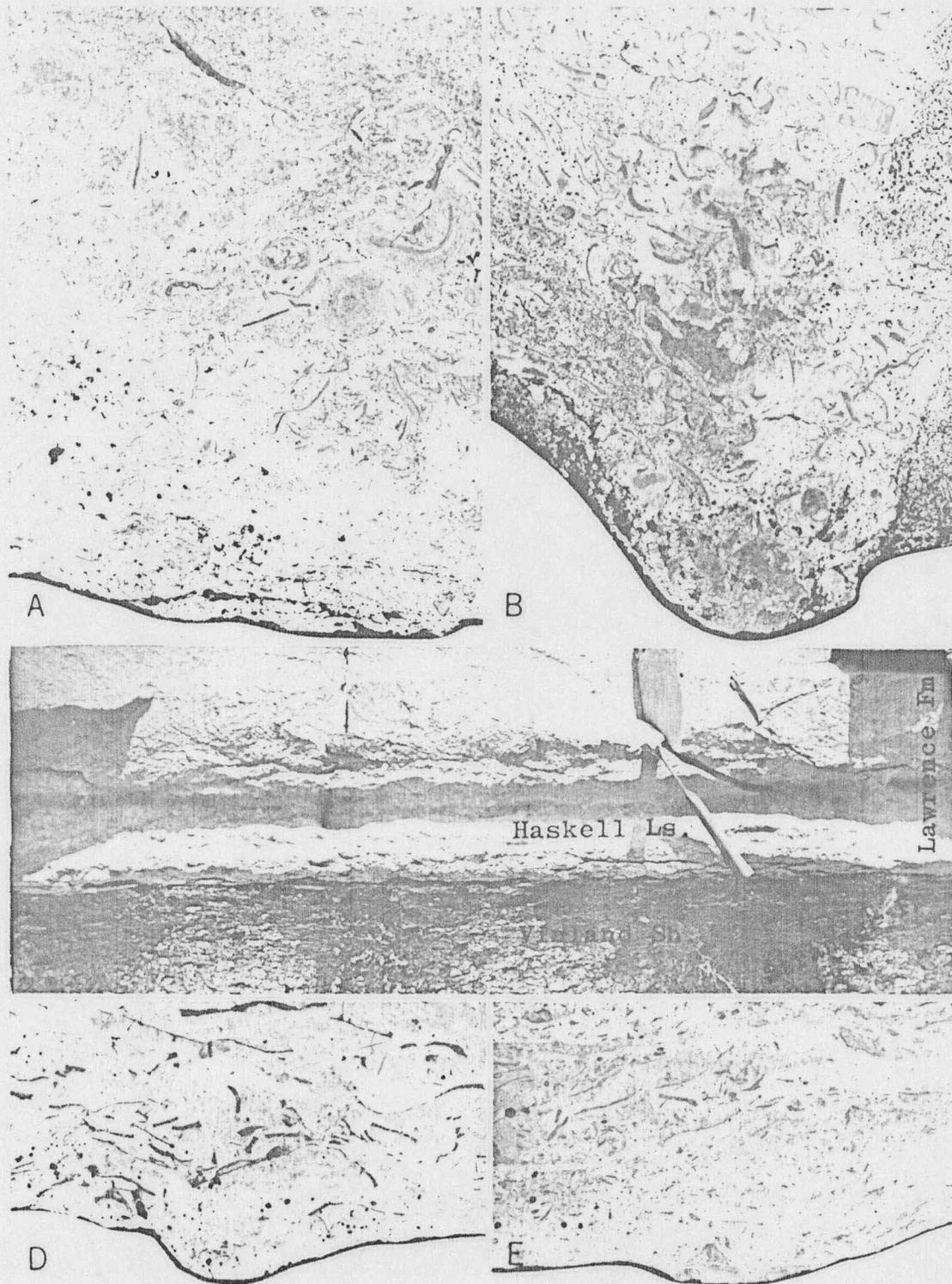


PLATE 47.-- Basal contact of Haskell Limestone. Kansas samples (A, B, D, and E) of lowermost Haskell Limestone and outcrop (C). A, Sample (X2.0) taken near center east line SW $\frac{1}{4}$ sec. 18, T. 7 S., R. 22 E., Atchison County. B, Sample (X1.7) taken near center north line sec. 14, T. 12 S., R. 20 E., Leavenworth County. C, Outcrop in SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 26 S., R. 14 E., Woodson County. D, Sample (X1.2) taken in NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 28 S., R. 14 E., Wilson County. E, Sample (X2.1) taken near center south line NW $\frac{1}{4}$ sec. 3, T. 32 S., R. 13 E., Chautauqua County. Negative pool prints. Orientation as shown.

shale or nodular argillaceous limestone, either of which may be present just below the contact, overlain by argillaceous limestone was noted in many exposures. Calcareous fossiliferous siltstone forms the lowermost part of the Haskell locally (e.g., SE $\frac{1}{4}$ sec. 17, T. 34 S., R. 13 E.) and where observed overlies calcareous silty Vinland Shale.

The Haskell Limestone in northern Leavenworth County and northeastward is composed largely of transported skeletal debris (see Pl. 26). Both the uppermost and lowermost parts of the member are commonly argillaceous although the contacts are relatively sharp. The clayey material is not concentrated in laminae but is irregularly distributed within the matrix.

Where exposed in Cass County, Nebraska, the basal contact of the Haskell (Shoemaker) Limestone is gradational and the upper contact sharp (Fig. 29). The lowermost 0.1 foot of the Haskell is extremely argillaceous and overlies limy fossiliferous shale. A crust of Crurithyris planoconvexa that partially covers the upper surface is characteristic of Cass County exposures of the Haskell.

Change of rock type at the upper contact of the Haskell is either gradational through a small thickness (not more than 0.1 foot) or abrupt. Two types of contact were noted where the uppermost 0.1 foot or less of the member disintegrates rapidly on exposure and weathers to rubble as if gradational. In some sections, clay-mineral laminae and discontinuous partings increase in frequency upward in the upper bed of the Haskell to an extent that the topmost 0.1 foot or less of the member is argillaceous limestone (Pl. 48). In other sections mixed-fossil lime wackestone is in sharp contact with calcareous siltstone to very fine-grained sandstone at



PLATE 46-- Upper contact of Haskell Limestone. Kansas samples (A-D) of uppermost Haskell Limestone. A, Sample (X2.0) taken near center east line SW $\frac{1}{4}$ sec. 18, T. 7 S., R. 22 E., Atchison County. B, Sample (X1.3) taken near center west line SW $\frac{1}{4}$ sec. 18, T. 12 S., R. 21 E., Leavenworth County. C, Sample (X1.8) taken near NW corner sec. 19, T. 14 S., R. 21 E., Douglas County. D, Sample (X1.2) taken in NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 28 S., R. 14 E., Wilson County. E, Sample (X1.5) taken near NE corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 12, T. 10 N., R. 12 E., Cass County, Nebraska. Negative photomicrographs (A-D) and negative print of thin section (E). Orientation as shown.

the Haskell Limestone-Robbins Shale contact. Fossil debris in the siltstone rind consists of rounded and polished sand to granule size fragments (Pl. 48C). Although the contact in both cases weathers as if gradational, gradation in the latter case is merely apparent.

The upper surface of the Haskell Limestone is markedly irregular locally in Douglas County, Kansas. Hummocks and ridges bounding closed depressions as much as 0.3 foot deep are characteristic (e.g., Plate 3C in Miller and Swineford, 1957, p. 2025). Contact of the hummocky Haskell surface with the overlying fossiliferous Robbins shale is sharply irregular and probably is the result of solution as concluded by Miller and Swineford (1957, p. 2028-2029) and not the result of current scour.

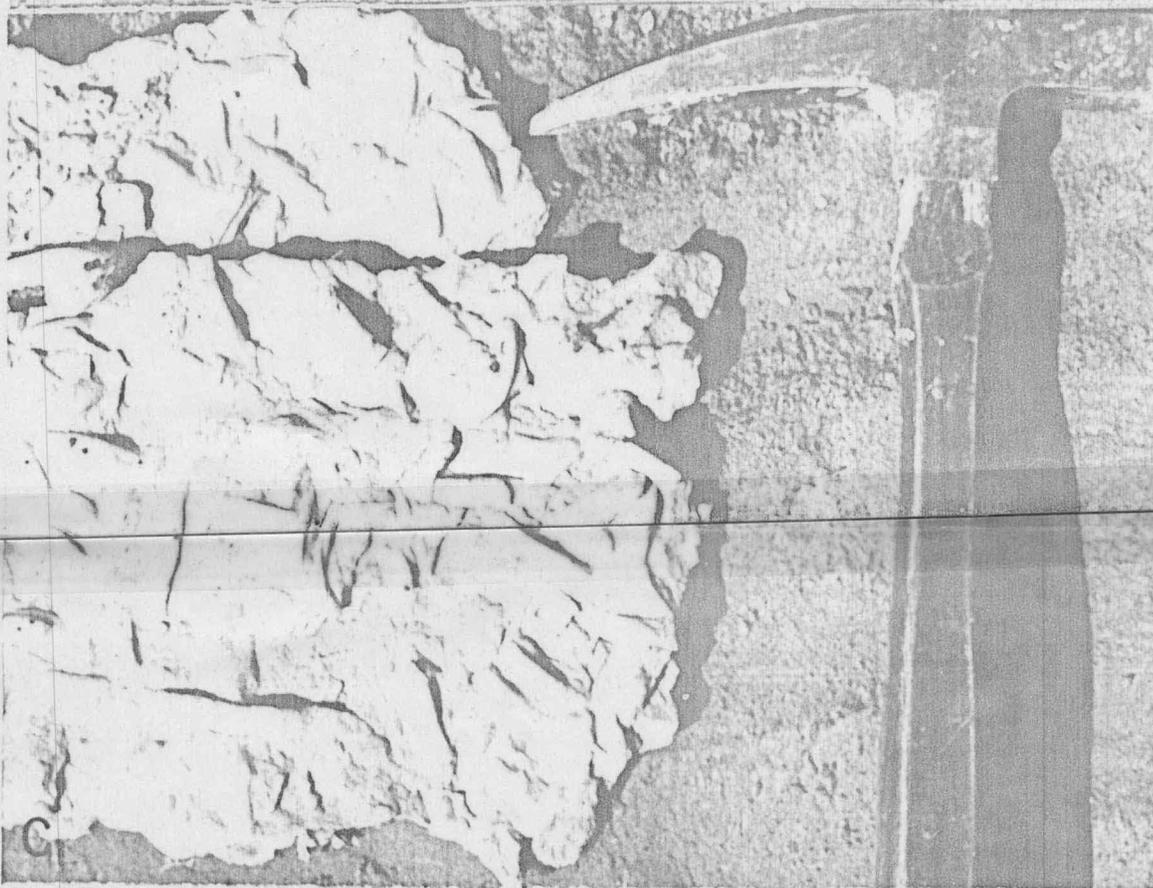
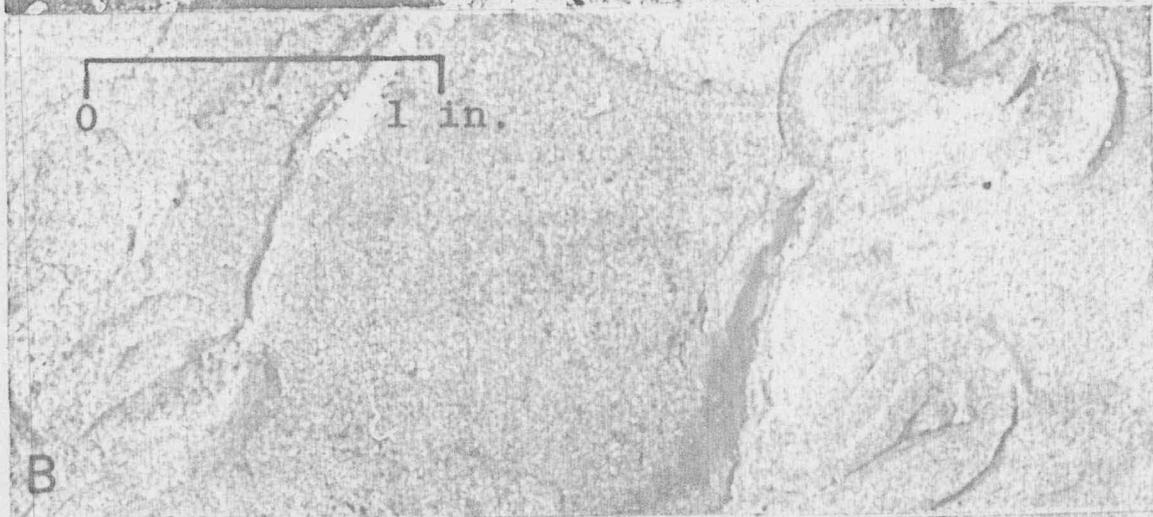
Amazonia Limestone contacts. -- Contacts of the Amazonia were studied in very few places. With the exception of the upper contact at one locality (selected section 54 in appendix), contacts of this limestone were apparently sharp. In two exposures sharpness of the upper contact resulted from post-depositional erosion (selected sections 17 and 20 in appendix). Contacts of the dolomitic, Lingula-bearing siltstone that crops out in the stratigraphic position of the Amazonia (e.g., selected section 45 in appendix) are gradational.

Basal contact of the Toronto Limestone. -- In most east-central and northeastern Kansas and in Missouri exposures this contact is relatively sharp (e.g., selected sections 57, 55, and 19 in appendix). However, in southern Kansas (Pl. 42) the basal contact of the Toronto is gradational and the classificatory boundary between the Lawrence and Oread Formations crosses section at a recognizable angle. The basal contact of the Toronto (Weepingwater) Limestone in the Nebraska exposures studied (Fig. 28, Fig. 29, and selected section 1 in appendix) is gradational.

Bottom markings. -- If the bottom markings shown on Plate 49 are correctly interpreted as trace fossils, they record parts of smothered bottoms (Shrock, 1948, p. 307). Such surfaces probably indicate relatively rapid burial (Shrock, op. cit., p. 307-310) of a lime mud bottom by argillaceous mud (Pl. 49A) and of an argillaceous surface by calcareous sediment (Pl. 49B to D).

Summary. -- Observations pertaining to sandstone-shale (p. 100 and p. 143), shale-coal (p. 309), and limestone-shale (p. 241) interfaces must be regarded as limited in number and as spot observations. Only rock-stratigraphic unit contacts as seen in outcrops or as studied in samples taken from outcrops are discussed in this report. I have studied a few incomplete cores from the Douglas and other parts of the section. Many of the contacts seen in these cores are apparently gradational, whereas corresponding exposed contacts are generally sharp. The effect of weathering on exposed contacts has not been closely studied.

Douglas Group rocks afford examples of: (1) both non-erosional and erosional limestone-shale contacts which are both sharp and gradational; (2) both non-erosional and erosional shale-sandstone contacts, which are both sharp and gradational; and (3) apparently sedimentational shale-coal contacts, which are generally gradational, but in one case (p. 299) are relatively sharp. It seems probable that rock-stratigraphic unit contacts within Douglas rocks represent time lines only very locally, for example, those cases in which small parts of smothered bottoms are recognized in single exposures. Even in single exposures this should not be assumed in many cases, for example, those in which the upper parts of limestones are locally cross stratified or have been otherwise locally reworked. I



LATE 49.-- Examples of bottom markings developed in Douglas and adjacent rocks. Kansas exposures. A, Part of upper surface of South Bend Limestone near NW corner SW $\frac{1}{4}$ sec. 33, T. 21 S., R. 19 E., Anderson County. B, Part of basal surface of Ireland Sandstone near center east line NE $\frac{1}{4}$ sec. 34, T. 24 S., R. 15 E., Woodson County. C, Part of basal surface of siltstone in Ireland-Wathena Member near center south line sec. 5, T. 18 S., R. 18 E., Franklin County. D, Part of upper surface of sandstone bed in Lawrence Formation in SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 35 S., R. 11 E., Chautauqua County.

do not regard any of the contacts studied as time lines; some recognizably are not (e.g., Lawrence-Oread contact in southern Kansas, Pl. 42). Basal contacts of Douglas Group limestones are apparently more gradational than the upper contacts in most of the exposures studied.

Disconformities

Multiplicity and local development of the numerous disconformities developed within the Douglas Group and adjacent parts of the section have already been stressed in the Classification part of the report (see especially Fig. 5). In addition to the number and local extent of disconformities in areas of outcrop; the types of erosion inferred, the magnitude of erosional relief, and the probable areal extent are important regarding the significance of the erosion surfaces.

Types of erosion recorded in strata studied. -- Dunbar and Rodgers (1957, p. 12-13) discussed the different effects of erosion by flowing water confined to channels and of erosion by broad ill-defined sheets of moving water. The first-mentioned type of erosion is generally either terrestrial or within the shore zone, tends to exaggerate the relief, and commonly, at least in part, affects bedrock. The latter type of erosion is submarine, has an antithetic topographic effect, and affects loose sediment. Dunbar and Rodgers suggested the term sublevation for this type of submarine erosion and stated (op. cit., p. 13):

Tidal currents and drift currents tend to move as a sheet, riding above local depressions in which sediment can come to rest. The net effect of sublevation is . . . to keep the surface of the shallow sea floor graded . . . and remarkably flat and its slopes gentle wherever tectonic disturbances do not interfere.

It seems probable that both of these types of erosion are recorded in Douglas and adjacent rocks--the former as local erosion surfaces at the base of sandstones or conglomerates and the latter, that is, sublevation, by some of the limestone facies such as the algal-fusulinid lime packstone facies of the Westphalia Limestone.

No direct evidence exists within the sandstones above the disconformities to indicate whether the erosion was of a terrestrial or shore zone type. Locally developed basal limestone conglomerates and characteristics of strata immediately below the erosion surfaces furnish the only direct indications of the type of erosion involved. Clearly some of the limestone pebbles have been plastically deformed since deposition and were not wholly consolidated when redeposited (see p. 294). The bizarre shape of the limestone pebbles is attributed largely to plastic deformation but extremely short-distance transportation is probably also involved because the conglomerates occur only in close proximity to the source limestones (see p. 282). The large volume of calcareous sand, both skeletal and non-skeletal, incorporated in the limestone conglomerates is not a normal product of terrestrial erosion (see p. 294). Seemingly, if these disconformities were subaerial erosion surfaces, whatever amount of uplift that was necessary to initiate subaerial erosion should cause an associated fluctuation of the ground-water table. Such fluctuation should result in at least small-scale^{1/} karst phenomena in the limestones immediately or close below the erosion surfaces. Solution cavities in the limestone might be partially or wholly filled by slump of

^{1/}Relative thinness of limestones in the area studied would allow only small-scale karst features.

younger sediment or soil. No such solution cavities of definite Pennsylvanian age were observed in limestones affected by or in areas of disconformities within Douglas and adjacent rocks. Numerous examples of karst cavities and fillings along ancient terrestrial erosion surfaces are cited by Shrock (1948, p. 224-229). However, general lack of solution features does not in itself negate the possibility that some of the disconformities studied were the result of subaerial erosion because karst phenomena would not necessarily be expected in coastal areas of low relief. Nonetheless, if a geologist regards those disconformities (Fig. 35) with which the limestone conglomerates are associated as fluvial in origin, the following conditions must have obtained: (1) exposure of partially consolidated source limestones or lime muds to the atmosphere and thence to fluvial erosion before complete consolidations of the limestones; (2) development, deposition, and preservation of large volumes of calcareous skeletal and nonskeletal sand in stream channels; (3) a stream regimen in which well-developed limestone conglomerates are characteristically basal to supposed channel sand or shale and in close proximity to source limestones but not disposed as parts of separate lenses within supposed valley fill as might be expected in floodplain deposits of a meandering river; and (4) an environment in which neither solution weathering of limestones nor formation of soil profiles were extensive and, if at all developed, were either not recognized during this study or not preserved. The mixed environments of the shore zone where both subaerial erosion during short-lived emergences resulting from temporary basinward shifts of strandline and shallow marine erosion obtained would be a much easier site for erosion of some incompletely consolidated limestone. The shore

zone would also be a more reasonable site for the preservation of large volumes of calcareous sand; for the characteristic basal aspect of the limestone conglomerates and the close proximity to source limestones; and for the apparent lack of karst phenomena and ancient soils. Some of the local disconformities within the Douglas are not clearly the result of stream erosion as has been generally assumed in the past (e.g., Lins, 1950) and are probably the result of shore zone erosion.

Disconformities within the Vamoosa Formation^{1/} in the northernmost Pontotoc-southern Creek Counties, Oklahoma, area are seemingly the product of multiple periods of terrestrial erosion. Conglomerates of the Vamoosa in the east-central Oklahoma area are composed primarily of foreign constituents, that is, chert cobbles and pebbles derived from source terrane outside the present area of Vamoosa outcrops. Another striking difference between these chert conglomerates and the limestone conglomerates of the Douglas is the irregular distribution of the former; they are not only basal to, but also generally occur as "interbeds" or zones within associated sandstones (e.g., selected sections 75 and 76 in appendix). The chert conglomerates are not clearly separated from overlying sandstones or shales like the limestone conglomerates (Fig. 35) but are intimately admixed (Pl. 43) as if deposited rapidly enough to partially mask the effects of gravity settling. An over-all gradation from coarse to fine upward is indicated by the occurrence of the coarsest conglomerates in the middle and lower parts of the Vamoosa (Tanner, 1956, p. 92), but,

^{1/} Probably in part correlative to Douglas Group of northern Midcontinent classification. See discussion of correlations in Oklahoma (p. 222).

in detail, vertical gradation is not uniform. Weller (1960, p. 405) discussed the implications of foreign constituents in conglomerates and wrote:

In the course of transport such pebbles are much worn. If they have come long distances, only the harder, tougher, and less soluble types are likely to have survived. Conglomerates of this kind are most commonly associated with non-marine sandstones. They may overlie an unconformity but they are almost as likely to occur within a rapidly deposited detrital sequence where their irregular distribution is a reflection of the variability of local current action and not necessarily of any interruption of deposition.

Seemingly the chertiferous conglomerates of the Vamoosa indicate relatively long-distance transportation from a southerly source terrane as postulated by Tanner (1956, p. 95) or a southeasterly source terrane as postulated by Taff (1904), Morgan (1924) and Oakes (1948). The Arbuckle Mountains region has been suggested as the probable southern source terrane and the Quachita Mountains as the probable southeastern source area. The apparent relatively long-distance transportation of a large volume of coarse chert, some cobbles of which are as much as seven inches in long dimension, tends to indicate terrestrial erosion and transportation along relatively high gradient surfaces. Whether the present outcrop area of Vamoosa chert conglomerates records an area of non-marine Pennsylvanian deposition is a moot question. Insofar as I know, no clearly indigenous fossils have been reported from the chert conglomerate-bearing parts of the Vamoosa. The extraordinarily erratic distribution of crudely developed beds, the tremendous size variation of fragments at a single locality or in a single layer, and the geographic setting of these deposits in an area flanking the Arbuckle Mountains region are regarded as indicative of remnants of a probable fluvial piedmont environment. However, other workers

have offered other speculation pertaining to deposition of the chert conglomerate-bearing parts of the Vamoosa; Oakes (1948) suggested stream deposition, Ries (1954) suggested deltaic deposition, and Tanner (1956) suggested sandy beach or offshore bar deposition.

Sublevation is indicated by some of the rock types developed within the Douglas Group. The algal-fusulinid lime packstone facies of the Westphalia Limestone (Pl. 19 and Pl. 20) is an example. This facies, which extends continuously from northern Anderson to northern Chautauqua Counties, Kansas, and discontinuously into northern Osage County, Oklahoma, is of variable thickness and, except for parts of the member locally (e.g., Pl. 20C), skeletal and quartz grains form the rock framework. Skeletal grains are primarily fusulinids and are commonly abraded and coated with Osagia. In some cases, the fusulinids are obviously current-lineated (e.g., Pl. 19, Pl. 20E and F, and Pl. 41). Locally the member is conglomeratic or cross-bedded (p. 249). Burrowing organisms such as clams (Pl. 50A) and sedimentary structures such as "mudlumps" (Pl. 50B) explain, at least in part, the random orientation of the elongate skeletal grains of some hand samples. This facies of the Westphalia originated as a calcareous sandstone. Osagia coatings in the Westphalia probably developed under conditions similar to those described by Lane (1958, p. 151-154).

If fusulinids were indeed benthonic, as many fusulinid specialists believe (Dunbar, 1957, p. 753-754), the bottoms on which they lived were commonly sublevated. The oft-written statements that where fusulinids occur in abundance they show little indication of transportation or abrasion, rarely occur with mollusks, and are good paleoecologic indicators of the deposits in which they are found (Dunbar, *ibid.*), do not seem to

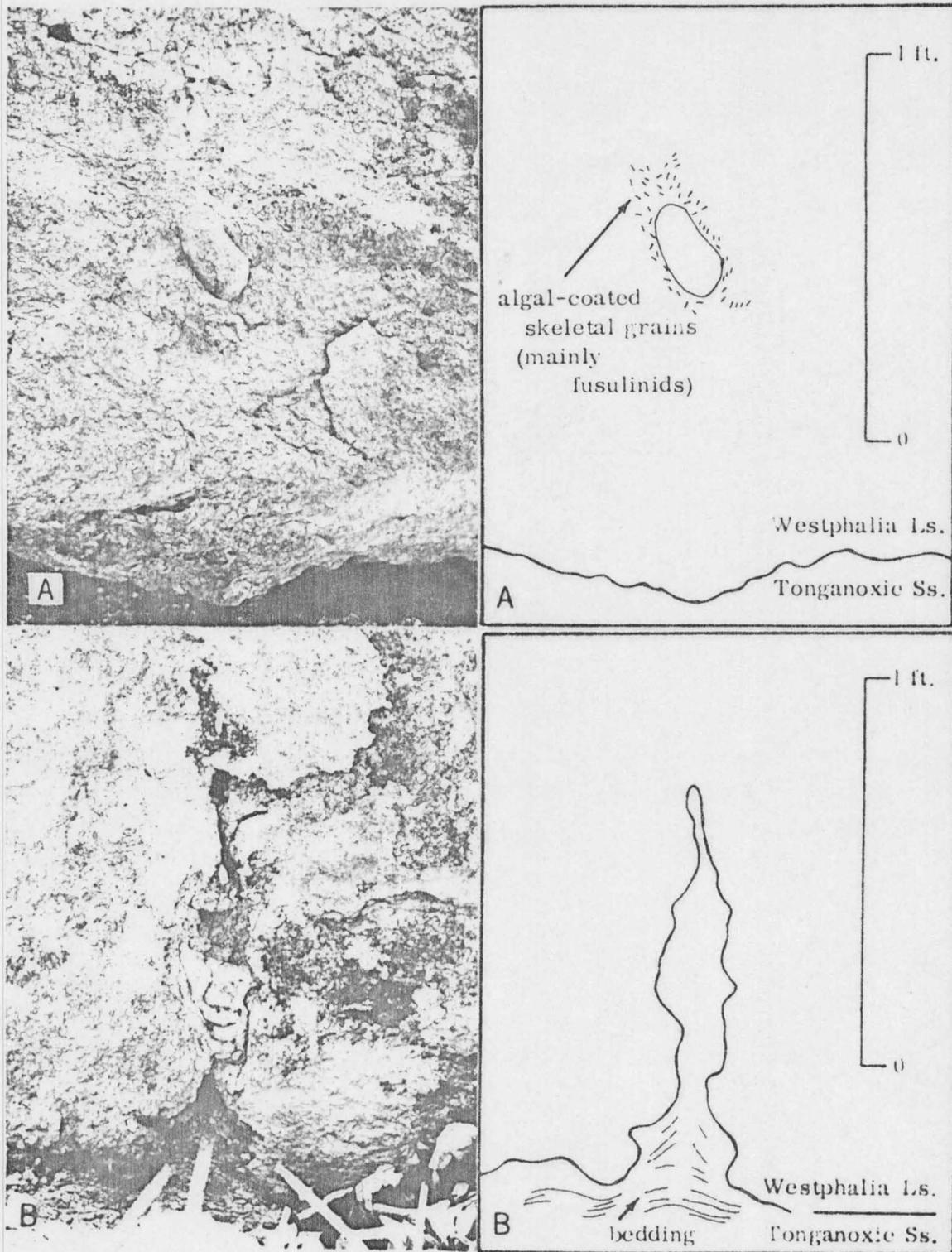


PLATE 50.-- Some causes of random orientation of elongate skeletal grains observed locally in the Westphalia Limestone. A, Pelecypod in burrowing position in SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 26 S., R. 14 E., Woodson County, Kansas. Orientation of grains adjacent to clam is shown in explanatory tracing on right. B, Mudlump of Tonganoxic Member in Westphalia Member. Deformed stratification in uppermost Tonganoxic within the mudlump is shown in explanatory tracing on right.

hold for examples of abundant fusulinid concentrations in Douglas and adjacent rocks. Examples other than the Westphalia Limestone include the uppermost bed of Nebraska exposures of the South Bend Limestone (Pl. 10) and lenticular limestone beds in the Lawrence Formation (Pl. 41). Where fusulinids occur in such abundance to have formed the rock framework, the possibility that the deposit represents a transported accumulation should not be overlooked.

The local areas of absence^{1/} within the areas of essential continuity of the various limestones studied may have resulted from sublevation. However, in cases other than the Westphalia Limestone, outcrop study did not make this possibility a probability and it should be stressed that in an attempt to identify areas of local absence of limestone members in the subsurface some error is inevitable.

Other areas of seafloor erosion that may be wholly the result of either shore zone erosion by channeled currents or intrabasinal shoaling or a combination of one of these mechanisms with sublevation are inferred by the cross stratification developed locally in some of the limestones (e.g., the Iatan (Nehawka) Limestone of Nebraska as shown on Pl. 18 and the upper part of the Haskell Limestone as noted on p. 131). Cross bedding in Douglas Group limestones is associated with only two limestone types, grainstones and packstones.

Some of the fossil zones, such as the abundant to profuse molluscan concentration developed as lenses in the uppermost part of the Vinland Shale in Kansas and Missouri exposures, indicate appreciable bottom

^{1/} See distribution maps in section on Stratigraphy.

currents locally. Commonly, and especially so in Kansas exposures, the most abundant element of this assemblage comprises large numbers of non-paired myalinid pelecypod valves. The single valves are characteristically aligned parallel to stratification in excavated exposures and locally valves in the stable position of convex side upward vastly predominate. In some cases (e.g., Pl. 22B and C), preferential algal growth took place on the convex upper side of the valves before burial. Other examples of current-strewn non-paired valves are known from Douglas rocks (e.g., Pl. 27E).

Evident reworking of the marginal parts of some of the Douglas limestones is just as well ascribed to the action of scavenging, burrowing, and crawling organisms, as to current action. Specific examples are discussed in the section on rock-stratigraphic unit contacts (p. 241).

Magnitude of erosional relief. -- Since the principal sandstone-containing units^{1/} of the Douglas Group have been assumed to represent valley fill deposited by streams (e.g., Lins, 1950), two methods have been used in attempt to ascertain depth of erosion. These methods are: (1) compiling from measured sections in near-by areas the footage of rock removed by erosion; and (2) measuring maximum thickness of the supposed valley fill (Lins, op. cit., p. 119). Using average thicknesses and assuming uniform deposition on perfectly flat surfaces during deposition of the units eroded along the disconformity at base of the Tonganoxie Sandstone in its type area, Lins (ibid.) cited an 80-95 feet estimate of maximum valley erosion.

^{1/} The Tonganoxie Sandstone Member of the Stranger Formation and the Ireland Sandstone Member of Lawrence Formation.

Figure 3 (Lins, op. cit., p. 127) shows a maximum relief per mile of about 15 feet^{1/} along this disconformity. I suggest that use of the first method mentioned above is based on invalid assumptions. Would the dip of eroded strata at the time of erosion have been zero even locally and would deposition of eroded strata have been uniform? Probably not, and the slightest deviation from the horizontal could falsify such an estimate of erosional relief. For example, about 0.15 degree of northwest dip of eroded strata at the time of erosion would essentially eliminate the 15 feet of apparent maximum erosional relief per mile shown by Lins (op. cit.), whereas southeast dip of the same magnitude would approximately double the apparent erosional relief. In addition to pre-erosion dip and degree of uniformity of deposition of eroded strata within the area of erosion, the effect of pre-erosion compaction upon strata eroded is another intangible as regards apparent erosional relief along Douglas disconformities. The second method that has been used to ascertain depth of erosion is based on the assumption that such units as the Tonganoxie Sandstone are composed of stream valley fill (Lins, op. cit., p. 119). This assumption cited in a definite tone and used as a foregone conclusion has no basis. The possibility that any part of the Tonganoxie is of non-marine origin is equivocal and largely subjective (see discussion of sandstones in section on environments of deposition).

Regarding the hypothesis of Lins (op. cit., p. 129-130) that the Ireland Sandstone rests disconformably on the Tonganoxie Sandstone in parts of Leavenworth County, Kansas, Sanders (1959, p. 145) believed such

^{1/} Between sections 2 and 3, Figure 3B.

a stratigraphic development improbable at the only locality which Lins discussed. Evidence cited by Lins includes: (1) 100- to 150-foot locally developed thicknesses of predominantly sandstone section; (2) reported absence of Haskell Limestone where sandstone occupies the interval in which the Upper Sibley coal should crop out if present; and (3) presence of what is reported as the lower part of the Ireland Sandstone at what is reported as the same stratigraphic level as shales of the Tonganoxie Sandstone. Lins (op. cit., p. 130) stated:

Absence of the Haskell limestone and the Upper Sibley coal in near-by areas and the presence of sandstone at the same stratigraphic horizon definitely identify the sandstone as Ireland. This points to deep post-Haskell erosion prior to deposition of Ireland sandstone.

Sanders (op. cit.) reported that little or no sandstone is present within the Ireland in the subsurface of western Leavenworth County and found no evidence for a thick sandstone part of the Ireland near the locality referred to by Lins (along north line sec. 36, T. 10 S., R. 22 E.). The first and second conditions cited by Lins as evidence for presence of Ireland Sandstone obtain in the Tonganoxie-Vinland part of section locally, but the Haskell Limestone is present (e.g., Fig. 15). The third condition cited by Lins is equally inconclusive. What Lins meant by stratigraphic level (op. cit., p. 129) is unclear. However, it is entirely clear that he presented no evidence of truncation of Robbins Shale, Haskell Limestone, Vinland Shale, Westphalia Limestone, and the upper part of the Tonganoxie Sandstone by disconformity at base of the Ireland Sandstone. Such truncation has not been observed in Leavenworth County, Kansas. Where Lins used the words stratigraphic level, he may have meant topographic elevation.

At some localities in Leavenworth County, top of the sandstone mass of the Tonganoxie-Vinland part of the Stranger Formation rises as much as 20 feet above outcrops of the Haskell Limestone no more than one mile to the west-northwest. Such field relations are the result of normal dips in Leavenworth County. Observations made during this study are in complete agreement with McLaren (1958, p. 40) and Sanders (1959, p. 145-146)-- there is no evidence either on the surface or in the subsurface, of disconformity at the base of the Ireland Sandstone in Leavenworth County, Kansas.

The maximum reported amount of stratigraphic relief along any of the disconformities within the Douglas Group is about 150 feet (O'Connor, 1960, p. 35). O'Connor (*ibid.*) also reported about 100 feet of erosional relief in an 0.5- to 1-mile distance. O'Connor (*op. cit.*) believed that erosion along the disconformity at base of the Ireland Sandstone in southeastern Douglas County extends as low stratigraphically as the Weston Shale. This disconformity can be shown to extend as low as the Vinland Shale Member of the Stranger Formation in local exposures in southeastern Douglas County and in Franklin County (Ball and others, 1963, p. 28). However, insofar as I know, there are no exposures in which the pre-Ireland disconformity clearly overlaps the entire Vinland Shale, the Westphalia Limestone, and the Tonganoxie Sandstone within the area of study. This does not preclude O'Connor's interpretation, which is based upon projecting identification of the Ireland Sandstone eastward and northeastward from known Ireland exposures to other sandstone exposures in areas where stratigraphic identification of the sandstone is problematical and upon interpretation of shallow subsurface data. Some of the sandstone mapped as the

Ireland Member of the Lawrence Formation in easternmost (R. 21 E.) Douglas County (O'Connor, op. cit., Pl. 1), sandstone questionably mapped as Ireland in northeastermost Franklin County (Ball and others, 1963, Pl. 1), and the Johnson County exposures of Douglas sandstone^{1/} could just as well be regarded the Tonganoxie Member of the Stranger Formation. The sandstone exposures in question overlie the Weston Shale Member of the Stranger Formation and, at least in part, have been previously regarded as the Tonganoxie (Newell, 1935). However, absence of the Westphalia and the Haskell Limestone, both of which are younger stratigraphically than the Tonganoxie but older than the Ireland, precludes unequivocal settlement of the question. If both the Tonganoxie and Ireland Sandstones are developed in southeastern Douglas County and if the Tonganoxie was correctly identified by Newell (op. cit.) in Johnson County, the amount of stratigraphic relief reported by O'Connor (op. cit.) is excessive. As mentioned above, O'Connor may be entirely correct and the maximum amount of stratigraphic relief developed within Douglas rocks may be at the base of the Ireland Sandstone in southeastern Douglas and in southwestern Johnson Counties, Kansas.

It is extremely difficult to estimate erosional relief along disconformities within Douglas rocks. Some basic aspects, such as shape, of those Douglas sandstones whose bases are locally disconformable and the depositional environments of most of the sandstones are so poorly known that attempted estimates should not involve unfounded assumptions.

An extreme case of the planar character of one of the Douglas disconformities

^{1/} Regarded by O'Connor (personal communication, 1963) as the Ireland Member of the Lawrence Formation.

in a particular area has been discussed (p. 87). No more than about a 50-foot estimated maximum of stratigraphic relief in a 4-mile distance along a single disconformity is clearly inferred, even though not proven, in more or less connected exposures along Missouri River bluffs between Leavenworth and Lansing, Leavenworth County, Kansas. The amount of stratigraphic relief developed along Douglas disconformities is generally no more than the structural relief shown by normal dips, 10 to 30 feet per mile, of strata within the study area. Locally (e.g., Pl. 51A) about 15 feet of apparently erosional relief is developed in a lateral distance of about 50 feet.

Probable areal extent of Douglas disconformities. -- Excepting the restricted distribution of the Westphalia Limestone (Fig. 19), which is regarded as largely the result of sublevation (p. 260) and non-deposition (p. 109), the discussion that follows pertains only to those disconformities developed locally below sandstones or conglomerates. Because of the paucity of cores, the types of subsurface data available for study do not allow too much speculation about the extent of sublevated areas. That most of the physically evident erosion surfaces are associated with sandstones or conglomerates in southernmost Missouri (Platte and Clay Counties), Kansas, and Oklahoma exposures has already been stressed in various parts of the report. Surface areas of marked erosion overlap geographically with areas of marked facies change (p. 228). Inverse thickness relationships between predominantly sandstone parts of the Douglas and underlying predominantly shale parts as well as the non-uniform

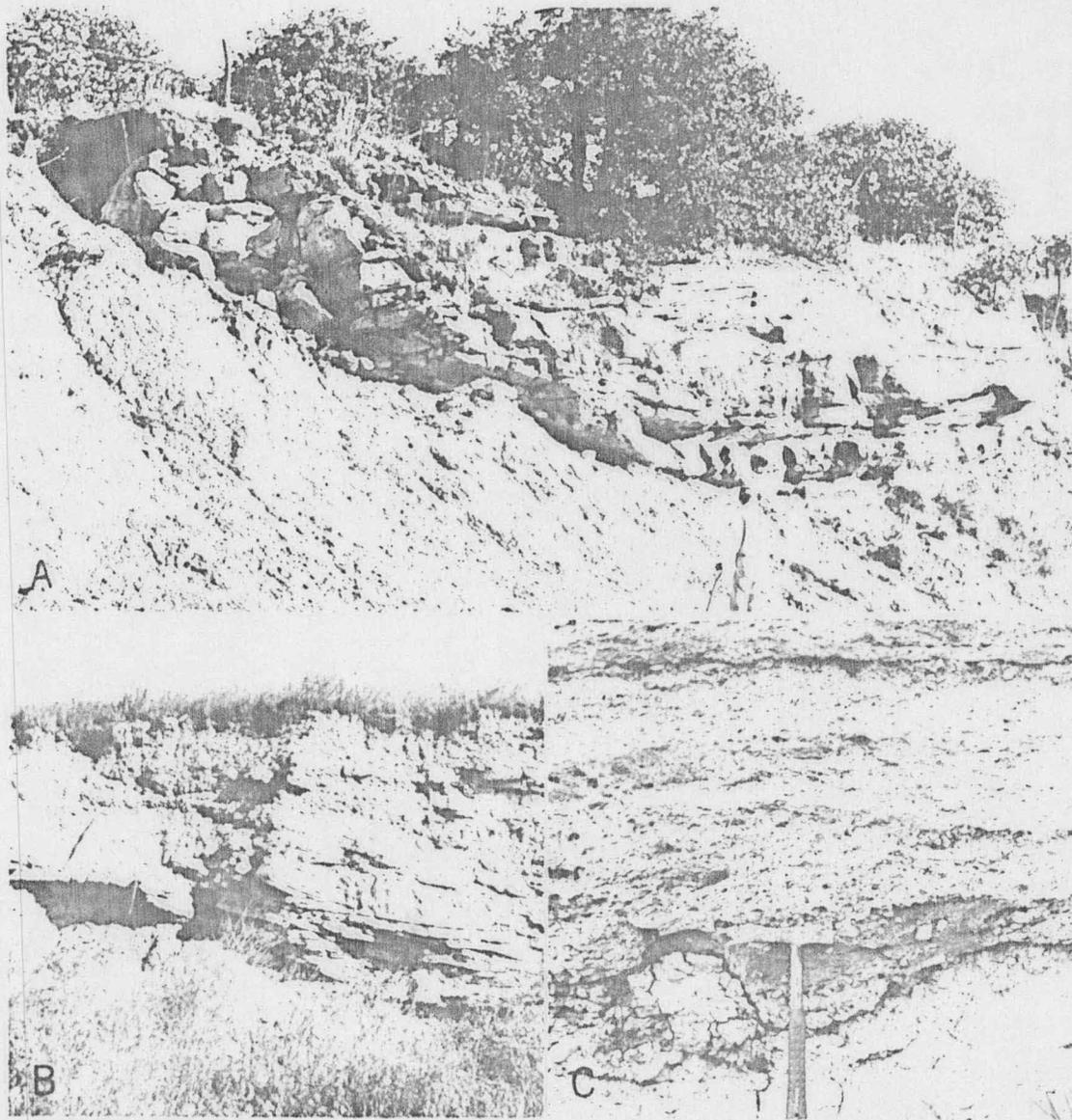


PLATE 51.-- Parts of local disconformities developed in Douglas rocks and in the Vamoosa Formation. A, Ireland Sandstone Member of the Stranger Formation near SW corner sec. 9, T. 28 S., R. 14 E., Wilson County, Kansas. B, Jonesburg Sandstone Member of Vamoosa Formation near center south line sec. 16, T. 25 N., R. 10 E., Osage County, Oklahoma. C, Vamoosa Formation near center south line SW $\frac{1}{4}$ sec. 1, T. 14 N., R. 8 E., Creek County, Oklahoma.

distribution of sandstone in the shallow subsurface^{1/} may be interpreted as evidence for disconformities or facies changes or both (see Plates 2 to 9 in pocket). The remarkable persistence of and the remarkably consistent thickness of individual thin units within the northwestern part^{2/} of the study area as exemplified by Plate 3 (in pocket) seemingly preclude the possibility of marked erosion surfaces in that area. Near lack of sandstone in this northwestern part of the study area (p. 240), which includes the area of shale-limestone facies (Fig. 12), does not suggest currents sufficiently strong to transport quartz sand into this area. If the general sedimentational framework that prevailed during Douglas sedimentation is correctly interpreted (p. 222), it is most unlikely that any appreciable erosional disconformities are developed in this northwestern part of the study area, which I regard as a more centrally located part of the Douglas sedimentary basin. The general distribution of rock types as well as the known areas of marked erosion and marked facies changes (p. 228) indicate that numerous local disconformities within the Douglas and adjacent parts of the section were persistently developed within the southern and southeastern parts of the study area and are largely lacking from the northern and northwestern parts of the study area. The number of physically evident erosion surfaces within Douglas and adjacent parts of the section increases southward and to a lesser degree southeastward.

^{1/}Area to south and southeast of that in which Douglas Group exceeds 150 feet in thickness (Fig. 10).

^{2/}That part of the study area in which the Douglas Group is less than 100 feet thick (Fig. 10).

Environments of Deposition

Limestones. -- All Douglas Group limestones are believed to be marine deposits. An attempt is made in the following discussion to differentiate between limestones deposited in relatively near-shore environs and those deposited relatively far from shore. It is not held that relative distance from shore necessarily implies marked differences in relative water depths. Inferences pertaining to depositional sites are drawn from such criteria as the distribution of limestones and specific rock types within limestones in relation to the sedimentational framework described on pages 222 to 240 .

The regional southward wedge outs of the seven limestones studied; the regional southeastward wedge outs of the Iatan and Cass Limestones; and the partial southeastward wedge out of the Amazonia Limestone (p. 233) are believed to be largely the result of marine onlap. That these wedge outs were conditioned by relative proximity to southern and southeastern shores of the Douglas sea is indicated by regional distribution of terrigenous detritus maxima, by regional facies changes coincident with the areas of wedge out, and by the geographic overlap between areas of marked erosion (p. 270). The regional northward and northwestward convergence of limestone-shale member contacts is believed to be the result of more nearly complete terrigenous detritus filling of the basin at any one stand of the sea and greater subsidence in the southern and southeastern basin-marginal areas. Therefore, the Douglas section on the whole thickens rather than thins in the southward and southeastward directions of regional wedge out of the limestones. The cumulative effects of erosion have caused southward thinning rather than thickening in the east-central Oklahoma area.

In certain cases, it is possible to postulate that lime deposition extended either relatively close to or relatively far from shore and to ascertain what rock types developed under either near-shore or far-from-shore conditions. Moore (1929, p. 484) pointed out that some Pennsylvanian lime deposition may have occurred almost to the shore line. The lenses of ostracode coaly lime mudstone (p. 105 and Pl. 21) of the Westphalia Limestone are good evidence of this. It seems probable that the packstone and grainstone facies of Douglas limestones (e.g., Pl. 20, Pl. 26, Pl. 18 in part, and Pl. 34 in part) originated as calcareous sands and were in greater part deposited in relatively near-shore environs. Packstones and grainstones are the only limestone facies with which cross stratification is associated (p. 262) and with one exception, Plate 18D, are developed in the principal outcrop area from DeKalb County, Missouri, southwestward. On the other hand, at least in some cases (e.g., Pl. 34), potential lime mud deposition was largely swamped by land-derived clastics. Gilluly (1949, p. 579) stated:

. . . a limestone section cannot represent the maximum deposit of its time span.

It seems probable that the proposed correlation of the 14 feet-thick Cass Limestone of Nebraska with almost twice as much section, which is largely clayey shale, in northwest Missouri and with an unknown thickness of Robbins Shale in Kansas is essentially correct. At least the lower two-thirds of the Robbins Shale is believed to be marine throughout the study area. Therefore, the Cass Limestone of Nebraska, at least in greater part, accumulated in an area relatively distant from southern and southeastern shore lines. The Cass Limestone contains largely mixed-fossil

lime wackestone and mixed-fossil lime mudstone (Pl. 32). It certainly does not follow that all lime wackestones or lime mudstones were necessarily deposited far from shore. Along a very low coast, at times when neither wave erosion nor sediment-laden streams supplied much land detritus, finely-laminated or otherwise bedded lime muds could accumulate almost to the shore line. The ostracode coaly lime mudstone facies of the Westphalia Limestone is an already proposed example.

Depths of deposition of individual limestones within the northern Mid-continent Pennsylvanian remains an enigma. Moore (1929) discussed numerous lines of evidence concerning probable depths of Pennsylvanian epicontinental seas and regarding limestones stated (op. cit., p. 473):

. . . the limestones were deposited in moderately shallow and very shallow waters, that is, at depths probably not more than 300 feet or less than 10 feet. There is no known indication of deep waters, that is, deeper than 600 feet.

Some geologists have attempted to ascertain specific depths of deposition for particular limestone types or particular named limestones (e.g., Elias, 1937; Imbrie and others, 1959; and Laporte, 1962). Elias (op. cit., p. 428) thought that fusulinids were benthonic and adapted to 160 to 180 feet depths. Laporte (op. cit., p. 541) thought that fusulinids were more typical of shallow water-- perhaps depths closer to 50 feet than 160-180 as suggested by Elias. Imbrie and others (op. cit., p. 78) thought that the fusulinid limestone they studied, that is, the Cottonwood Limestone reflected deposition in turbulent water probably less than 30 feet deep. Too much emphasis has been placed on the mere presence of fusulinids as an index of depositional depth. In some cases, fusulinids were deposited in large numbers as part of current-laid calcareous sandstones (p. 260)

and these deposits do not reflect the fusulinid habitat. Laporte (op. cit., p. 530) noted scour and fill structure, broken and worn fusulinids, and associated Osagia in the fusulinid facies he studied. The fusulinid facies of the Cottonwood Limestone may be largely a current-laid deposit.

Since some fusulinid-bearing limestones were transported accumulations and since the ecologic controls for fusulinids are poorly known and probably varied with species, it seems to me that generalities regarding the depositional depth of fusulinid-bearing rocks are unwarranted. At present, attempts to be more specific than Moore (quoted above) concerning depths of deposition of Pennsylvanian limestones are largely subjective. The use of limestone textures in interpretation of depositional depths has been proposed (e.g., Wanless and others, 1957) and may lead to greater precision. However, Ham and Pray (1962, p. 8-9) pointed out the need for better criteria upon which to base interpretation of relative "energy" levels involved in the transportation of carbonate particles. Such criteria are basic to the use of depositional textures in interpretation of water depths.

Shales. -- The predominantly greenish-gray or bluish-gray clayey shales of the Douglas Group, that is, the Weston, Vinland, and Robbins Shales, characteristically contain marine megafossils and, in the few samples that have been washed, generally contain marine microfossils also. These shale members, considered regionally, are remarkably uniform lithologically throughout broad areas even though they contain prominent fossiliferous and apparently non-fossiliferous quartzose sandstone lenses locally. The quartzose sandstones are developed within the principal area of outcrops--locally from Leavenworth County, Kansas southward in the Vinland;

locally from Anderson County, Kansas southward in the Robbins; and locally in the Weston in southernmost Kansas and northernmost Oklahoma. These shale members are judged to be largely, if not exclusively, marine deposits.

The prolific fauna developed locally in the upper part of the Weston Shale from Platte County, Missouri, to Douglas County, Kansas, is largely concentrated in an approximately 0.5-foot thick zone in some exposures. Fossils are crowded into this bed in such profusion that it is classed as an argillaceous limestone, which weathers to a rubble of fossils. This accumulation of fossils was not observed north of Platte County, Missouri, south of Douglas County, Kansas, nor in Nebraska exposures. The disposition of individual shells and shell fragments in fresh exposures indicates that the fossils were in contact when deposited and the excellent preservation of many fragile shells, such as chonetid brachial valves, precludes this thin fossil concentration having undergone much post-depositional compaction. These fossils apparently formed an interconnected framework at the time of deposition and the crowded aspect of the thin zone is apparently original. Most of the fossils represent benthos and the extraordinary profusion and variety suggest that this accumulation was neither the population density at the site of deposition nor a grouping of forms compatible in a single environment. It seems probable that this thin profusion of fossils is in part a transported accumulation even though the over-all state of preservation does not indicate either long-distance or rigorous transport.

The only other Douglas shale fossil accumulations that are both equally profuse and equally varied are disposed as lenses in the upper part of the Vinland Shale, the lower part of the Robbins Shale, and the upper part of

The molluscan fauna of the Vinland Shale is described on pages 114 to 115 and some aspects of this fauna are shown on Plates 22 and 23. Faunas of the lower part of the Robbins Shale in Kansas and Nebraska exposures are compared in Table 4. Myalinid clams are the keynote group represented in the Vinland molluscan fauna (p. 115) of Missouri, Kansas, and Oklahoma exposures, whereas Derbyia crassa (Pl. 34 in pocket) is the keynote form of the brachiopodal fauna of the uppermost part of the Tonganoxie-Vinland Shale of Nebraska. Although these faunas may not be exactly correlative, the fact remains that no myalinids or abundant mollusks of any kind were observed in the Nebraska fauna. The Robbins Shale faunas are probably not exactly correlative even though faunas of the basal 0.5 foot of section immediately above the Haskell Limestone are compared in Table 4, localities 1 and 4. Nonetheless, no mollusks were recorded in the Nebraska sample, whereas mollusks are either an important or the predominant element of the Kansas samples. The extraordinarily large number of a single species (Crurithyris planoconvexa) in the Nebraska sample indicates some sort of inhospitability of environment and the Nebraska fauna is much less varied than the Kansas faunas. Profuse pelecypods and gastropods in Douglas shales are known only from Missouri, Kansas, and Oklahoma exposures and, as yet, there is no evidence that these molluscan lenses extend an appreciable distance northwest^{1/} of these areas of outcrops; insofar as correlations are establishable, corresponding faunas where developed in Nebraska exposures are brachiopodal.

^{1/}Detailed subsurface data are not abundant and, at best, only generally confirmative.

Newell (1942, p. 16-19) discussed the probable ecologic significance of Paleozoic Mytilacea and believed that the myalinas preferred the shallow, turbid waters of the shore zone. Students of the northern Midcontinent Pennsylvanian are apparently agreed that gastropods and pelecypods generally inhabited nearer-shore environments than brachiopods. This belief, the distribution of gastropods and pelecypods within Douglas shales, and the general aspects of sedimentational framework described above (p. 222 to 240) are corroborative. The brachiopod-bearing shales in Nebraska exposures are nearly identical lithologically to the Missouri-Kansas-Oklahoma, mollusk-bearing shales except in the lack of local quartz sandstone lenses. Whatever relative difference in water depths that might be suspected as corollary with relative distance from shore does not seem to have been sufficient to impart any marked differences in sediment type.

Grayish-black fissile to platy shale was observed at only one stratigraphic horizon within the Douglas Group, that is, in the basal foot of the Robbins Shale (p. 139). Grayish-black shale is intercalated with the Upper Sibley coal bed locally (p. 297), but is not a rock type identical to the black shales so characteristic of many Pennsylvanian limestone formations. The grayish-black, fissile to platy shale in the basal part of the Robbins crops out in numerous Buchanan and DeKalb Counties, Missouri exposures (e.g., selected sections 23 and 24 in appendix) but is known from outcrops farther south only in Wilson County, Kansas. However, this black fissile shale is present in all Nebraska exposures of the Little Pawnee Shale studied (e.g., selected sections 1 and 3) and is apparently quite widespread in the subsurface (Fig. 34). I believe that essential continuity of a black fissile component of the shale between the Haskell

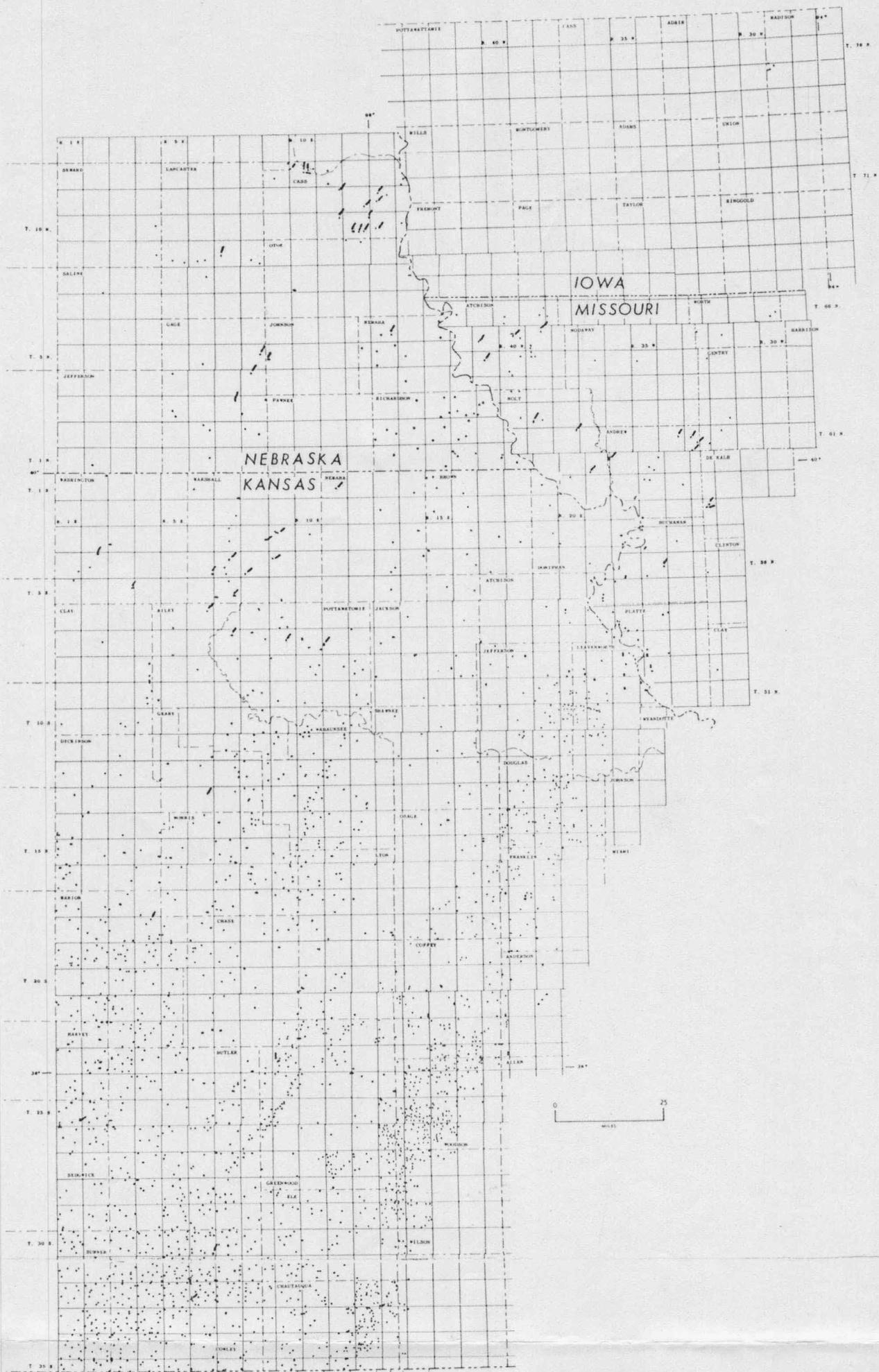


FIGURE 34.-- Plot of wells and sections (short black dashes) showing widespread yet discontinuous extent of black fissile shale in lowermost foot of the Robbins Shale Member of the Lawrence Formation. The subsurface of southwestern Iowa was not studied. See Figure 1 for qualification of control points. The vast majority of subsurface control points represent electric logs and have no significance regarding presence or absence of black fissile shale.

and Cass Limestones will ultimately be shown within the area of essential continuity of the Cass (Fig. 23). The phosphatic nodule zone within the basal mollusk-bearing foot of the Robbins Shale in numerous Kansas exposures (p. 139) is regarded as in part correlative with black fissile shale, which is best developed to the north and northwest (Pl. 34 and Fig. 29).

Association of this black fissile shale with marine strata, its wide distribution, even though thin and not perfectly continuous throughout its extent, an included meager marine fauna of at least conodonts and inarticulate brachiopods, and lateral gradation into mollusk- and fossiliferous phosphatic nodule-bearing greenish gray shale demand a marine origin. The amount of humus muck necessary for such a deposit makes plants the logical source material. Such plants were probably largely marine types since it seems unlikely that a large volume of land-derived plants were deposited on an extensive marine surface of sedimentation. Growth of the plants and depths of deposition apparently took place within moderately shallow water, that is, within the photic zone. Moore (1929, p. 465) pointed out the shortcomings of a moderately deep-water hypothesis as pertains to black fissile shales of the Kansas Pennsylvanian and suggested (*ibid.*):

. . . stagnation not unlike that of the coal swamps and quiet, undisturbed sedimentation of a humus muck. Extremely shallow water, with sunlight promoting abundant plant growth and aiding in partial decay, with too little depth for circulation and effective wave or tidal agitation, seem to offer the environment required.

Moore's hypothesis (*op. cit.*) offers a reasonable explanation for the origin of the basal Robbins black shale. This black fissile shale may be correlative

with the phosphatic nodule zone described by Miller and Swineford (1957) and, if so, the hypotheses of Moore (op. cit.) and Miller and Swineford (op. cit.) substantiate each other. Miller and Swineford (op. cit., p. 2012) stated:

The former regional picture is reconstructed as a warm, humid, semitropical area, with low-lying land areas nearby. The sea floor was nearly flat and only shallowly covered with sea water that lacked strong currents of overturning at the time the nodules formed.

If the interpretation of sedimentational framework (p. 222 to p. 240) is correct, the phosphatic nodules accumulated in a basin-marginal area on the southeast and the black, fissile shale in a basinward area to the northwest. Upper reaches of the sea were probably better aerated than the lower reaches so as to allow for the pelagic (Miller and Swineford, op. cit., p. 2030) fauna of the phosphatic nodules.

The characteristically silty and sandy shales of the Douglas Group are best developed in the Tonganoxie Member of the Stranger Formation and the Ireland Member of the Lawrence Formation along the principal area of outcrops in Missouri, Kansas, and Oklahoma and in the shallow subsurface. These shales commonly contain land-derived plants and locally contain marine invertebrates. Almost no investigation for microfauna in these shales has been attempted. Insofar as is known to me, the only records of such attempts are those of Patterson (1933) and the few washings done during this study--knowledge as regards microfauna is seriously inadequate. Considered regionally, silty and sandy shales of the Douglas record an immense volume of sediment. Like the sandstones into which they characteristically grade both vertically and laterally, these shales are probably deposits of mixed environments.

Grayish-red mudstones. -- This rock type is developed locally in the Tonganoxie-Vinland Shale of Missouri and Nebraska exposures and the Weston-Vinland Shale of Nebraska exposures. Grayish-red mudstone within the Wathena Shale is surprisingly extensive (p.163 and Fig. 27) and is one of the best stratigraphic markers within the Douglas Group. This stratigraphic marker contains sparse marine invertebrates locally. Patterson (1933) reported both marine and fresh-water forms from one locality in Douglas County, Kansas. However, on the whole this unit is apparently^{1/}very poorly fossiliferous. Widespread extent of the grayish-red mudstone of the Wathena Shale indicates that it is part of a sheet-like marine deposit. Consistent stratigraphic position relative to marker limestones both above (Toronto Limestone) and below (Amazonia Limestone) implies that the red coloration is either primary or penecontemporaneous. Grayish-red mudstone, like black fissile shale, did not form under normal conditions and apparently developed under conditions inhospitable to abundant life.

Conglomerates. -- Two types of limestone conglomerate, one quartzose and the other calcareous (Pl. 52), are common and volumetrically important rocks in the Douglas Group and are also commonly developed in local areas where, due to absence of the lower member of the overlying Oread Limestone, the base of the latter is defined by limestone conglomerate at the base of the Snyderville Shale Member. These conglomerates occur in close association, both areally and stratigraphically, with the limestone members

^{1/} Grayish-red mudstones within the Douglas Group have not been extensively investigated for microfossils.

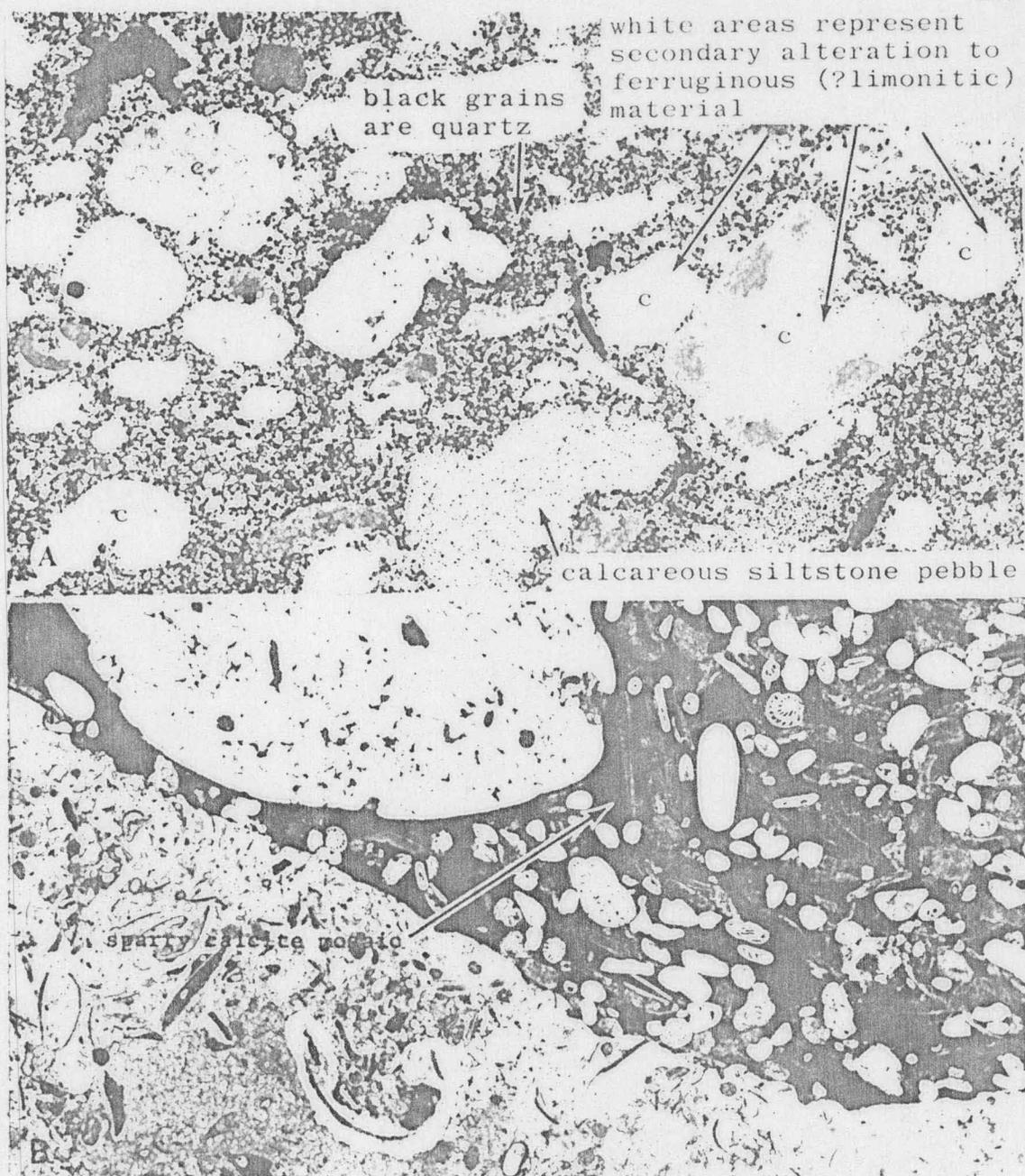


PLATE 52.-- Types of limestone conglomerate developed within Douglas rocks. Kansas samples. A, Quartzose type sampled near center west line NW $\frac{1}{4}$ sec. 8, T. 11 S., R. 23 E., Wyandotte County. B, Calcareous type sampled in NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, T. 9 S., R. 23 E., Leavenworth County. Negative prints of thin sections (X4.0). Orientation as shown. Crinoid remains (shown by c designations in A) have undergone extensive secondary alteration.

from which the gravels were derived. The Iatan Limestone and the limestone members of the Stanton Limestone were principal source rocks for conglomerate of the Tonganoxie Sandstone; the Amazonia and Toronto Limestones for conglomerate of the Snyderville Shale. The conglomerates are characteristically basal to the units with which they are classified and are not scattered promiscuously throughout overlying strata. General aspects of the limestone conglomerate types are listed in Table 5.

| Quartzose Conglomerate | Calcareous Conglomerate |
|---|---|
| 1. Coarse fraction-limestone granules and pebbles, sparse to common mudstone and shale pebbles, coarse silt- to medium sand-size quartz particles, mica flakes, fragments of invertebrate fossils and plant material common | 1. Coarse fraction-limestone, sand, granules, pebbles, and cobbles; mudstone and shale pebbles sparse; quartz particles and mica flakes extremely sparse; invertebrate fossils common to abundant and sparse plant material |
| 2. Matrix calcareous or siliceous | 2. Matrix calcareous |
| 3. Very thin to very thick, irregular, ill-defined bedding; massive splitting. | 3. Laminated to thin-bedded; well-defined even to irregular and cross bedding common; platy to slabby splitting |
| 4. Overlying rock types - siltstone, and sandstone | 4. Overlying rock types - shale, mudstone and siltstone |
| 5. Highly weathered and ferruginous | 5. Relatively unweathered |
| 6. Locally developed and basal to Rock Lake, Tonganoxie, Vinland, Ireland, and Snyderville Members. | 6. Locally developed and basal to Tonganoxie and Snyderville Members. |

Table 5.-- General characteristics of conglomerates of the Douglas Group and contiguous formations.

Four exposures that are considered representative of Douglas Group conglomerates are discussed in detail below and illustrated as Figure 35.

The quartzose type of limestone conglomerate is exemplified by the exposure illustrated as Figure 35A. Medium silt- to medium sand-size, subangular to subrounded, elongate to equant quartz particles interstitial to larger grains, as much as approximately 5 percent mica flakes, patchily distributed siliceous cement, extensive solution and recrystallization including partial dolomitization and partial pyritization of some skeletal grains, and the ferruginous (?limontic) character are striking aspects of this rock type. Weathering has largely obliterated the details of original matrix-grain contacts other than those of most of the quartz particles, some of which however display quartz overgrowths. The much more extensive solution and recrystallization of the quartzose conglomerates as compared to the calcareous conglomerates may be attributed to the permeability of the sandstone overlying the former whereas the latter are encased in much less permeable shale.

Parts B, C, and D of Figure 35 are illustrative of exposures of calcareous limestone conglomerates within the Douglas Group and contiguous formations. In each of these exposures, the generally irregular shape of granules, pebbles, and cobbles; the abundance of free, that is, not included in lithiclasts, fossils that form parts of the coarse fraction, and the predominant calcite matrix are definitive features of this conglomerate type.

Random saw cuts of samples taken from the Leavenworth County exposure (Fig. 35B) show the following textural characteristics: (1) numerous apophyses of matrix and sand fraction into larger grains; (2) tear-drop

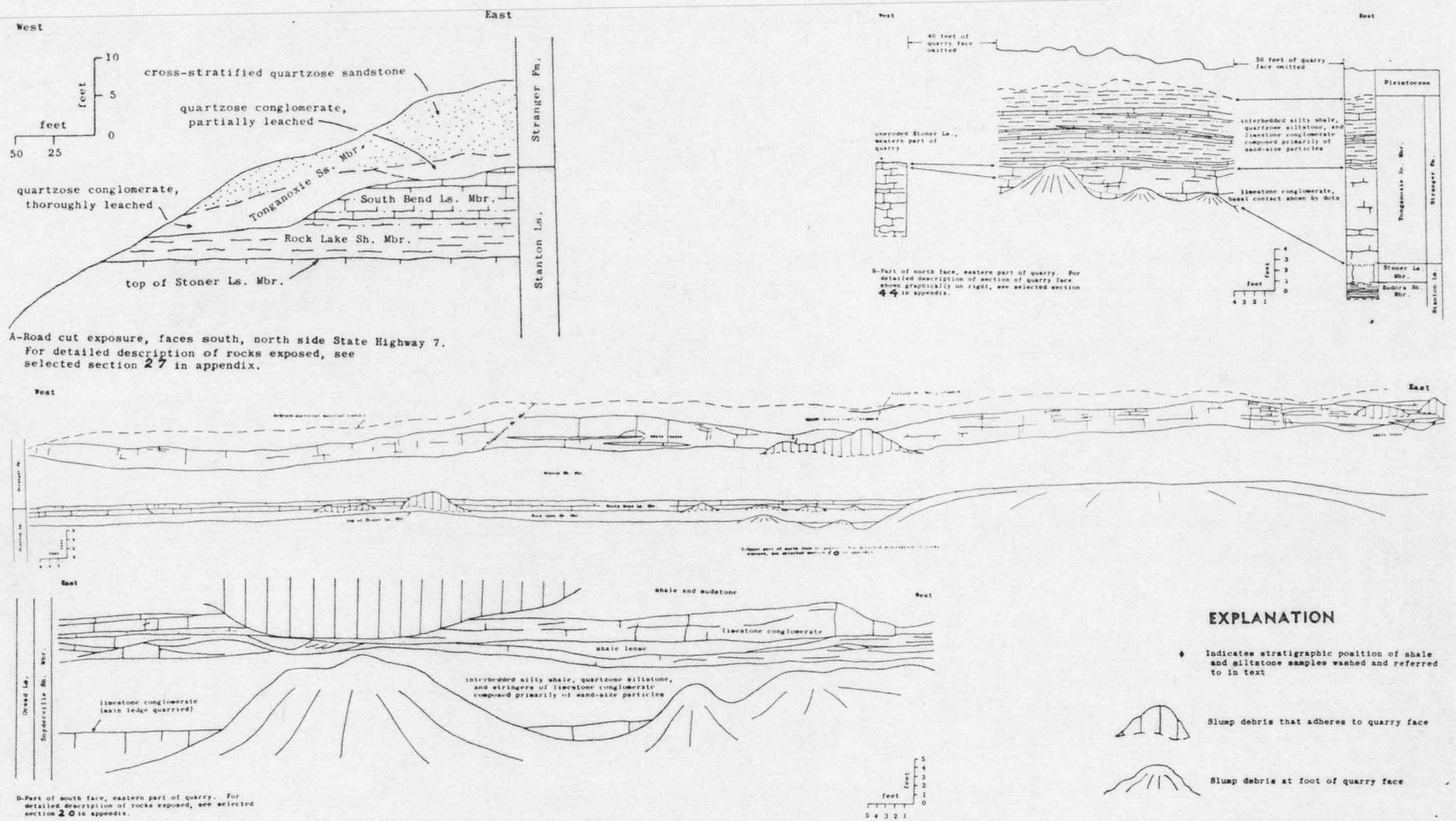


FIGURE 35.-- Diagrammatic sections showing representative stratigraphic relationships of limestone conglomerates within (A, B, and C) and adjacent to (D) Douglas Group rocks. A, Near center west line NW $\frac{1}{2}$ sec. 8, T. 11 S., R. 23 E., Wyandotte County, Kansas. B, NE $\frac{1}{2}$ SE $\frac{1}{2}$ sec. 18, T. 9 S., R. 23 E., Leavenworth County, Kansas. C, Center NE $\frac{1}{2}$ SE $\frac{1}{2}$ sec. 31, T. 53 N., R. 35 W., Platte County, Missouri. D, Near SE corner SW $\frac{1}{2}$ sec. 19, T. 58 N., R. 35 W., Andrew County, Missouri.

shaped parts of larger pebbles that remain attached; and (3) matrix and sand fraction that appears to be included within pebbles (Fig. 36). In the latter case, horizontal and oblique saw cuts show that the inclusion apparent in vertical cuts is not complete but nearly so (Fig. 36C and D).

A sample of coral lime gravel impregnated on the beach in such a way as to preserve natural packing and then reimpregnated in the laboratory and sliced was kindly given to me by R. J. Dunham^{1/} and is shown (Pl. 53A). For comparison, a sample taken at the uneroded Stoner Limestone-limestone conglomerate contact (Fig. 35B) is shown (Pl. 53B). The only textural difference between the lower part of the Recent sample and the Pennsylvanian sample is the impregnation plastic matrix of the former and the sparry calcite matrix of the latter. Above and below a boundary (indicated by arrow on Pl. 53A) that corresponds approximately to mean sea level, interstices of the gravel are free of carbonate sand and partially filled with carbonate sand respectively (R. J. Dunham, written communication, May, 1963).

The limestone conglomerate at the base of the Tonganoxie Sandstone (Fig. 35C) is composed predominantly of closely packed limestone pebbles, granules, and sand in a 30- to 100-micron spar matrix. Very close spacing of the pebbles some of which are fitted like puzzle pieces separated by a thin matrix film and others of which are not separated at all but intergrown along microstylolitic contacts precludes the texture having resulted from normal sedimentary processes. Bizarre-shaped larger pebbles partially wrapped around smaller ones and pebbles flattened between other pebbles occur on many of the blocks slumped to the quarry floor (Pl. 54D).

^{1/}Geologist, Shell Development Company, Houston, Texas.

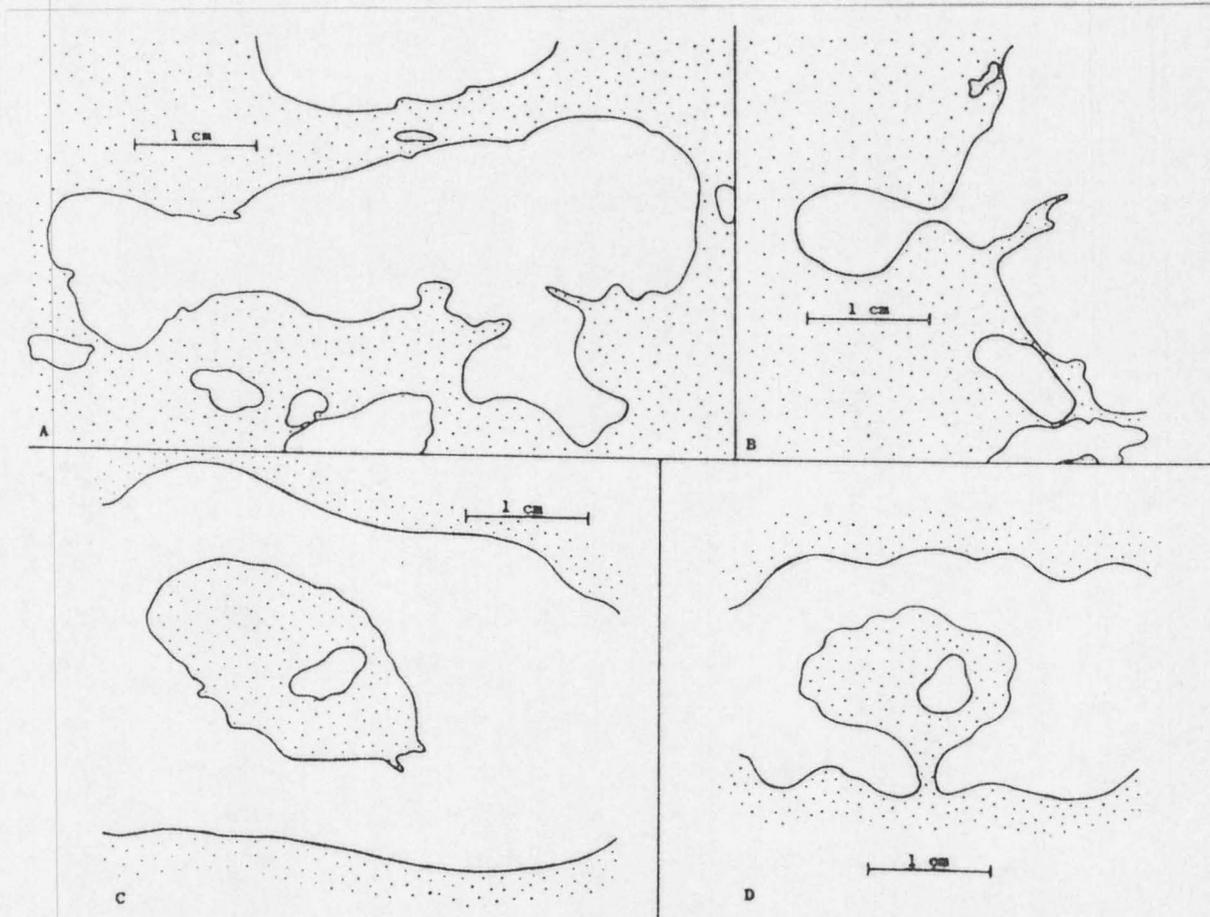


FIGURE 36.-- Tracings of peel prints of samples from limestone conglomerate at base of Tonganoxie Sandstone Member of Stranger Formation. Samples collected in NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, T. 9 S., R. 23 E., Leavenworth County, Kansas. Note bizarre shape of pebbles. Areas of calcareous skeletal and lithiclast sand cemented by spar are stippled. Surfaces represent random saw cuts.

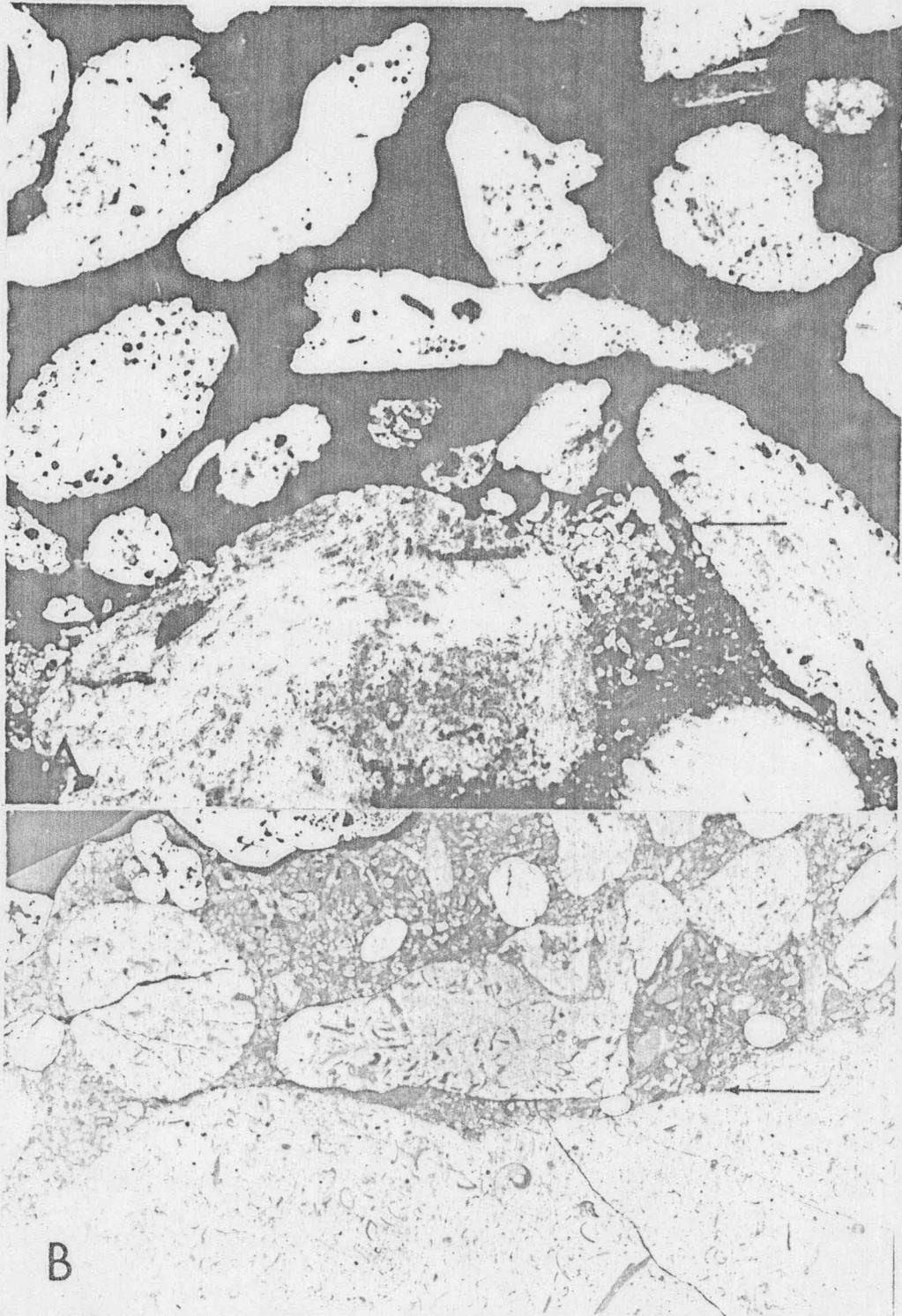


PLATE 53.-- Textural comparison of a Recent coral lime gravel and a Pennsylvanian limestone conglomerate. A, Photograph of slice of coral lime gravel (X1.25) impregnated on beach at Cayo Centro, Cayos Arcas, Campeche Banks, Mexico. Arrow referred to in text. B, Peel print of limestone conglomerate sample (X1.25) collected in NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, T. 9 S., R. 23 E., Leavenworth Co., Kans. (see Fig. 35B). Arrow indicates position of uneroded Stoner Ls.-limestone conglomerate contact. Vertical surfaces, orientation as shown.

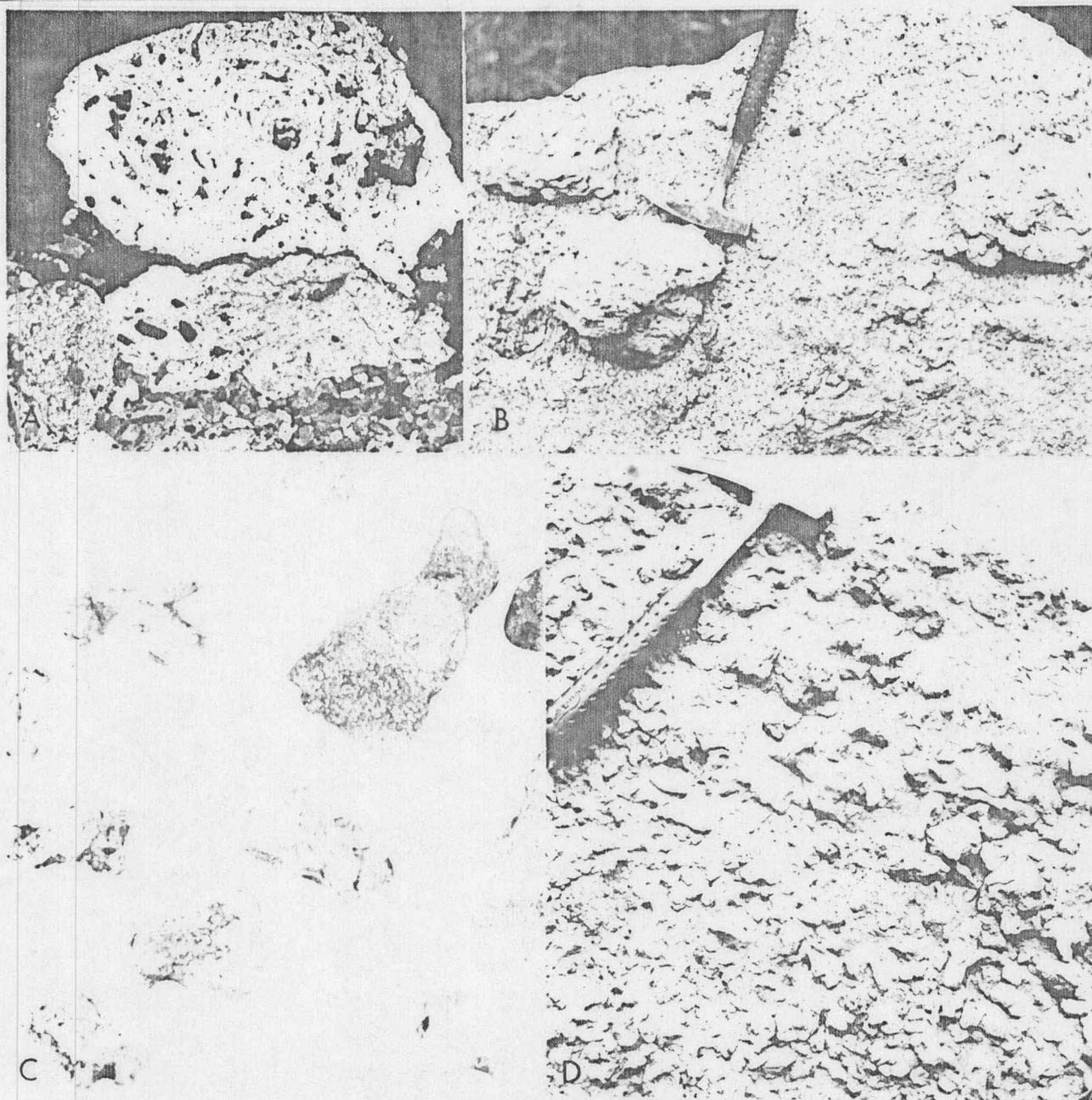


PLATE 54.-- Some aspects of limestone conglomerates within Douglas and adjacent rocks. A, Negative print (X3.5) of transverse section through one of the structures interpreted as trace fossils. See text discussion. White areas are pyrite. B, Boulders in limestone conglomerate. C, Bizarre shape of pebbles from limestone conglomerate. A, B, and C from locality shown as Figure 35D. D, Overly close packing and deformation of limestone pebbles of conglomerate from locality shown as Figure 35C.

Shape, wrapping, flattening, and intergrowth of pebbles in the conglomerate designated the main ledge quarried (Fig. 35D) are analogous (Pl. 54C) to those described above.

The abundance of carbonate sand interstitial to larger grains and extensive sparry calcite cement in the conglomerate exposed in Andrew County, Missouri, is very similar to the Leavenworth County, Kansas, exposure (Fig. 35B). Limestone boulders scattered promiscuously throughout the conglomerate (Pl. 54B) are more common at this exposure and the tubular structures (Pl. 54A) were not observed in the other exposures. The structures are meandering or relatively straight to slightly curved and the largest observed was a meandering type about 2.5 feet long and as much as 0.75 inch in diameter. Ends of the structures do not taper and do not end abruptly along fracture surfaces as if broken up in the conglomerate; rather the ends either merge nebulously with the carbonate sand parts of the conglomerate or bend downward and penetrate the carbonate sand. The tubular structures appear to skirt some pebbles, cut across other pebbles, and pass through still other pebbles (Fig. 37). These structures are apparently not abundant; they were observed on only about one-half dozen blocks of the conglomerate. In thin section, the tubes show gross asymmetrical concentric structure around centers (Pl. 54A) and parts of the structure are pyritized. Exact origin of these structures is of course problematical. They are interpreted here as a trace fossil probably referable to the *Repichnia* (Hantzshel, 1962, p. W181). The vague asymmetrical concentricity seen in thin section is possibly related to the peristaltic movement of some worm through mud and sand and if so, this trace fossil could be a combined feeding and crawling route.

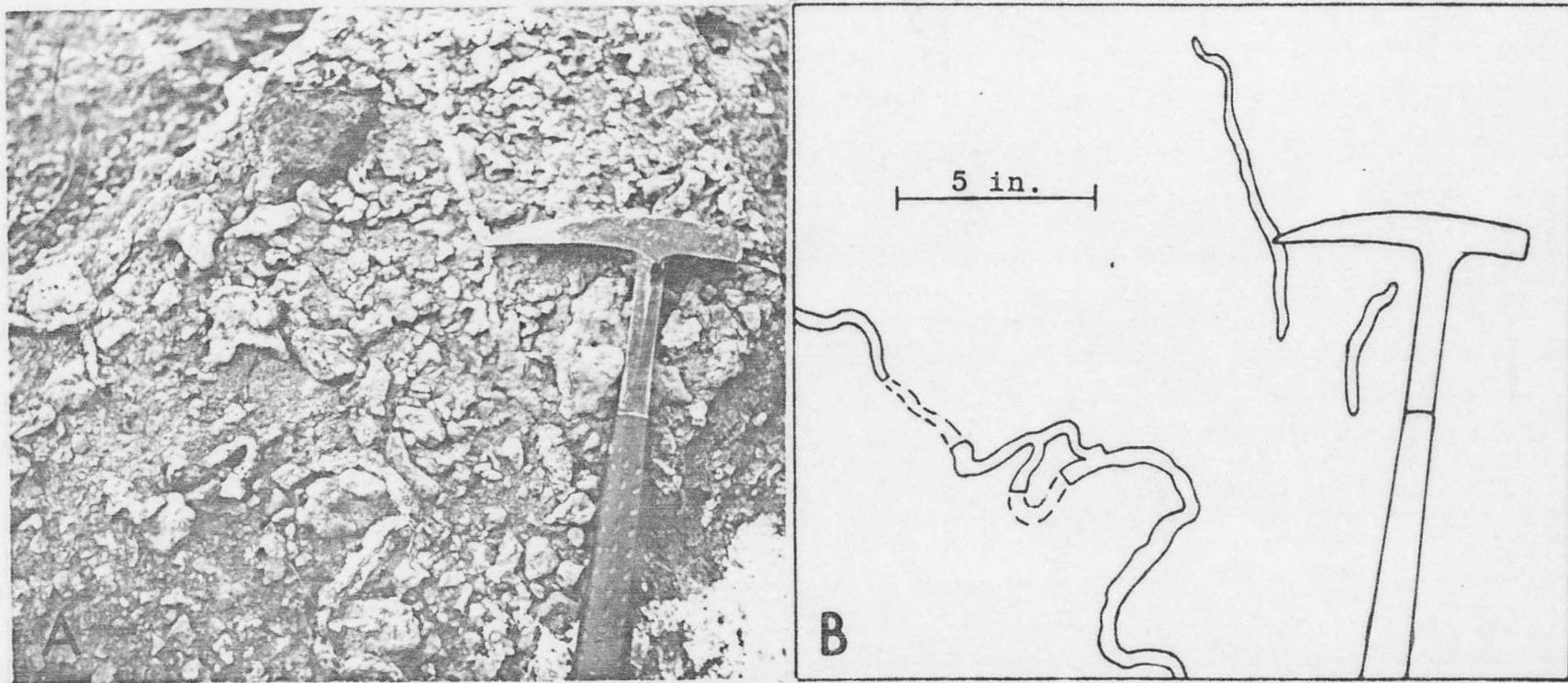


FIGURE 37.-- Structures interpreted as trace fossils (?Repichnia). A, Limestone conglomerate block on floor of quarry near SE corner SW $\frac{1}{4}$ sec. 19, T. 58 N., R. 35 W., Andrew County, Missouri. B, Explanatory tracing from A showing reconstruction of structure at lower left, parts (dashed) of which have been broken off during or since quarrying.

Fossils found within the conglomerates and interbedded shales are listed in Table 6.

| Location | Stratigraphic Placement | Fossils |
|--|--|---|
| 1. Near center west line NW $\frac{1}{4}$ sec. 8, T. 11 S., R. 23 E. Wyandotte Co., Kans. (Fig. A) | In conglomerate | Brachiopods, productid spines, crinoid columnals, echinoid spines, pelecypods, fusulinids, carbonized plant remains. |
| 2. NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, T. 9 S., R. 23 E. Leavenworth Co., Kans. | In conglomerate | Brachiopods, productid spines, echinoid spines, bryozoans, carbonized plant remains. |
| | In washings of shale interbedded with conglomerate, position indicated by diamond in Figure B | <u>Composita</u> and other brachiopods, productid spines, macerated plant debris. |
| 3. Center NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 31, T. 53 N., R. 35 W. Platte Co., Mo. | In conglomerate | Brachiopods, crinoids |
| | In washings of shale interbedded with conglomerate, position indicated by diamond in Figure C | <u>Punctospirifer</u> , <u>Rhipidomella</u> , chonerids, other brachiopods, productid spines, myalinid pelecypods, pyritized gastropods, pyritized nautiloids, <u>Ammodiscus</u> , <u>Ammovertella</u> , ostracodes |
| 4. Near SE corner SW $\frac{1}{4}$ sec. 19, T. 58 N., R. 35 W. Andrew Co., Mo. | In conglomerate | Brachiopods, productid spines, crinoids, echinoid spines, bryozoans, fusulinids, trace fossils (? <u>Repichnia</u>) |
| | In washings of shale interbedded with conglomerate, sample taken from 1 foot to 1.5 feet above the ledge designated the main ledge quarried (Fig. D) | <u>Crurthyris planoconvexa</u> , other brachiopods, productid spines, crinoid columnals and calyx plates, arenaceous foraminifers, ostracodes |

Table 6.-- Fossils in Douglas Group conglomerates and in shales interbedded with the conglomerates.

In all cases noted in Table 6, invertebrate fossils are much more abundant than the plant fossils and, for the most part, the fossils are extensively abraded or fragmented, or both. Excepting the probable trace fossils (Table 6, loc. 4), which are regarded as indigenous, and possibly parts of the faunas washed from the interbedded shales of localities 3 and 4 (Table 6), which show no abrasion nor extensive fragmentation, all of the fossils noted in the conglomerates are either extensively polished or fragmented or both and are reworked.

Grain-size gradation from coarse to fine upward is a general characteristic of the conglomerates even though over-all sorting at a particular horizon is generally poor (see selected sections 10, 20, and 44 in appendix). Continuity of decrease in grain size upward is interrupted by locally developed alternate coarse and fine layers, sets of cross strata, and boulders scattered throughout carbonate sand (Pl. 54B).

It should be stressed that detailed reconstruction of the depositional environment in which these limestone conglomerates accumulated is ultimately thwarted by a poor knowledge of their shape and extent. Original texture of the quartzose type of limestone conglomerate has been extensively altered by secondary solution and recrystallization. Assumedly, a close association both areally and stratigraphically indicates that origin of both the quartzose and the calcareous limestone conglomerates did not differ appreciably. Relative amounts of quartz and relative degrees of weathering are the only marked differences between the conglomerate types (see Table 5) and only the former is an original difference.

The bizarre shape and overly crowded arrangement of grains and the abundance of carbonate sand are the most striking aspects of the calcareous limestone conglomerates. Several authors have realized that the intergranular contacts common in some carbonate rocks could not be the result of movement into position during sedimentation. Murray (1960, p. 66) stated:

Indeed most particulate carbonate rocks with little mud exhibit a particle fit that is much tighter than could possibly be produced by simple sedimentation.

He attributes the interlocking texture to pressure solution. Hardman (1961,

p. 27) has called limestones of similar texture quasi-breccias and stated (*ibid.*):

This close-fitting or dove-tailing shows clearly that the limestone fragments could not have been moved into position . . .

He believes that the quasi-brecciation of the limestones he studied was due to desiccation soon after deposition of lime mud and possibly before its complete consolidation. The types of contacts observed in oolitic limestones are illustrated by Kahle (1962, Fig. 2, p. 9). He considers the type of contact represented by his Figure 2C, where one ooid is partially wrapped around another, the result of plastic deformation and judges that the microstylolitic or sutured contact shown as his Figure 2E resulted from pressure solution.

Pebbles showing incipient solution rims and pebbles intergrown along microstylolitic contacts are common in the Douglas Group calcareous limestone conglomerates, as are pebbles partially wrapped around or flattened between one another (see Fig. 38). The bizarre shape and overly close fit of the grains (see Fig. 36 and Pl. 54C and D) is the result of plastic deformation of carbonate, not all of which was totally consolidated when reworked, and pressure solution after consolidation. If the trace fossils described above are correctly interpreted, some of the pebbles were probably mudballs when incorporated in the conglomerate (see Pl. 54A and Fig. 37).

Accumulation of abundant lime sand seems to be largely restricted to marine environments and rarely occurs as a nonmarine deposit. Erosion of limestone outcrops in a fluvial environment must result in sand-size

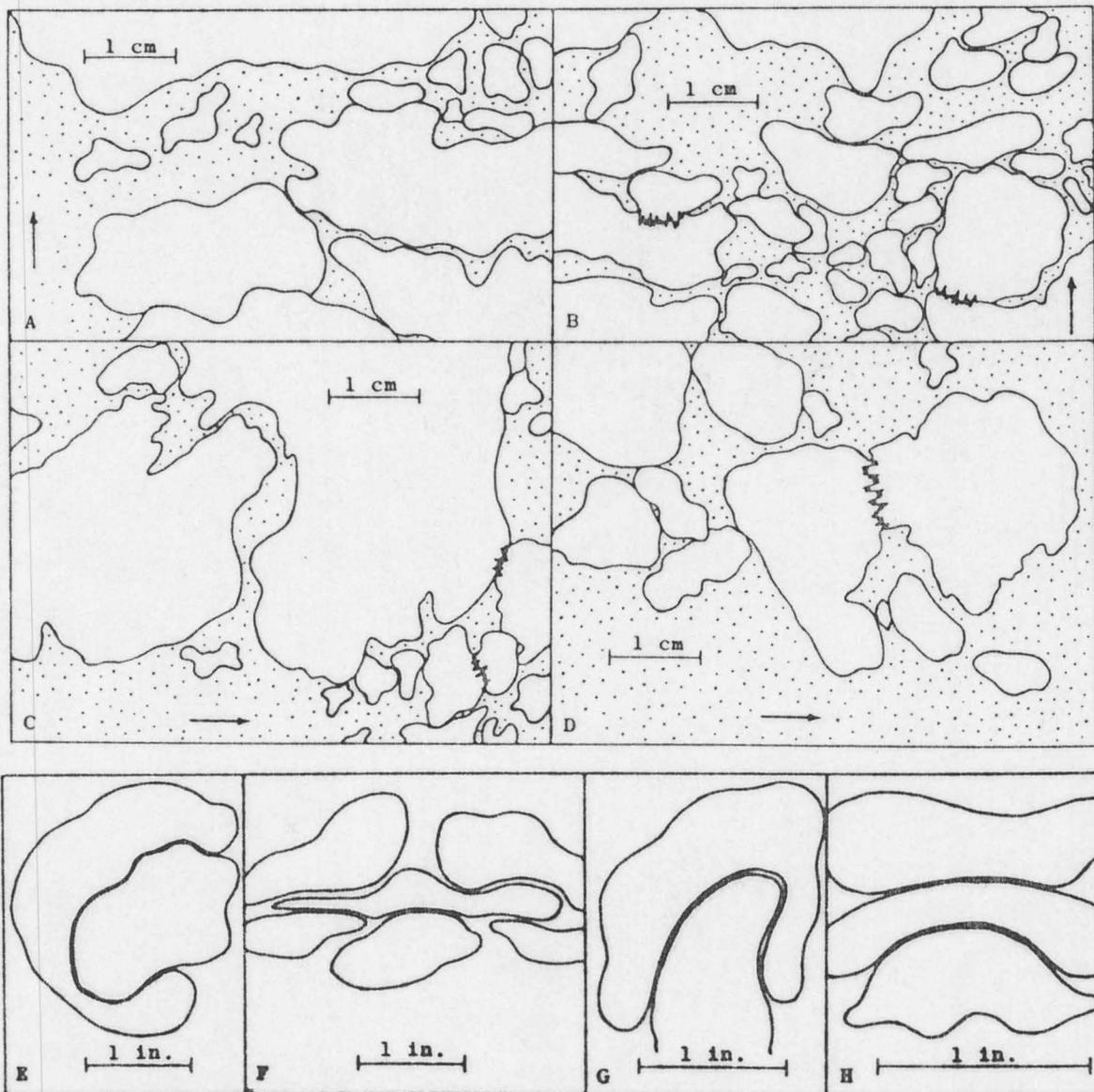


FIGURE 38.-- Tracings of peel prints (A-D) and field sketches (E-H) showing pebble contacts in Douglas Group limestone conglomerates. A, B, E, and F from conglomerate at center $NE\frac{1}{4}SE\frac{1}{4}$ sec. 31, T. 53 N., R. 35 W., Platte County, Missouri (see Fig. 35C). C, D, G, H from conglomerate near SE corner $SW\frac{1}{4}$ sec. 19, T. 58 N., R. 35 W., Andrew County, Missouri (see Fig. 35D). Vertical surfaces, orientation shown by arrows, areas of calcareous sand in a spar matrix stippled (A-D). E-H unoriented.

or smaller stages in the breakdown of limestone. However, such calcareous sand would probably be short-lived and have little chance to become a part of the geologic record as a fluvial deposit. It seems probable that the strong leaching action of rain water as compared with sea water (Rankama and Sahama, 1950, p. 271) affecting the progressively larger surface areas acquired during the breakdown of limestone particles would preclude the accumulation of large volumes of calcareous river sand. According to Weller (1960, p. 61):

Calcareous sand or finer sediment is not a normal product of terrestrial erosion. The abrasion of large limestone fragments in stream beds and upon beaches probably produces small particles that are soon dissolved and disappear. Almost all lime sand consists of broken shells and other organic debris on beaches or in very shallow strongly wave-agitated water in situations where detrital material is not present in important quantities.

E. D. McKee (personal communication, 1963) has observed areas of calcium carbonate deposition from solution but has not observed transportation or deposition of calcareous sand during his studies of Recent river deposits. McKee has studied at least one ancient calcareous sand-containing limestone conglomerate that has been regarded as a stream deposit, but studies now in progress have led him to question such an interpretation.

Even in areas where limestone vastly predominates over other rock types as sources of stream load, calcareous sand is almost nonexistent.

M. D. Turner^{1/} (written communication, July, 1963) stated:

In some parts of Puerto Rico river systems drain largely limestone terrane. I have not seen any limestone fragments smaller than granule size except in trifling amounts, which were ephemeral.

^{1/} Research Associate, Dept. of Geology, Univ. of Kansas; formerly State Geologist of Puerto Rico.

Neither the incomplete consolidation of some of the limestone when eroded nor the large volume of calcareous sand indicate that Douglas limestone conglomerates are products of terrestrial erosion. Although limestone conglomerates of the Douglas Group display many characteristics of beach gravels, it does not follow that they are beach gravels. Until the detailed shape and extent of these conglomerates are known, I choose to regard them as deposits of a marginal or mixed environment. The idea that the limestone conglomerate of the Tonganoxie Sandstone Member of the Stranger Formation is a fluvial deposit (Lins, 1950, p. 132-133) is improbable.

Coals. -- Two theories for the accumulation of vegetal matter that may subsequently alter to coal are discussed by E. S. Moore (1940, p. 136-138). The autochthonous theory ascribes to accumulation in situ, where the vegetation grew and fell, whereas the allochthonous theory requires transportation by water prior to accumulation. Whether deposition took place in a nonmarine, mixed, or marine environment, or any combination thereof, is an additional problem.

Moore (1936, p. 148-149) first recorded peculiarities of Douglas Group coals:

Some and possibly all of these coals in the lower part of the member are detrital, having been reworked before final deposition. . . . Probably none of these coals, with the possible exception of the one 55 feet below the top, . . . represent normal conditions of coal deposition. . . . A peculiarity of the Sibley coal near Leavenworth and northward is a fine interbedding of thin coal streaks and black carbonaceous shale.

Moore's observations are in description of coals within the Tonganoxie Sandstone.

Bowsher and Jewett (1943, p. 38) conclude:

. . . (1) most of the coals in the Douglas Group were accumulated under environmental conditions different from those generally thought to be operative in accumulation of peat during the Pennsylvanian epoch; (2) they were probably deposited as fragmentary plant material in a marine littoral environment; (3) they did not for the most part accumulate in situ; and (4) present theories of accumulation do not satisfactorily explain lithologic and structural peculiarities of coal beds in the Douglas Group of eastern Kansas.

Lins (1950) studied some of the same coals as did previous workers and he records a number of exactly opposite conclusions, one of which (op. cit., p. 135) is:

I am of the opinion that the lower and upper Sibley coals are of continental autochthonous origin.

The following observations are generally agreed upon: (1) coal beds within the Douglas Group are locally as much as 20 inches thick, range downward to featheredge smuts, but commonly are 8 inches or less thick and have a considerable range in thickness in short distances; (2) coal beds within the Douglas Group are lenticular. Their outcrop distribution in Kansas is accurately portrayed by Bowsher and Jewett (1943, Fig. 8, p. 30-31) except that the upper Williamsburg coal is not perfectly continuous across Franklin, Coffey, and Woodson Counties; (3) coal beds within the Douglas Group characteristically grade into adjacent clayey to silty carbonaceous shales and mudstones. Where more than 0.5 foot thick, the medial parts of the coal beds are relatively pure; and (4) no clay beds that possess the characteristics ascribed to old soils (underclays or seat earths) have been found beneath any coal bed in the Douglas Group.

At localities where Douglas Group coal beds are less than 0.5 foot thick, the coal is commonly interlaminated with shale throughout. This

condition prevails; (1) for the upper Sibley coal locally in Douglas and southern Leavenworth Counties and generally in northern Leavenworth County, north of the town of Leavenworth, southern Atchison County, and in Platte County, Missouri exposures of this coal; (2) for the upper Williamsburg coal throughout Douglas County and locally farther south; and (3) locally for the other less extensive coal beds of the Douglas Group. One exposure (Fig. 39) shows interbedded coal and carbonaceous limestone.

Many of the bonafide underclays and fire clays composed predominantly of fire-clay mineral^{1/} or kaolinite. According to E. S. Moore (op. cit., p. 163-165), lack of stratification, bleached appearance, common occurrence of Stigmaria, and high plasticity are other characteristics commonly ascribed to underclays. As pointed out by Bowsher and Jewett (op. cit., p. 33), most of the Douglas Group coal beds overlie well-bedded clayey or silty shale. However, apparently unstratified, bleached, plastic mudstones are present locally, immediately below the coal seams. Samples from three such beds (0 to 3 inches below upper Sibley coal, NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 24, T. 11 S., R. 21 E.; and 0 to 3" below lower Sibley coal, same location; and 0 to 3" below Ottawa coal, cen. W. line sec. 14, T. 17 S., R. 19 E.) were subjected to standard clay-mineral analysis by x-ray diffraction. The samples contained illite, kaolinite, ?vermiculite, and illite-mixed layer clay; none contained fire-clay mineral nor more kaolinite than is generally present in Douglas Group shales and mudstones. If presence of definite underclay even locally developed could be

^{1/} Mellorite, a poorly crystallized (partly disordered) kaolinite.

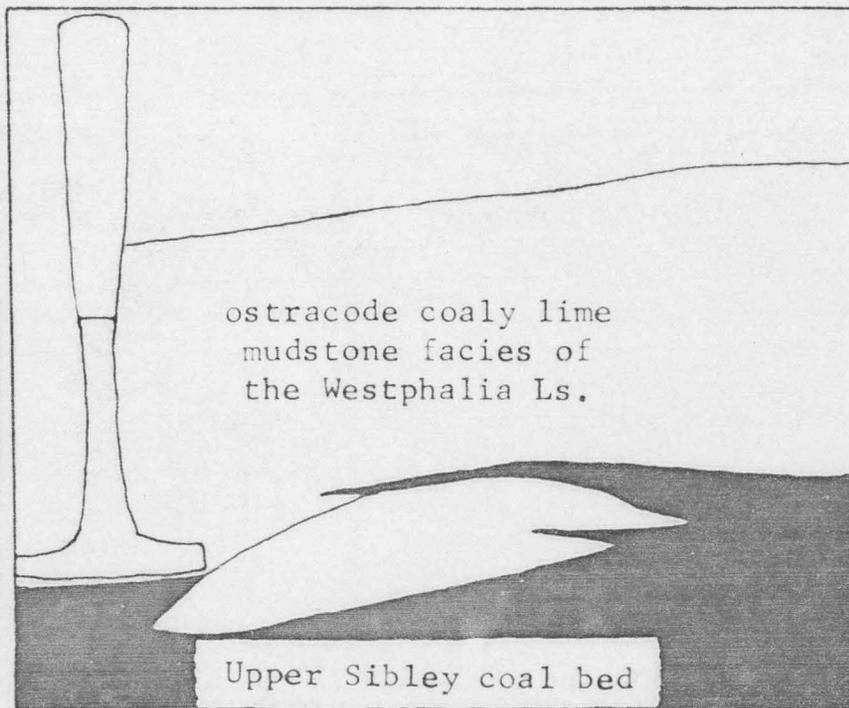
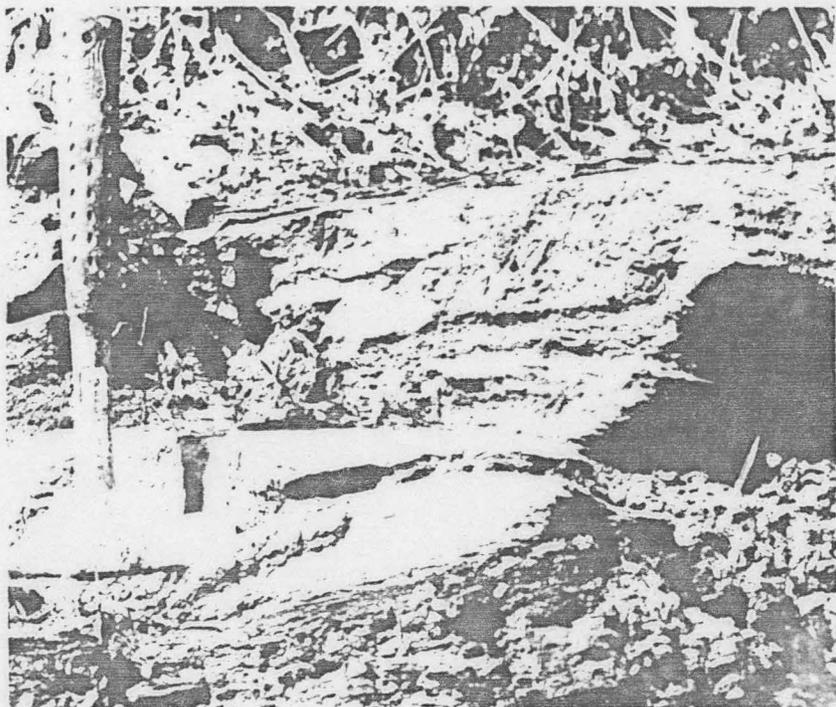


FIGURE 39 .-- Intercalation of Upper Sibley coal bed and Westphalia Limestone near SW corner NE $\frac{1}{4}$ sec. 4, T. 8 S., R. 22 E., Leavenworth County, Kansas.

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established, the idea of autochthonous origin for the coals would be strengthened. It does not follow that lack of definite underclay proves allochthonous origin (E. S. Moore, op. cit., p. 164) and it should be stressed that not everyone agrees upon what characteristics so-called underclays have.

Table 7 shows a comparison of different authors' conclusions pertaining

| Patterson, 1933 | Bowsher and Jewett, 1943 | Lins, 1950 |
|--|---|--|
| 1. Not specifically mentioned | 1. Plant remains generally poorly preserved in adjacent shales, but in some places are well preserved although fragmentary. | 1. Plant remains in adjacent shales are well preserved and show no signs of transportation by currents. |
| 2. Not specifically mentioned. | 2. Plant material in subjacent shales generally parallel to bedding surfaces. | 2. Subjacent shales commonly well bedded but plant material not parallel to bedding surfaces. |
| 3. Subjacent shales marine in Vinland (southern Douglas Co.) and Kickapoo (northern Leavenworth Co.) areas. | 3. Found marine fossils in marginal shale layers at base of coal beds locally. | 3. Subjacent shales nonmarine; states that no invertebrate fossils have been found in these shales. |
| 4. Found marine fossils in insoluble residues of carbonaceous limestone that is a caprock on the upper Sibley coal in many places in Douglas and Leavenworth Counties. | 4. Found marine limestone locally contiguous with the underlying upper Sibley coal. | 4. ?Fresh to brackish-water forms occur in overlying beds; states that no definitely marine fossils have been found. |
| 5. Coals interpreted as nonmarine. | 5. Coals interpreted as allochthonous littoral marine. | 5. Coals interpreted nonmarine autochthonous. |

Table 7.-- Observations pertaining to origin of Douglas Group coals. Many of the notes pertain specifically to the upper Sibley coal, a seam considered representative by the authors listed.

to the origin of Douglas Group coals. Patterson disagrees with Bowsher and Jewett only on the last point noted in Table 7. At the time of

Patterson's work, coals were generally considered nonmarine deposits.

Disagreement between Lins and Bowsher and Jewett is consistent.

Considering points 1 and 2 of Table 7, field observations as recorded in the stratigraphic sections in the appendix verify those of Bowsher and Jewett. Point 3 by Lins and Patterson pertains specifically to the shales subjacent to the upper Sibley coal, whereas the corresponding point by Bowsher and Jewett pertains to shales marginal below Douglas Group coals considered collectively. Since Patterson's work (op. cit.), marine fossils have been known to occur in these shales. Patterson found marine fossils throughout this shale in T. 14 S., R. 20 E., Douglas County, Kansas, in the vicinity of Kickapoo, northern Leavenworth County, Kansas, and in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T. 12 S., R. 21 E. Bowsher and Jewett (op. cit.) did not cite locations pertaining to point 3, but measured sections^{1/} by these men substantiate their statement. Patterson (op. cit.) found marine ostracodes and gastropods in carbonaceous limestone immediately above the upper Sibley coal and, where the limestone was absent, the ostracode Jonesina howardensis, other ostracodes, and foraminifers in correlative shale. In addition to the sparse megafossils found locally in the field, the fossils listed (Table 8) below were found in washings of samples taken from rocks adjacent to the upper Sibley coal.

General characteristics of Douglas Group coals include: lenticularity; marginal gradation into shale, mudstone, or limestone, rocks that commonly contain marine fossils; shale interbeds especially prominent marginally, but present throughout where the coals are 0.5 foot or less thick; and

^{1/} In Basic Geology Division, State Geological Survey of Kansas files.

| LOCATION | STRATIGRAPHIC PLACEMENT OF SAMPLE | FOSSILS |
|--|-----------------------------------|---|
| Near cen. S. line sec. 12, T. 7 S., R. 21 E. Atchison Co., Kans. | 0 to 0.2 foot above coal | The megaspore <i>Triletes</i> ; carbonized plant fragments (A); ostracodes (C); gastropods, pelecypods, <i>Composita</i> and polished fragments of other brachiopods, echinoid spine fragments (S) |
| Same | 0 to 1 foot below coal | Ostracodes and arenaceous foraminifers (S) |
| Same | 6.5 to 7.5 feet below coal | Brachiopod fragments (S) |
| SW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 13, T. 10 S., R. 21 E. Leavenworth Co., Kans. | 0 to 0.1 foot above coal | Sand-size carbonized plant stem fragments, macerated carbonaceous matter, ostracodes (A); ? <i>Hypaelentoma</i> and other gastropods (C); echinoid spine fragments, <i>Lingula</i> fragments, articulate brachiopod and productid brachiopod spine fragments (S) |
| SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 33, T. 54 N., R. 36 W. Platte Co., Mo. | 0 to 0.1 foot above coal | Carbonized plant fragments, <i>Mylina</i> , <i>Astartella</i> , other pelecypod fragments, <i>Bairdia</i> and other ostracodes polished brachiopod valve and productid brachiopod spine fragments (A); the arenaceous foraminifer <i>Ammodiscus</i> and minute (1 to 4 mm high) spired gastropods (C); the arenaceous foraminifers <i>Ammoverbella</i> , <i>Hyperamina</i> , and ? <i>Bathysiphon</i> (S) |
| Same | 1.8 to 2 feet below coal | Carbonized plant debris (C); ostracodes, the arenaceous foraminifer ? <i>Bathysiphon</i> , minute spired gastropods, echinoid spine and plate fragments, brachiopod valve fragments (S) |

Table 8.-- Fossils found in washings of rock samples from above and below upper Sibley coal. (A), (C), and (S) represent abundant, common, and sparse respectively and are notations of apparent relative abundance as visually estimated from binocular microscope study.

highly fragmentary condition of plant material arranged parallel to bedding surfaces. The sequence of conglomerate, sandstone, shale and coal beds in varying succession argues strongly for the drift theory, as it would appear that very frequently there was almost complete assortment of sediments on the basis of specific gravity and rate of settling (E. S. Moore, op. cit., p. 155). This sequence of rock types in varying succession is another general characteristic of the coal-bearing parts of the Douglas Group section. As previously concluded by Moore (op. cit.) and by Bowsher and Jewett (op. cit.), coals of the Douglas Group did not for the most part accumulate in situ; they are predominantly allochthonous.

It seems probable that the Ottawa coal is essentially autochthonous because a part of the source vegetation was preserved in place (Ball and others, 1963, p. 25). The general characteristics noted above for Douglas Group coals as a whole are not well developed in the case of the Ottawa coal lens.

Three-dimensional extent of Douglas Group coals is still too poorly known to justify reconstruction of detailed environmental conditions under which deposition took place. However, observations made upon the upper Sibley coal, the upper Williamsburg coal, and the Ottawa coal are sufficiently detailed to justify hypotheses on their depositional environments.

The first two mentioned coals and adjacent strata exhibit the general characteristics described above and are considered allochthonous. Considering the fossils present in strata marginal to the coal and locally interbedded with the coal, parts of the assemblage are probably not indigenous. Abundance and state of preservation indicate that the ostracodes, arenaceous foraminifers, and mollusks are reasonably interpreted as indigenous, whereas the polished articulate brachiopod, echinoid, and plant fragments are inferred to be transported extraneous additions to the environment. The almost imperceptible gradation between and interbedding of rock types commonly characteristic of the sequence associated with these coals indicates that the coal depositional environment did not differ appreciably from that of the invertebrate fossil-bearing rock types. Deposition of the plant material by ordinary processes as an integral part of these sequences is apparent and possibly took place in shallow bays. For the upper Sibley and upper Williamsburg coals, I am in

full agreement with the probable littoral marine origin postulated by Bowsher and Jewett (op. cit.). Assuming the comments pertaining to the general sedimentational framework are correct (see Figure 12), sites of deposition of the vegetal material that now forms these coals would be intermediate between continental conditions to the east-southeast and more open marine conditions to the west-northwest.

Insofar as I have been able to determine, the Ottawa coal is a single lens best exposed at the center west line SW $\frac{1}{4}$ sec. 14, T. 17 S., R. 19 E. A detailed description of the rocks exposed there is given in the appendix (see selected section 40 in appendix). Stumps and trunks of trees (Bowsher and Jewett, op. cit., Pl. 4B, p. 28) rooted in the Ottawa coal, were preserved in the upright position of growth, having been buried before they had time to rot away or fall. A number of fossilized twigs and branches, which cut stratification surfaces at angles of about 90 degrees, and numerous well-preserved plant fossils (Ball and others, 1963, Pl. 9, p. 26) have been collected from the basal 5 to 10 feet of siltstone and sandstone overlying the Ottawa coal. Contacts of the Ottawa coal are relatively sharp. The vegetal matter that now forms this coal accumulated where it grew and fell.

Sandstones. -- Much of the literature on sandstones of the northern Midcontinent and Eastern Interior late Paleozoic sections impresses an apparent simplicity upon the reader concerning the question of marine or nonmarine origin. In much of the literature, so-called channel sandstones, and other sandstones, the shape of which is even more vaguely known, have been given a categorical nonmarine placement because they contain plant

fossils but few, if any, marine fossils. As pointed out by Siever (1957) the theory of cyclic sedimentation has greatly influenced interpretation of the depositional environment of many late Paleozoic sandstones. Notwithstanding objections by Moore (1953, 1957) and Howe (1956), American geologists have classically considered many of these sandstones the basal phases of cyclothems. As such the sandstones would be the oldest non-marine beds of the cycles and would represent sediment deposited in channels cut on surfaces of subaerial erosion. Directional data indicative of a dominant direction of current transport to the southwest has been repeatedly cited as evidence for: (1) regional slope to the southwest; (2) southwestward flowing rivers; and (3) predominant sediment source to the northeast and east (e.g., Lins, 1950; Wanless, 1957, 1963; Siever, 1957; and Bower, 1959).

Reports of marine channel deposits or deposits that, had they not contained marine fossils, might have been interpreted as nonmarine channel sands, are few. Newell (1940) studied the Whitehorse Sandstone (late Permian) and presents a convincing theory that the fossiliferous lenses in the Whitehorse represent geologic record of migratory offshore bars. According to Newell (*ibid.*), physical characteristics of the fossiliferous lenses include: a linear plan view, lenticularity in section; average thickness 10 to 40 feet, breadth less than half a mile, length several miles--exceptionally as much as 12 miles wide and relatively longer and thicker; length more or less parallel to regional strike of beds; a relatively unidirectional dip of cross-stratification, a disconformable base; fossils in the dolomitic sandstone generally preserved as molds; and

bivalves generally abraded with valves not in apposition. Bass (1939) had studied one of the lenses of the complex subsequently studied by Newell (op. cit.) and noted that although dip of cross strata was predominantly parallel to the long dimension of the sandstone lens, locally dip into all four quadrants was observed. With the exception of abundant fossils, the lenses described by both Bass and Newell display characteristics similar to some of the individual sandstone lenses of the Douglas Group. Channel-fill deposits thought to be marine are reported by Mudge (1956, p. 665, p. 675). He concluded (ibid.) that these upper Pennsylvanian and lower Permian deposits represented marine fillings of sub-aerially eroded channels. Mudge (1957, p. 105) stated:

When current investigations of modern subaqueous channels are completed, future investigators of the Pennsylvanian channels may conclude that some or all of these older channels may be of marine origin.

Shoestring sandstones in Cherokee rocks of the Greenwood and Butler Counties, Kansas subsurface (Bass, 1936) were considered offshore bars rather than fluvial channel deposits.

Wanless and others (1963, p. 477) favor an hypothesis of delta distributaries rather than fluvial channel sandstones for many of lenticular sandstones they mapped.

Hayes (1963) believed that the channel sandstones of the Krebs Subgroup of western Missouri were tidal channel deposits and stressed the important point that no evidence exists within the channel sandstones themselves to indicate a certain depositional environment.

Considerations by two authors are quoted below because they explicitly outline the problem of the origin of many late Paleozoic sandstone and

because they are admirably objective. Two importantly different modes of terrigenous detritus dispersal cited by Moore (1957, p. 82) are:

- (1) The clastics were spread by low-gradient subaerial running water (streams and possibly sheet wash) . . .
- (2) The clastics were spread mostly at near-zero gradients throughout most of the area of sedimentation . . . transportation being effected by generally slow back-and-forth shifting induced by waves and currents in . . . discontinuous, fluctuating ponds, extremely shallow lakes and lagoons of varying size, and semienclosed extensions of shallow seas, the plexus of water bodies ranging from fresh or slightly brackish to normally saline sea water.

Question as to which of these mechanisms was dominant is one of the outstanding problems relating to Pennsylvanian-Permian cyclic sedimentation (see Moore, *ibid.*).

After extensive study of Pennsylvanian sandstones of the Eastern Interior Coal Basin, Siever (1957, p. 246-247) concluded:

Evidence is inconclusive on the knotty question of the marine or nonmarine origin of the sandstones. In essence this question is not concerned with the difference between saline and fresh waters but with discrimination between terrestrial and submarine or shore-line environments . . . It is possible to harmonize the somewhat conflicting evidence into a unified hypothesis. This hypothesis is that the sandstones were deposited in a variety of shallow water, littoral, lagoonal, deltaic, and coastal plain alluvial environments in which the time rate of migration of the strand line was high . . . Thus, characterization of the specific environment of these sediments, whose original depositional features are so uninformative in terms of possible analogues . . . at a point in both space and time becomes almost indeterminate.

Not much evidence was observed in many of the Douglas sandstones themselves to place their environment of deposition unquestionably. Apparently indigenous marine fossils in some localities and bottom markings (p. 253), if these enigmatic structures are correctly interpreted, are the only direct evidences reported herein. Characteristics of

associated strata, such as the limestone conglomerates and the coals, are interpreted as evidence that much of the sandstone should be regarded as deposits of mixed environments. The reported sedimentational framework (p. 222) places the predominance of Douglas sandstones in basin-marginal areas and makes the second dispersal mechanism cited by Moore (op. cit.), the mixed environments hypothesis of both Moore (op. cit.) and Siever (op. cit.), and the evidence of fossils and associated strata feasible and parts of an integrated whole. If one grants that Douglas sandstones are, in greater part, deposits of mixed environments, then these sandstones are a part of the complex record of the shore zone and probably contain non-marine as well as marine deposits even though no clearly non-marine strata have been demonstrated. General lack of marine fossils, cut-and-fill cross stratification, and vague conception of shape of the sandstones have suggested to some that Douglas sandstones are non-marine deposits. However, no one would argue that general lack of calcareous marine shells in a quartz sand necessarily means non-marine deposition or that cut-and-fill cross stratification is exclusively, or even characteristically, a non-marine phenomenon (e.g., see Dunbar and Rodgers, 1957, p. 69). Geologists familiar with stratigraphy of the sandstone-shale parts of northern Midcontinent Douglas rocks would agree that until a detailed coring program is undertaken shapes of Douglas sandstones will remain poorly known. It seems probable that deposits of a number of specific environments will ultimately be identified in Douglas sandstones. Until much more detailed studies than have yet been undertaken document specific environments, I choose to regard Douglas sandstones as deposits of mixed environments.

Sandstones and associated chert conglomerates of east-central Oklahoma Vamoosa Formation outcrops are another matter and are probably non-marine deposits. These strata probably record fluvial piedmont deposition (p. 259).

Principal Controls Upon Distribution of Rock Types

Many writers (e.g., Elias, 1937; Hattin, 1957; and Lane, 1958) have believed that depth of deposition was the major control on distribution of rock types. Since the work of Elias (op. cit.), the fusulinid facies has been generally regarded as the deepest water cyclothemic phase. On the other hand, some stress has been placed more upon an offshore than a depth significance of the fusulinid phase. Moore (1929, p. 467) discussed the abundance of fusulinids in many Pennsylvanian rocks and (ibid.) stated:

. . . depths ranging from 5 to 50 feet may, under certain conditions, afford surroundings quite as favorable to foraminiferal population as depths of 400 or 500 feet and they may be even more favorable.

Moore (e.g., 1950, p. 14) has placed major emphasis on distance from shore as regards the fusulinid habitat. He has believed that depth of water was of lesser importance than distance from shore in controlling the distribution of invertebrate assemblages that characterize particular parts of cyclic sequences and wrote (1957, p. 80):

The local small stratigraphic sections showing these paleontological features furnish the record of paleo-ecologically different conditions on the shallow sea bottom that were introduced at the locality of the section as the sea gradually became deeper, or (probably more important) as the shoreline became farther and farther distant.

Several authors have reported probable shallow-water habitats for the fusulinids studied (Newell and others, 1953; Myers and others, 1956; and Harbaugh, 1959). Imbrie and others (1959, p. 77-78) and Laporte

(1962, p. 540-541) questioned: (1) the major importance of water depths; (2) the previously reported depth significance of fusulinids; and (3) the widespread extent of transgressions and regressions during deposition of sediments that now form the Beattie Limestone (Permian).

Regarding the rocks and the area studied, it seems that the same questions raised by Imbrie and others (op. cit.) and reiterated by Laporte (op. cit.) are warranted. Regional distribution of Douglas Group rock types indicates that the sedimentational framework did not change radically during Douglas deposition. Quartzose sand in sandstones (p. 92, p. 118, p. 149, and Fig. 11), in shales (p. 274), and in limestones (p. 67, p. 109, and p. 132); coals (p. 90, p. 145, and Fig. 11); calcareous sands (p. 272); conglomerates (p. 284); and recurrent mollusk-bearing shales (p. 277); are largely restricted to and, to a surprising extent, their areal distribution overlaps within the southern and southeastern parts of the area of detailed study (Fig. 1). The northwestern part of the study area, that is, the area of general continuity of the Cass Limestone (Fig. 23), is markedly impoverished as regards these rock types. This belief is documented by Nebraska exposures (see stratigraphic sections in appendix), by sample logs of both cable tool and rotary cuttings (described or referred to in appendix), by two core descriptions (in appendix), and, pertaining to quartzose sandstone distribution, by electric log interpretation of lithology (see Fig. 1 for control point density).

The distribution of limestones (Fig. 8, 13, 19, 21, 23, 24, and 26) reflects a surprising degree of areal coincidence. Areas of marked facies changes of the limestones and areas of marked erosion (p. 217 and p. 228)

overlap geographically. Both the facies changes and the erosion were conditioned primarily by relative nearness to southern and southeastern shores and the corollary more or less continuous and greater influx of terrigenous detritus derived largely from southern and southeastern source areas.

The Haskell is the most widespread (Fig. 21) of the limestones and of the area studied. The Cass Limestone, which is closely associated stratigraphically (Pl. 34 and Fig. 29), is much less widespread (Fig. 23). Post-depositional erosion is not believed to have been an important factor in the regional distribution of either of these limestones. During deposition of lime muds that now form the Haskell Limestone, the deposition of terrigenous detritus in amounts sufficient to swamp carbonate deposition covered a much lesser part of the area studied than during the deposition of the Cass Limestone. Does the relative extent of the Haskell and the Cass afford even a crude index of the extent of marine regression between their relative times of deposition? I suggest that it does not. Restricted distribution of the Cass Limestone was controlled largely by the more extensive spread of terrigenous clastics and not by widespread regression to the northwest inasmuch as the Haskell-Cass part of the section, in its entirety, and the Haskell-Robbins part of the section, at least in greater part, were definitely marine deposits.

Clay-mineral analyses of samples taken from Missouri and Kansas exposures of Douglas Group clayey shales (Weston, Vinland, Robbins, and Wathena Shales) indicate only minor vertical and lateral variations in clay mineralogy. The only variations recognized were relatively more intense kaolinite peaks in the sandy uppermost part of the Weston and Robbins

Members locally, the local presence of montmorillonite in the uppermost part of the Weston just below Iatan Limestone base (Pl. 16), and the local absence of ?vermiculite (Fig. 25). The first two-mentioned variations are likely the result of secondary alteration by ground-water movement.

Illite and kaolinite are present in all Missouri and Kansas samples analyzed. Miller and Swineford (1957, p. 2018-2019) noted that diffractometer patterns of shales in Douglas County, Kansas exposures of the lowermost foot of Robbins Shale section displayed kaolinite reflections that were relatively stronger than in typical marine Pennsylvanian shales in eastern Kansas. They concluded (op. cit., p. 2035) that the larger amount of kaolinite indicates either a short period of marine inundation or proximity of land and believed (ibid.) the latter more probable. The relatively strong kaolinite reflections on diffractometer patterns of all Missouri-Kansas samples analyzed from the Weston, Vinland, Robbins, and Wathena Shales justifies their choice because deposition of these shales does not record marine inundations of short duration. Persistently large amounts of kaolinite in these shale members is interpreted as indicative of persistent proximity to land and corroborates the other evidences for relative nearness to southern and southeastern shores during the major part of Douglas deposition. Twelve diffractometer patterns were run for three samples of grayish-red mudstone in a single exposure of the upper part of the Lawrence Formation in Nebraska (Fig. 28) and selected section 1 in appendix). These three samples contained illite and illite-mixed layer clay and were the only shale or mudstone samples analyzed that lacked kaolinite. However, this amount of data is far too meager

to afford basis for meaningful clay-mineralogical comparison of Nebraska and Missouri-Kansas Douglas Group shales and mudstones.

It seems probable that the amount of terrigenous detritus supplied at varying rates and in differing volumes and relative nearness to shore were the principal controls upon distribution of Douglas sediment types, whereas related factors such as water depths and turbulence were of lesser importance. That fusulinids do not necessarily imply any general depth significance has already been discussed (quotation of statement by Moore, p. 308; and p. 274). The vastly greater number of lateral and vertical variations within Douglas rocks of Missouri-Kansas-Oklahoma outcrops (Fig. 11) as compared with the widespread area of uniform deposition to the northwest (Pl. 3 in pocket) is believed to be largely the result of shore-zone deposition of a much greater volume of terrigenous detritus in the southern and southeastern parts of the study area.

CONCLUSIONS

The following statements apply to Douglas rocks within the northern Midcontinent unless otherwise indicated.

1. The two-formation subdivision of a single group of rocks, the Douglas Group, bounded by Lansing Group top below and Shawnee Group base above, is the most utilitarian classification of these strata for purposes of both surface and subsurface study and is based on objective continuity of key beds.

2. Individual disconformities within the Douglas Group are not regionally developed, but are more numerous and physically more prominent in southern and southeastern marginal parts of the study area.

3. Documentations of regional correlations are stressed. The regional distribution maps of the various limestone members are regarded as generally accurate notwithstanding some error involved in any attempt for even this degree of precision throughout a sizeable area.

4. On the whole, the Douglas Group is a terrigenous detritus wedge thickest in the southern Kansas-northernmost Oklahoma area and thinnest in Nebraska. Greatest thickening is approximately twelve-fold southward along about a 200-mile distance from Nebraska to about 600 feet in southernmost Kansas. Approximately three- to four-fold southeastward thickening are characteristic along 100-mile distances from Nebraska to northwestern Missouri. Northward and northwestward convergence is, of course, not perfectly progressive. Nonetheless, in true perspective, the Douglas Group is indeed the shape of an incomplete and imperfect wedge.

5. The Upper Pennsylvanian section, which includes Douglas correlatives, displays over-all southward thinning in Oklahoma exposures from

Osage County to the Arbuckle Mountains region. I believe this thinning resulted from the cumulative effect of numerous disconformities.

6. The Arbuckle Mountains region and northern flank areas are judged to have been the principal source terrane for Douglas terrigenous detritus. The Ozark Dome and its western periphery is believed to have been of secondary importance as a source area. Eastern, northeastern, and northern margins of that part of the Douglas sedimentary basin studied apparently bordered lower-lying land areas from which relatively minor amounts of finer-grained detritus were derived.

7. The Ouachita Mountains region was probably an important source terrane for the terrigenous detritus of east-central Oklahoma outcrops of the Vamoosa Formation.

8. Increments of the Arbuckle Orogeny are thought to have spanned parts of the post-Belle City (\approx Drum) Limestone, pre-Lecompton Limestone interval. The culmination of this orogeny is probably post-dated by the chert conglomerates of the Vamoosa Formation. However, marked imperfections in the geologic record between the Arbuckle Mountains region and Osage County, Oklahoma preclude more precise dating of the Arbuckle Orogeny acme relative to northern Midcontinent stratigraphic classification.

9. Areas of marked facies changes and areas of marked erosion within Lansing, Douglas, and lower Shawnee rocks were persistently situated within southern and southeastern parts of the study area and overlap geographically. These areas are believed to have been basin-marginal, that is, relatively nearer southern and southeastern shores of the sedimentary basin. Southern shores of the Douglas sedimentary basin are judged to have been

within the latitudes spanned by the present Creek-Seminole Counties, Oklahoma area and southeastern shores probably extended to within the study area during parts of Douglas deposition. At least in greater part, eastern, northeastern, and northern shores are believed to have been outside the area of study. Only a general positioning of strandlines relative to a small part of a single sedimentary basin is warranted by this study.

10. Douglas strata of the northern Midcontinent are regarded as largely deposits of marine environments and mixed environments. Although the deposits of mixed environments probably contain non-marine components, no definitely non-marine rocks were recognized. The chert conglomerates of the Vamoosa Formation in Pontotoc-Creek Counties, Oklahoma outcrops are interpreted as record of an appreciable volume of non-marine deposition.

11. Influx of terrigenous detritus and relative proximity of depositional sites to shores are judged to have been the principal controls upon the distribution of Douglas sediment types, whereas related factors such as water depths and turbulence were of lesser importance.

12. Douglas Group packstones and grainstones, which include the abundantly fusulinid-bearing limestones, are believed to have been deposited as calcareous skeletal sands and as such cannot signify water depths of specific habitats.

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STRATIGRAPHY OF THE DOUGLAS GROUP (PENNSYLVANIAN, VIRGILIAN)
IN THE NORTHERN MIDCONTINENT REGION

VOLUME II
(Appendix and pocket illustrations)

by

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APPENDIX

Selected Stratigraphic Sections

An attempt has been made to document sources of data by description, illustration, or reference. Definitions of descriptive terms and sources of terminology are given in the glossary (p. 16 to p. 18). Color descriptions refer to fresh rock surfaces unless otherwise indicated. Dunham's (1962) carbonate classification is applied only in some section descriptions and parts of other section descriptions. Shales were washed for microfossils and analyzed for clay-mineral content only where so indicated. Generally, only Douglas rocks and contiguous stratigraphic units are described.

Surface Sections

Nebraska

- 1.--Composite of quarry exposures near center south line SW $\frac{1}{4}$ sec. 10 (Vilas Sh. to Little Pawnee Sh.), near center west line SW $\frac{1}{4}$ sec. 10 (Cass Ls.), and in SE $\frac{1}{4}$ sec. 16 (Lawrence Fm., upper part, and Toronto Ls., lower part), T. 12 N., R. 10 E., Cass Co., Nebr. See Pl. 2, Pl. 10, Pl. 32, Fig. 28, and Fig. 29. Section by S. M. Ball, W. A. Crawford, and F. R. Siegel; Jan., 1959.

| | Thickness, feet |
|---|--------------------|
| Shawnee Grp. | |
| Oread Ls. Fm. | |
| Toronto Ls. Mbr. (only basal part described) | |
| Limestone; medium gray; nodular; shaly; abundantly fossiliferous, <u>Chonetes</u> , other brachiopods, fenestrate bryozoans, ramose bryozoans, crinoids; thickness described..... | 5.2 |
| Douglas Grp. | |
| Lawrence Fm. | |
| Unnamed upper part | |
| Mudstone; greenish-gray; calcareous; contains illite and illite-mixed layer clay; thickness variable..... | 0.4-1.0 |

| | Thickness, feet |
|---|--------------------|
| Mudstone; grayish-red, in part mottled greenish-gray; contains illite and illite-mixed layer clay; thickness exposed..... | 16.0-17.0 |
| Covered interval; about..... | 10.0 |
| Note - this part of section is poorly exposed near center west line SW $\frac{1}{4}$ sec. 10, T. 12 N., R. 10 E. and comprises largely grayish-red mudstone. Greenish-gray mudstone forms the lowermost 1.0 foot of section. | |
| Cass Ls. Mbr. | |
| See Pl. 32 and p. 179 to p. 183 for detailed description about..... | 15.0 |
| Little Pawnee Sh. Mbr. | |
| Mudstone; greenish-gray; weathers to subcubical blocks as much as 2 inches in long dimension; slightly silty; slightly calcareous; about..... | 0.8 |
| Shale; black; fissile to platy; abundantly fossiliferous in lower half, <u>Crurithyris planoconvexa</u> , ramose bryozoans, crinoid stem fragments; basal contact gradational; about..... | <u>0.8</u> |
| Total thickness of Little Pawnee Sh. Mbr..... | 1.6 |
| Haskell (Shoemaker) Ls. Mbr. | |
| Limestone (brachiopod lime wackestone); medium dark gray to medium gray; crinoids, ramose bryozoans, abundant <u>Crurithyris planoconvexa</u> ; basal contact gradational; thickness variable..... | 0.2-0.3 |
| Shale; greenish-gray; calcareous; crinoids, ramose bryozoans; about..... | 0.15 |
| Limestone (mixed-fossil lime mudstone); medium bluish-gray; fusulinids, ramose bryozoans, crinoids, productid brachiopods; about..... | <u>0.8</u> |
| Total thickness of Haskell (Shoemaker) Ls. Mbr... | 1.15-1.25 |
| Note - the Haskell (Shoemaker) Ls. comprises a single limestone bed near center west line SW $\frac{1}{4}$ sec. 10, T. 12 N., R. 10 E. | |
| Stranger Fm. | |
| Weston-Vinland Mbr. | |
| Shale; light gray; calcareous; <u>Neospirifer</u> ; about.... | 0.15 |
| Conglomerate; sand- to pebble-size limestone, ferruginous limestone, and ?fossil fragments in an argillaceous limestone matrix; extensively leached and discontinuous in places along quarry face; a resistant bed at west end of quarry; maximum thickness.. | 0.5 |
| Mudstone; greenish-gray; slightly calcareous; about... | 2.0 |
| Mudstone; grayish-red, abrupt color change at top, part mottled greenish-gray; part calcareous; about..... | 13.0 |

Thickness,
feet

| | |
|---|---------|
| Limestone; light greenish-gray stained grayish-red; nodular; shaly; sparse pelecypod fragments; discontinuous; about..... | 0.1 |
| Note - this trace of limestone occupies the stratigraphic position of the Iatan (Nehawka) Ls., but is a vastly different facies. | |
| Shale; grayish-red; flaky; slightly micaceous; about. | 1.0 |
| Shale; light greenish-gray; micaceous; calcareous in lower part; both contacts gradational, basal contact highly irregular; about..... | 0.7 |
| Total thickness of Weston-Vinland Mbr..... | 17.45 |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| See Pl. 10 and p. 50 to p. 54 for detailed description, about..... | 10.0 |
| Rock Lake Sh. Mbr. | |
| Covered interval; thickness variable; about..... | 7.0 |
| Note - the Rock Lake Sh. crops out about 1000 yards west of quarry in railroad cutbank exposures. | |
| There the member comprises grayish-red and greenish-gray mudstone. | |
| Stoner Ls. Mbr. | |
| Limestone; light gray; weathers into 0.5 to 1.0 inch plates; apparently unfossiliferous; about..... | 1.4 |
| Limestone; light gray; very thin- and irregularly-bedded; sparse brachiopod fragments; about..... | 0.9 |
| Shale; light greenish-gray; calcareous; about..... | 0.4 |
| Limestone; medium gray to light gray; thick massive bed that weathers into ill-defined thin beds locally; stylolites common; finely crystalline; brachiopods, crinoids, fusulinids, ramose bryozoans, ?linear algae; about..... | 3.6 |
| Shale; greenish-gray; about..... | 0.1 |
| Limestone; light gray; very thin-bedded; finely crystalline; <u>Composita</u> ; about..... | 0.3 |
| Shale; greenish-gray; about..... | 0.06 |
| Limestone; light gray; massive; finely crystalline; brachiopods, crinoids, fusulinids, ?linear algae; about..... | 1.8 |
| Shale; greenish-gray; about..... | 0.2 |
| Limestone; light gray; indistinctly-bedded locally; argillaceous; <u>Composita</u> , fusulinids locally abundant, pelecypod fragments, crinoids; thickness variable... | 1.2-1.5 |
| Shale; light gray to medium gray; calcareous; productid brachiopods, crinoids; about..... | 2.0 |

Thickness,
feet

| | |
|---|-----------|
| Limestone; light gray; thin- to thick-bedded; slightly argillaceous; contacts gradational; brachiopods, crinoids, shark teeth; about..... | 2.0 |
| Total thickness of Stoner Ls. Mbr..... | 14.0-14.2 |
| Eudora Sh. Mbr. | |
| Mudstone; medium gray; weathers into subcubical blocks as much as 0.2 foot in long dimension; about. | 0.8 |
| Shale; black; fissile; about..... | 0.7 |
| Total thickness of Eudora Sh. Mbr..... | 1.5 |
| Captain Creek Ls. Mbr. | |
| Limestone; light gray; slightly argillaceous; brachiopods, crinoids; about..... | 0.7 |
| Vilas Sh. Fm. | |
| Shale; medium gray; carbonaceous; micaceous; exposed above ice in quarry pond..... | 2.0 |
| 2.--Quarry exposure in NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 16, T. 12 N., R. 11 E., Sarpy Co., Nebr. See Plates 11, 12, and 18D. Measured and described in Dec., 1959. | |
| Cretaceous (Dakota Fm.) | |
| Disconformity | |
| Douglas Grp. | |
| Stranger Fm. | |
| Tonganoxie-Vinland Mbr. | |
| Shale; grayish-orange; lamination indistinct; mica- ceous; about..... | 1.0 |
| Mudstone; greenish-gray; slightly calcareous; about. | 1.0 |
| Mudstone; grayish-red and greenish-gray mottled; part calcareous; thickness variable..... | 6.0-7.0 |
| Iatan (Nehawka) Ls. Mbr. | |
| Limestone (mixed-fossil lime packstone); grayish- orange; slightly argillaceous in upper part; chert nodules in lower part; brachiopods, crinoids; foram- inifers, bryozoans; about..... | 2.5 |
| Limestone (foraminiferal lime packstone); light gray to medium gray; basal contact gradational; about.... | 2.5 |
| Total thickness of Iatan (Nehawka) Ls. Mbr..... | 5.0 |
| Note - lateral variation of the Iatan from this exposure westward is illustrated in Pl. 18D. | |
| Weston Sh. Mbr. | |
| Mudstone to shale; grayish-red purple; vague lami- nation developed locally, in greater part weathers into irregular to subcubical blocks as much as 0.2 foot in long dimension; silty; upper contact grada- tional; about..... | 3.5 |

Thickness,
feet

| | |
|---|---------|
| Shale; greenish-gray; micaceous part slightly calcareous; about..... | 0.7 |
| Total thickness of Weston Sh. Mbr..... | 4.2 |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (coated-grain lime packstone); grayish-orange; shaly in uppermost 0.3 foot; prominent vertical joint surfaces extend through single massive bed; distinctive nodular chert zone from 0.3 to 0.6 foot above base; abundantly fossiliferous, gastropods, pelecypods, echinoids, crinoids, brachiopods, abundant fusulinids, other foraminifers, and ostracodes; skeletal grains show abrasion and some are coated with <u>Osagia</u> ; about..... | 1.1 |
| Limestone (coated-grain lime packstone); light gray to medium gray; similar to overlying unit but shaly and weathers nodular; about..... | 0.9 |
| Shale; greenish-gray to dark greenish-gray upward; micaceous; calcareous in upper 0.5 foot; sparse brachiopod and pelecypod fragments that are ?indigenous; thickness variable..... | 2.0-2.4 |
| Limestone (coated-grain lime packstone); medium light gray; very thin to thin beds that are irregular and discontinuous; fusulinids, other foraminifers, pelecypods including <u>Myalina</u> , crinoids, brachiopods including <u>Crurithyris planoconvexa</u> and <u>Phricodothyris</u> , <u>Osagia</u> -coated skeletal grains common; contacts gradational; thickness variable..... | 2.7-3.0 |
| Limestone (mixed-fossil lime wackestone); similar to overlying unit but contains fewer fusulinids, more crinoid fragments, and less abundant fauna; contacts gradational; thickness variable..... | 0.8-1.0 |
| Total thickness of South Bend Ls. Mbr..... | 7.5-8.4 |
| Rock Lake Sh. Mbr. | |
| Shale; greenish-gray; calcareous; brachiopods, crinoids, fenestrate bryozoans, polished and worn shell fragments common; about..... | 0.3 |
| Shale; dark greenish-gray; clayey to silty; about... | 0.2 |
| Mudstone; grayish-red, part mottled greenish-gray; calcareous; about..... | 4.0 |
| Total thickness of Rock Lake Sh. Mbr..... | 4.5 |
| Stoner Limestone Mbr. | |

3.--Streambank exposure at NE corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 12, T. 10 N., R. 12 E., Cass Co., Nebr. See Pl. 12B, Pl. 23A, Pl. 33, Pl. 34A, Fig. 29, and Table 4, Loc. 1. Section by S. M. Ball and W. D. Johnson, Jr., Mar., 1962.

| | Thickness, feet |
|--|--------------------|
| Surficial deposits | |
| Disconformity | |
| Douglas Grp. | |
| Lawrence Fm. | |
| Cass Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone); light gray; single bed; productid brachiopods, crinoids, fenestrate bryozoans, foraminifers; matrix entirely lime mud; about..... | 0.4 |
| Shale; greenish-gray; calcareous; about..... | 0.5 |
| Limestone (mixed-fossil lime mudstone to wackestone); similar to next younger limestone but contains fewer fossils; about..... | 1.2 |
| Shale; greenish-gray; calcareous; contains limestone stringers locally; crinoids, brachiopods including <u>Chonetes</u> , <u>Derbyia</u> , <u>Rhipidomella</u> , and <u>Neospirifer</u> ; about..... | 1.2 |
| Limestone (mixed-fossil lime wackestone in upper half, crinoid lime packstone in lower half); light gray; single bed; crinoids, echinoids, brachiopods, bryozoans, and foraminifers; about..... | 1.2 |
| Little Pawnee Sh. Mbr. | |
| Shale to mudstone; greenish-gray; lamination poorly developed; slightly micaceous; part calcareous; sparsely fossiliferous; thickness variable..... | 0.6-0.7 |
| Shale; black; fissile; conodonts; about..... | 0.2 |
| Mudstone; greenish-gray; calcareous; abundantly fossiliferous, especially in lower 0.2 foot, contains myriad of <u>Crurithyris planconvexa</u> ; about..... | 0.5 |
| Total thickness of Little Pawnee Sh. Mbr..... | 1.3-1.4 |
| Note - see Table 4, Loc. 1 for detailed listing and count of Little Pawnee Sh. fauna from this outcrop. | |
| Haskell (Shoemaker) Ls. Mbr. | |
| See Pl. 33, p. 183 to p. 185, and Pl. 34A for detailed description, about..... | 1.3 |
| Tonganoxie-Vinland Mbr. | |
| Shale to mudstone; greenish-gray; lamination indistinct; extremely calcareous; abundantly fossiliferous, contains brachiopods, crinoids, bryozoans; contacts gradational; about..... | 0.6 |
| Mudstone; greenish-gray; weathers into 2 resistant beds of equal thickness; extremely calcareous; contains a myriad of <u>Derbyia crassa</u> , about..... | 0.4 |

| | Thickness, feet |
|--|--------------------|
| Mudstone; olive gray to greenish-gray; calcareous, weathers into irregularly shaped chunks of all sizes up to 6 inches in long dimension; about..... | 3.0 |
| Mudstone; grayish-red; slightly calcareous; thickness exposed..... | 1.0 |
| Covered interval..... | <u>4.0</u> |
| Total thickness of Tonganoxie-Vinland Mbr..... | 9.0 |
| Iatan (Nehawka) Ls. Mbr. | |
| Limestone (brachiopod lime mudstone); light gray to medium light gray; bedding poorly developed and discontinuous; sparse productid brachiopods; contacts gradational; shaly and nodular in lower 0.5 foot; forms 3 water falls in creek; sparse crinoids and pelecypods in lower 0.5 foot; about..... | 6.0 |
| Weston Sh. Mbr. | |
| Shale; greenish-gray; calcareous; fossiliferous, contains crinoids and brachiopods; about..... | 0.7 |
| Covered interval..... | <u>0.3-0.5</u> |
| Total thickness of Weston Sh. Mbr..... | 1.0-1.2 |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (coated-grain lime packstone); light gray; illustrated as Pl. 12B; thickness exposed..... | 0.2 |
| 4.--Road cut exposure near center west line SE $\frac{1}{4}$ sec. 12, T. 12 N., R. 10 E., Sarpy Co., Nebr. Measured and described in Apr., 1958. | |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone; medium light gray to light brownish-gray; single bed displays prominent vertical jointing; brachiopods, crinoids; overlain by loess; thickness about..... | 1.0 |
| Limestone; yellowish-brown; bedding thin, irregular, and indistinct; abundantly fossiliferous, crinoids, brachiopods, fusulinids; argillaceous; about..... | 3.0 |
| Limestone; yellowish-brown to light gray; single bed; finely crystalline; abundant brachiopods including <i>Crurithyris planoconvexa</i> and abundant crinoid remains; about..... | 0.7 |
| Rock Lake Shale Mbr. | |
| Mudstone; medium light gray; thickness variable..... | 0.7-1.0 |
| Mudstone; grayish-red mottled greenish-gray locally; about..... | 6.5 |
| Shale; greenish-gray; calcareous; about..... | <u>0.2</u> |
| Total thickness of Rock Lake Sh. Mbr..... | 7.4-7.7 |

5.--Quarry exposure in NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 29, T. 12 N., R. 14 E., Cass Co.,
Nebr. See Fig. 28. Measured and described in Dec., 1959.

| | Thickness, feet |
|---|--------------------|
| Shawnee Grp. | |
| Oread Ls. Fm. | |
| ?Kereford Ls. Mbr. | |
| Limestone; light gray to light brownish-gray; a single vertically-jointed bed; predominantly sand- size skeletal fragments in a finely crystalline matrix; <u>Osagia</u> coatings on skeletal grains common; fusulinids, brachiopods; overlain by loess bank as much as 40 feet thick; about..... | 1.0 |
| ?Heumader Sh. Mbr. | |
| Shale; light brown; vague lamination; weathers into subcubical blocks as much as 2 inches in long dimen- sion; sparse fragments of fossils (?brachiopods) in lower 0.2 foot; basal contact gradational through 0.1 foot; slightly silty; about..... | 1.0 |
| Plattsmouth Ls. Mbr. | |
| Limestone; light gray to light brownish-gray; bed- ding thin to thick, indistinct, and discontinuous; finely crystalline matrix; fusulinids and <u>Osagia</u> abundant throughout, productid brachiopods and crinoids common; about..... | 4.7 |
| Shale; light brown; calcareous; fossiliferous; thick- ness variable..... | 0.1-0.3 |
| Limestone; as second above; contacts gradational; thickness variable..... | 0.5-1.0 |
| Shale; greenish-gray; calcareous; contains limestone nodules; abundantly fossiliferous, <u>Neospirifer</u> , other brachiopods, crinoids, fusulinids; thickness variable..... | 0.5-1.5 |
| Limestone; medium gray; a single vertically-jointed bed; very finely crystalline; sparse fusulinids, crinoids, brachiopods, <u>Osagia</u> ; thickness variable | 0.6-0.7 |
| Sh.; as fourth above; about..... | 0.1 |
| Limestone; light brownish-gray; bedding poorly de- veloped and discontinuous; finely crystalline; patches of sparry calcite common; dark greenish- gray chert zones in lower and upper parts; large productid brachiopods, especially <u>Linoproductus</u> and <u>Echinaria</u> in central part, other brachiopods, fusu- linids concentrated in discontinuous shale partings in upper half of unit, sparse <u>Osagia</u> in uppermost foot; about..... | 5.2 |
| Limestone; greenish-gray; shaly; discontinuous; as much as..... | 0.3 |

Thickness,
feet

| | |
|---|-----------|
| Limestone; similar to second above as regards color, bedding, and texture; chert nodules in upper foot; crinoids and brachiopods, especially in lower part, including <u>Hustedia</u> and productids, fusulinids, abundant in central part; about..... | 4.2 |
| Total thickness of Plattsmouth Ls. Mbr..... | 15.4-17.0 |
| Heebner Sh. Mbr. | |
| Shale; light gray; calcareous, <u>Crurithyris planoconvexa</u> , crinoids; about..... | 0.3 |
| Mudstone; light gray to light brownish-gray; calcareous; brachiopods; about..... | 1.0 |
| Shale, grayish-black; fissile in lower 2 feet, platy above; conodonts common, <u>Orbiculoidea</u> sparse; about..... | 2.7 |
| Total thickness of Heebner Sh. Mbr..... | 4.0 |
| Leavenworth Ls. Mbr. | |
| Limestone; medium gray; single bed; finely crystalline; shaly in lower 0.1 foot; fusulinids, crinoids, productid brachiopods, sponges, small spired gastropods, capped by a coquinoid crust composed largely of abundant <u>Chonetes</u> ; sharp upper contact; thickness variable..... | 0.7-0.8 |
| Limestone; medium gray; shaly; crinoids, brachiopods; about..... | 0.1 |
| Limestone; as second above; basal contact gradational through 0.2 foot; thickness variable..... | 0.6-0.7 |
| Total thickness of Leavenworth Ls. Mbr..... | 1.4-1.6 |
| Snyderville Sh. Mbr. | |
| Mudstone; greenish-gray; clayey to silty; slightly calcareous; about..... | 0.2 |
| Shale; greenish-gray; calcareous; extremely abundant <u>Chonetes</u> ; thickness variable..... | 0.05-0.1 |
| Mudstone; as second above; thickness exposed..... | 6.0 |

6.--Quarry exposure near center south line NE $\frac{1}{4}$ sec. 28, T. 13 N., R. 12 E., Sarpy Co., Nebr. See Pl. 35A. Measured and described in Dec., 1959.

Kansas City Grp.

Dennis Ls. Fm.

Winterset Ls. Mbr.

| | |
|--|-----|
| Limestone; light gray to light brownish-gray; bedding indistinct and discontinuous; finely crystalline; discontinuous shaly break in uppermost foot; productid brachiopods, other brachiopods, crinoids, ramose bryozoans, sparse small fusulinids in lower 3 feet, abundant <u>Osagia</u> -coated skeletal grains; about..... | 8.0 |
| Shale; olive gray; slightly calcareous; sparse crinoid fragments; about..... | 0.5 |

| | Thickness, feet |
|---|--------------------|
| Limestone; light gray; single vertically-jointed bed; sparse small fusulinids, <u>Osagia</u> , productid brachiopods, crinoids, ramose bryozoans; about..... | 0.7 |
| Shale; greenish-gray; extremely calcareous; fossiliferous; about..... | 0.1 |
| Limestone; light gray; single bed; finely crystalline; <u>Osagia</u> , small fusulinids, productid brachiopods, <u>Neospirifer</u> , ramose bryozoans, crinoids; dark greenish-gray nodular chert band in upper 0.5 foot; chert nodule-limestone contacts extremely irregular; examples of chert in which limestone blebs are included are common; about..... | 2.0 |
| Limestone; light gray to medium gray; bedding discontinuous; finely crystalline; locally argillaceous; <u>Linoproductus</u> , fenestrate and ramose bryozoans, small fusulinids, crinoids; sparse chert nodules about 1 foot above base; chert light gray and smaller than in overlying unit; about..... | 2.0 |
| Shale; greenish-gray; crinoids; about..... | 0.1 |
| Limestone; as second above; about..... | 3.2 |
| Shale and limestone interbedded; shale, greenish-gray, calcareous, crinoids; limestone, light gray, very thin bedded, shaly, crinoids, sparse brachiopods; about... | 2.5 |
| Limestone; light gray to medium gray; thin- and irregularly-bedded; finely crystalline; productid brachiopods, sparse crinoids, sparse fusulinids, ?linear algae; about..... | 1.3 |
| Shale and limestone interbedded; as second above; about..... | 2.5 |

Iowa

7.--Composite of exposures in SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 5, near center west line NE $\frac{1}{4}$ sec. 7, and in SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 7, T. 75 N., R. 29 W., Madison Co., Ia. Measured and described in Nov., 1959.

Shawnee Grp.

Oread Ls. Fm.

Plattsmouth Ls. Mbr.

| | |
|---|-----|
| Limestone; light brownish-gray; finely crystalline; very thin to thin, wavy bedding; argillaceous in lower part; abundant fusulinids, brachiopods and crinoids common; thickness exposed..... | 1.7 |
| Shale; greenish-gray to light brownish-gray; calcareous; a very argillaceous 0.6 foot thick limestone 1 foot below top; crinoids, brachiopods; about..... | 7.4 |

| | Thickness, feet |
|--|--------------------|
| Limestone; yellowish-brown; earthy; brachiopods; about..... | 1.0 |
| Limestone and shale interbedded; limestone, light gray to light brownish-gray, thin wavy bedding, argillaceous, brachiopods, including <u>Chonetes</u> , crinoids; shale, greenish-gray, calcareous, contains some carbonaceous shale in lower part; about..... | 3.5 |
| Limestone; medium gray; as first above but a single, even, vertically-jointed bed; about..... | 1.5 |
| Heebner Sh. Mbr. | |
| Shale; light gray; calcareous; micaceous; abundantly fossiliferous, <u>Crurithyris planoconvexa</u> , marginiferids, crinoids; about..... | 0.4 |
| Mudstone; greenish-gray to olive; slightly micaceous; about..... | 0.5 |
| Shale; grayish-black; fissile to platy; slightly silty; both bar- and blade-type conodonts; about..... | 1.4 |
| Shale; medium gray; calcareous; abundantly fossiliferous, <u>Crurithyris planoconvexa</u> , crinoids; thickness variable..... | 0.1-0.3 |
| Total thickness of Heebner Sh. Mbr..... | 2.4-2.6 |
| Leavenworth Ls. Mbr. | |
| Limestone; medium gray; single even bed; well developed vertical joint system; very finely crystalline; fractures conchoidally; abundant isolated "heads" of <u>Ottonosia</u> -like algae, bellerophontid gastropods, small slender fusulinids, <u>Crurithyris planoconvexa</u> ; about..... | 1.1 |
| Lawrence-Oread Fm. (boundary not identified) | |
| Snyderville Sh. Mbr. (base not recognized) | |
| Shale; medium gray; slightly silty; calcareous; sparse brachiopods and crinoids; about..... | 2.0 |
| Siltstone to silty limestone; medium gray with blue overtones; nodular; sparsely fossiliferous, brachiopods, ?crinoids; about..... | 0.2 |
| Note-the siltstone zone is as much as 1.5 feet thick at a point 75 yards west of this exposure. | |
| Shale; as second above; but apparently lacks fossils; about..... | 4.0 |
| Shale; greenish-gray; silty; micaceous; about..... | 2.0 |
| Siltstone; grayish-red mottled greenish-gray; slightly calcareous; about..... | 6.0 |
| Siltstone; greenish-gray; calcareous; micaceous; about..... | 2.5 |
| Siltstone and silty shale interbedded; medium gray to greenish-gray upward; micaceous; about..... | 4.0 |
| Shale; medium dark gray to grayish-black; slightly silty; ?conodonts; about..... | 1.0 |

Thickness,
feet

| | |
|--|------------|
| ?Cass Limestone Mbr. | |
| Limestone (mixed-fossil lime packstone); medium gray, silty; skeletal grains are mostly sand- to granule-size and include gastropods, crinoids, ramose bryozoans, pelecypods, and brachiopods; sparse minute fragments of wood; 0.2 inch thick calcareous, apparently unfossiliferous siltstone rind with poorly developed cone-in-cone at top of unit; about..... | 1.0 |
| Shale; greenish-gray; silty; micaceous; poorly exposed; about..... | 3.0 |
| Limestone; as second above; about..... | 0.7 |
| Shale; as second above; about..... | 0.8 |
| Limestone (crinoid lime packstone); light gray with yellowish-brown overtones; argillaceous; crinoids, brachiopods, foraminifers; about..... | <u>0.7</u> |
| Total thickness of ?Cass Ls. Mbr. | 6.2 |
| ?Little Pawnee Sh. Mbr. | |
| Shale; light brownish-gray; silty; micaceous; about. | 1.2 |
| Shale; dark greenish-gray to grayish-black; silty; about..... | 0.2 |
| Shale; as second above; about..... | <u>0.2</u> |
| Total thickness of ?Little Pawnee Sh. Mbr..... | 1.6 |
| ?Haskell Ls. Mbr. | |
| Limestone (coated-grain lime wackestone to packstone); medium gray mottled light brownish-gray; skeletal grains include crinoids, brachiopods, bryozoans, and foraminifers; argillaceous to silty and micaceous; about..... | 1.3 |
| ?Stranger Fm. | |
| ?Tonganoxie-Vinland Mbr. | |
| Shale; light brownish-gray; silty; micaceous about.. | 2.1 |
| Siltstone; yellowish-brown; micaceous; indistinct bedding; about..... | 0.8 |
| Mudstone; greenish-gray; slightly calcareous; slightly micaceous; fractures into subcubical to irregularly-shaped fragments as much as 3 inches in long dimension; about..... | 2.3 |
| Mudstone; grayish-red; as first above; about..... | 5.2 |
| Mudstone; as second above; about..... | 0.3 |
| ?Iatan Ls. Mbr. | |
| Limestone (lime mudstone); medium gray to light brownish-gray; argillaceous to silty; weathers rubbly; sparsely fossiliferous, minute fragments of brachiopods; about..... | 1.0 |
| Limestone (coated-grain lime packstone); light brownish-gray; skeletal grains include ramose bryozoans, brachiopods, crinoids, and foraminifers; about..... | <u>1.0</u> |
| Total thickness of ?Iatan Ls. Mbr..... | 2.0 |

| | Thickness, feet |
|--|--------------------|
| ?Weston Sh. Mbr. | |
| Shale; greenish-gray; calcareous; slightly silty; sparsely fossiliferous; about..... | 0.7 |
| Mudstone; grayish-red; slightly calcareous; slightly micaceous; about..... | 1.0 |
| Mudstone; grayish-red purple; as first above; about. | 6.0 |
| Shale; dark greenish-gray to medium dark gray; slightly silty; micaceous; crinoids, brachiopods, pelecypods including <u>Aviculopecten</u> ; about..... | <u>1.3</u> |
| Total thickness of the ?Weston Sh. Mbr..... | 9.0 |
| ?Lansing Grp. | |
| ?Stanton Ls. Fm. | |
| ?South Bend Ls. Mbr. | |
| Limestone; light brownish-gray; thin to thick and slightly irregular bedding; finely crystalline; argillaceous to silty upward; well-developed pyrite crystals common in central part of unit; brachiopods including <u>Chonetina flemingi</u> and <u>Crurithyris plano-</u> <u>convexa</u> , horn corals, crinoids, and ?linear algae; thins gradually to north in quarry face; basal con- tact gradational; thickness where measured..... | 3.0 |
| Rock Lake Sh. Mbr. | |
| Shale; greenish-gray to medium gray; slightly silty; semi-continuous nodular limestone in upper half of unit; a discontinuous, 0.2 foot thick, grayish-black, coaly shale 0.3 foot below top of unit; <u>Derbyia</u> <u>crassa</u> , <u>Neospirifer</u> , <u>Linoproductus</u> , <u>Crurithyris</u> <u>planoconvexa</u> , abundant <u>Chonetina flemingi</u> , dictyo- clostids, fenestrate bryozoans, and crinoids; about. | 4.0 |
| ?Stoner Ls. Mbr. | |
| Limestone; pinkish-gray; discontinuous thin to very thin beds; very finely crystalline to sublithographic; nodular chert in central part locally; very sparse fauna, spare brachiopods and crinoids in lower part, apparently unfossiliferous in upper 1.5 feet; about. | 4.5 |
| Limestone (coated-grain lime packstone); very light gray to light brownish-gray; thin to thick discon- tinuous beds; grain coatings some of which are definitely <u>Osagia</u> as much as 2 mm thick; skeletal grains include fragments of brachiopods, crinoids, bryozoans, and foraminifers and tiny, unfragmented, high-spined gastropods; thickness described..... | 4.0 |
| Note - about 13 additional feet of section is exposed but was not studied. | |

8.--Quarry exposure in NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 13, T. 76 N., R. 28 W., Madison Co., Ia. About 2.5 miles north of Winterset, Iowa on U. S. Highway 169. See Pl. 35C. Measured and described in Nov., 1959.

| | Thickness, feet |
|---|--------------------|
| Kansas City Grp. | |
| Dennis Ls. Fm. | |
| Winterset Ls. Mbr. | |
| Limestone; light brownish-gray; single bed; osagite texture; <u>Osagia</u> -coated, sand- to granule-sized skeletal grains include crinoids, brachiopods, and pelecypods; fusulinids, other foraminifers, bryozoans, silicified brachiopod and pelecypod valves; sparse chert nodules in lower 2 feet; about..... | 3.9 |
| Shale, yellowish-brown; calcareous; brachiopods, crinoids; about..... | 0.3 |
| Limestone; yellowish-gray; upper 0.7 foot a single bed, lower 0.6 foot very thin bedded; finely crystalline; ?linear algae, productid brachiopods, pelecypods, crinoids; lower part contains irregularly-shaped and sharply-bounded areas of osagite that weathers as nodules; about..... | 1.3 |
| Shale; yellowish-brown; extremely calcareous; about. | 0.5 |
| Limestone; light olive gray; a single bed; finely crystalline; lower 0.2 foot and upper 0.2 foot argillaceous to silty; crinoids, productid brachiopods, bellerophontid gastropods, robust fusulinids, ?linear algae; about..... | 1.0 |
| Shale; as second above; about..... | 0.5 |
| Limestone; light olive gray mottled grayish-yellow; wavy beds 0.3 foot to 1.3 feet thick and separated by greenish-gray calcareous shale partings; texture as second above; fauna as second above but fusulinids are slender and not as robust; nodular chert in upper 1.5 feet; about..... | 6.1 |
| Stark Sh. Mbr. | |
| Shale; greenish-gray; slightly calcareous; sparse brachiopod and crinoid fragments in upper part; about. | 1.0 |
| Shale; grayish-black; fissile; conodonts; thickness variable..... | <u>2.1-2.3</u> |
| Total thickness of Stark Sh. Mbr..... | <u>3.1-3.3</u> |
| Note - because the Canville Ls. Mbr. is absent, base of the Dennis Ls. Fm. is placed arbitrarily at base of the black, fissile part of the Stark Sh. Mbr. | |
| Galesburg Sh. Fm. | |
| Shale; yellowish-brown to greenish-gray; slightly calcareous and contains sparse crinoid fragments in upper 0.5 foot; thickness measured and described. | 3.0 |

Missouri

9.--Quarry exposure in NW $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 52 N., R. 35 W., Platte Co., Mo. See Pl. 46 for illustration of South Bend Ls. lithology and Fig. 9, section 1. Measured and described in Jul., 1959.

| | Thickness, feet |
|---|--------------------|
| Douglas Grp. | |
| Stranger Fm. | |
| Weston Sh. Mbr. | |
| Shale; light bluish-gray; vague lamination; weathers into irregularly-shaped to subcubical fragments as much as 0.5 foot in long dimension; slightly silty; contains numerous clay-ironstone concretions that are (in part) arranged in "layers"; thickness exposed below Pleistocene deposits, about..... | 20.0 |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone); light olive gray to light brownish-gray in lower and upper beds, medium light gray with medium bluish-gray overtones in middle bed; relatively even beds that are 0.1 foot, 1.4 feet, and 1.2 feet thick in descending order; elongate (as large as 0.2 inch by 3 inches) inclusions of medium bluish-gray shale weather out and impart a distinctive pocked surface upon the middle bed; brachiopods including <u>Chonetina flemingi</u> and <u>Meekella striatocostata</u> , crinoids, fusulinids, high-spired gastropods, <u>Osagia</u> , and <u>Ottonosia</u> ; algal coatings of fragmented skeletal grains common especially in lower bed, e. g. Pl. 46C); about..... | 2.7 |
| Limestone (quartzose molluscan lime wackestone); medium light gray with medium bluish-gray overtones; weathers as a single bed in upper half and into numerous discontinuous beds in lower half; abundant quartz silt in lower foot (e. g. Pl. 46E); contacts gradational; sparse brachiopods including <u>Composita</u> , gastropods common, pelecypods including <u>Myalina</u> and <u>Aviculopecten</u> abundant; about..... | <u>1.4</u> |
| Total thickness of South Bend Ls. Mbr..... | <u>4.1</u> |
| Rock Lake Sh. Mbr. | |
| Shale; greenish-gray to light olive gray; clayey to silty upward; upper contact gradational; thickens slightly westward in quarry face; thickness where measured, about..... | 6.8 |
| Stoner Limestone Mbr. | |
| Note - The Stoner Ls., Eudora Sh., and Captain Creek Ls. Members of the Stanton Ls. are exposed | |

Thickness,
feet

at this locality and are shown graphically (see Fig. 9, section 1) for the purpose of documenting correlations. Descriptions of these members are not regarded as necessary to this report.

10.--Quarry exposure near center NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 31, T. 53 N., R. 35 W., Platte Co., Mo. See Fig. 35B. Measured and described in Nov., 1959.

Douglas Grp.

Stranger Fm.

Vinland Sh. Mbr.

Shale; greenish-gray; clayey to slightly silty; micaceous; thickness exposed below Pleistocene deposits..... 1.0

Westphalia Ls. Mbr.

Limestone; a discontinuous stringer observed at only one spot above quarry face; carbonaceous; crinoids, brachiopods, ostracodes; featheredge to about..... 0.1

Tonganoxie Ss. Mbr.

Coal (Upper Sibley bed); interlaminated coal and clayey shale; about..... 0.5
Shale; as third above; about..... 11.0

Conglomerate; light gray; relatively even and discontinuous bedding; cut-and-fill stratification locally; coarse fraction includes sand- to pebble-sized limestone fragments, sparse mudstone and shale pebbles, extremely sparse quartz grains and mica flakes, common to abundant invertebrate fossils and sparse carbonaceous matter; fragments of the Iatan and South Bend Limestones were recognized; coarse constituents cemented by microspar and sparry calcite; matrix constituents other than calcium carbonate are negligible; overly close fit of particles could not have been the product of normal sedimentary processes (see Fig. 38A, B, E and F and Pl. 54D for textural details); contains fossiliferous (see Table 6, location 3); shale lenses locally; small-scale intercalation with underlying shale observable locally; conglomerate pinches out to north of quarry face; thickness variable in quarry face; about... 1.0-9.0

Note - this conglomerate unit is developed as lenses northward along bluff and questionably passes laterally into the Iatan Ls. Mbr. of the Stranger Fm. The Iatan was the principal source of the conglomerate at this locality and distance of transport was short.

| | Thickness, feet |
|---|--------------------|
| Disconformity | |
| Weston Shale Mbr. | |
| Shale; light bluish-gray; clayey to slightly silty; thickness variable; about..... | 7.0-15.0 |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone); facies as in stratigraphic section 9 but is a single bed; about..... | 1.0 |
| Limestone (quartzose molluscan lime wackestone); facies as in stratigraphic section 9; about..... | 1.5-1.6 |
| Rock Lake Sh. Mbr. | |
| Shale; facies as in stratigraphic section 9; about.. | 2.5 |
| Stoner Ls. Mbr. | |
| Limestone; not described; thickness exposed, about.. | 13.0 |
| 11.--Road cut exposure in SW $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 31, T. 53 N., R. 35 W., Platte Co., Mo. See Pl. 16. Measured and described in July, 1959. | |
| Douglas Grp. | |
| Stranger Fm. | |
| Iatan Ls. Mbr. | |
| Limestone; light gray to light brownish-gray; finely crystalline; moderately fossiliferous, contains brachiopods including <u>Composita</u> and <u>Phricodothyris</u> , sparse crinoids; exposed below Pleistocene deposits, about..... | 9.0 |
| Weston Sh. Mbr. | |
| See Pl. 16 and p. 73 to p. 75 for detailed descrip- tion; about..... | 59.0 |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone); facies as in stratigraphic section 9; yellowish-brown and reddish-brown rind that is 0.1 foot thick developed at top of unit; about..... | 1.5 |
| Total thickness of South Bend Ls. Mbr..... | 3.0 |
| Rock Lake Sh. Mbr. | |
| Note - the entire Stanton Ls. Fm., about 28.0 feet thick, and the upper 11.0 feet of the Vilas Shale are exposed at this locality (see Pl. 16). | |

12.--Composite of quarry exposures near center sec. 30 and near center west line NE $\frac{1}{4}$ sec. 30, T. 53 N., R. 35 W. (Stoner Ls. Mbr. of Stanton Ls. Fm. to Iatan Ls. Mbr. of Stranger Fm.) and in SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 33, T. 54 N., R. 36 W. (Iatan Ls. Mbr. of Stranger Fm. to Robbins Sh. Mbr. of Lawrence Fm.) Platte Co., Mo. See Pl. 34E and Table 8 (last locality). Measured and described in July, 1959.

| | Thickness, feet |
|---|--------------------|
| Douglas Grp. | |
| Lawrence Fm. | |
| Robbins Sh. Mbr. | |
| Shale; greenish-gray; clayey to slightly silty; micaceous; exposed below Pleistocene deposits, about..... | 2.0 |
| Haskell Ls. Mbr. | |
| Limestone; greenish-gray; very thin-bedded; argillaceous; weathers to a rubble; abundantly fossiliferous, crinoids, brachiopods, bryozoans; about..... | 1.1 |
| Stranger Fm. | |
| Vinland Sh. Mbr. | |
| Mudstone; greenish-gray to yellowish-brown; calcareous; weathers into irregularly-shaped to sub-cubical blocks as much as 0.4 foot in long dimension; sparse small pelecypods and brachiopods including <u>Crurithyris planoconvexa</u> ; about..... | 8.8 |
| Limestone; yellowish-brown; silty to argillaceous upward; in part weathers to a rubble; abundant <u>Myalina</u> and nuculid pelecypods, abundant marginiferid brachiopods; about..... | 1.0 |
| Mudstone; as second above but abundantly fossiliferous; profuse <u>Myalina</u> , abundant nuculid pelecypods, <u>Composita</u> common; about..... | <u>4.1</u> |
| Total thickness of the Vinland Sh. Mbr..... | 13.9 |
| Westphalia Ls. Mbr. | |
| Limestone (ostracode coaly lime mudstone); light gray to greenish-gray and black interlaminae of limestone and coaly material; ostracodes, gastropods; discontinuous, exposed only at north end of quarry face; thickness variable; featheredge to about..... | 0.3 |
| Tonganoxie Ss. Mbr. | |
| Coal (Upper Sibley bed); shaly; contacts gradational; about..... | 0.6 |
| Mudstone; yellowish-brown to greenish-gray; silty to clayey upward; calcareous; in part weathers to a rubble; thickness variable, about..... | 5.5 to 9.0 |
| Note - see Table 8 (last locality) for listing of fossils obtained from washings of a sample of the Tonganoxie Ss. and a sample of basal | |

Thickness,
feet

Vinland Sh. collected at a spot where the Westphalia Ls. is absent.

Note - Upper Sibley coal bed truncates upper half of Tonganoxie Ss. in southern part of quarry face.

Iatan Ls. Mbr.

Limestone; light gray mottled yellowish-brown; thin to thick discontinuous beds; bedding relatively even to slightly irregular; brachiopods including Composita, Chonetes granulifer, crinoids, horn corals, fenestrate bryozoans, ramose bryozoans, fusulinids, and Osagia-coated skeletal fragments in upper 2 feet; about.....

14.5

Note - upper 2.5 feet studied in SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 33, T. 54 N., R. 36 W. and remainder of member studied near center west line NE $\frac{1}{4}$ sec. 30, T. 53 N., R. 35 W. At the last-mentioned locality the Iatan Ls. is faulted. The fault trends slightly east of north-slightly west of south and the northwest block is downthrown about 12 feet. Fault breccia and slickensides were observed at north end of quarry face.

Weston Sh. Mbr.

Shale; light brownish-gray to greenish-gray; calcareous; fossiliferous in lower part; about.....

1.0

Limestone; light gray; extremely argillaceous; abundantly fossiliferous; brachiopods including Composita, Wellerella, Derbyia, Hustedia, Punctospirifer, the crinoid Delocrinus, fenestrate bryozoans, and ramose bryozoans; contacts gradational; about.....

1.0

Shale; mostly covered; upper and lower parts light gray with light bluish-gray overtones; about.....

67.0

Total thickness of Weston Sh. Mbr.

69.0

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr. top.

Note - Stoner Ls. Mbr. to South Bend Ls. Mbr. of Stanton Ls. is exposed but was not measured or described.

12A.--Quarry and bluff exposures near center east line sec. 24, T. 53 N., R. 36 W., Platte Co., Mo. This section extends from the lower part of the Vinland Sh. Mbr. (Stranger Fm., Douglas Grp.) to the Stoner Ls. Mbr. (Stanton Ls. Fm., Lansing Grp.) and is illustrated as Pl. 34E. (lower part). Rock types developed within the various members are similar to corresponding facies described in stratigraphic section 12.

13.--Quarry exposure near center SE $\frac{1}{4}$ sec. 33, T. 54 N., R. 36 W., Platte Co., Mo. See Pl. 18A. Measured and described in July, 1959.

| | Thickness, feet |
|---|--------------------|
| Douglas Grp. | |
| Stranger Fm. | |
| Tonganoxie Ss. Mbr. | |
| Siltstone; greenish-gray to yellowish-brown; platy bedding; calcareous; micaceous; carbonaceous; exposed below loess, about..... | 0.7 |
| Shale; greenish-gray; silty; micaceous; about..... | 2.5 |
| Mudstone; light brownish-gray; micaceous; sparse carbonaceous material; about..... | 0.7 |
| Iatan Ls. Mbr. | |
| Limestone; light gray to light brownish-gray; see Pl. 18A for bedding, textural, and faunal characteristics; genera identified include the brachiopods <u>Neospirifer</u> , <u>Composita</u> , <u>Phricodothyris</u> , and <u>Punctospirifer</u> ; about..... | 17.4 |
| Weston Sh. Mbr. | |
| Shale; greenish-gray; silty, contains a 0.1 foot thick siltstone in uppermost foot; thickness exposed, about..... | 2.0 |

14.--Quarry access road exposure in NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 30, T. 54 N., R. 36 W., Platte Co., Mo. See Pl. 21A and B for illustration of Westphalia Limestone lithology. Measured and described in Nov., 1959.

| | |
|--|-------|
| Shawnee Grp. | |
| Oread Ls. Fm. | |
| Toronto Ls. Mbr. base. | |
| Douglas Grp. | |
| Lawrence Fm. | |
| Robbins-Wathena Mbr. | |
| Shale and mudstone; mostly covered; grayish-red mudstone within upper 10 feet; remainder is greenish-gray silty shale where exposed; about..... | 40.0 |
| Shale and mudstone; greenish-gray to light brownish-gray; in part silty; micaceous; several horizons of clay-ironstone concretions and a coal smut in the upper 25 feet; exact stratigraphic positions of coal and concretions not established because of slumping and partial cover; about..... | 103.0 |
| Total thickness of Robbins-Wathena Mbr..... | 143.0 |
| Haskell Ls. Mbr. | |
| Limestone; light gray; very thin bedded; argillaceous; weathers to a rubble; composed largely of fossil detritus (especially crinoid debris), brachiopods, mollusks; about..... | 0.5 |

| | Thickness, feet |
|---|--------------------|
| Stranger Fm. | |
| Vinland Sh. Mbr. | |
| Mudstone; greenish-gray; abundantly fossiliferous, molluscan fauna of mainly pelecypods and gastropods, brachiopods; about..... | 1.0 |
| Limestone; greenish-gray; contacts gradational; argillaceous to silty; brachiopods including abundant chonetids, mollusks; about..... | 0.4 |
| Mudstone to shale; as second above but part has vague lamination and is much less fossiliferous; brachiopods and pelecypods in uppermost 2 feet; about..... | <u>10.0</u> |
| Total thickness of Vinland Sh. Mbr..... | 11.4 |
| Westphalia Ls. Mbr. | |
| Limestone (ostracode coaly lime mudstone, see Pl. 21A); greenish-gray to light brownish-gray, in part streaked black by carbonaceous interlaminae; argillaceous; ostracodes; about..... | 0.4 |
| Shale; yellowish-brown; calcareous; carbonaceous; micaceous; about..... | 0.2 |
| Limestone; as second above (see Pl. 21B) but fewer ostracodes and more carbonaceous; contacts gradational; about..... | <u>0.4</u> |
| Total thickness of the Westphalia Ls. Mbr..... | 1.0 |
| Tonganoxie Ss. Mbr. | |
| Mudstone; greenish-gray to olive gray; weathers to subcubical fragments as much as 0.2 foot in long dimension; about..... | 2.8 |
| Siltstone; yellowish-brown; very thin-bedded; small-scale ripple marking and cross-stratification; calcareous; about..... | 3.2 |
| Shale; greenish-gray to light brownish-gray; silty; micaceous; about..... | <u>3.2</u> |
| Total thickness of Tonganoxie Ss. Mbr..... | 9.2 |
| Iatan Ls. Mbr. top | |

15.--Railroad cutbank exposure at NW corner NE $\frac{1}{2}$ SW $\frac{1}{2}$ sec. 19, T. 54 N., R. 36 W., Platte Co., Mo. See Pl. 17. Measured and described in Jul., 1959.

Douglas Grp.

 Lawrence Fm.

 Robbins Sh. Mbr.

 Shale; light brownish-gray to greenish-gray; micaceous; thickness exposed; about..... 1.5

Thickness,
feet

| | |
|--|-----|
| Haskell Ls. Mbr. | |
| Limestone (crinoid lime packstone, see Pl. 26C); light gray; weathers into platy beds; composed largely of skeletal debris (mainly crinoid detritus); exposed in gulley above cutbank about 125 yards north of Iatan; about..... | 0.7 |
| Stranger Fm. | |
| Vinland Sh. Mbr. | |
| Shale; greenish-gray; calcareous; extremely fossiliferous, abundant brachiopods including <u>Chonetes</u> , <u>Composita</u> , <u>Phricodothyris</u> , <u>Nudirostra</u> , and <u>Chonetina</u> , the pelecypod <u>Myalina</u> , the gastropods <u>Retispira</u> and <u>Hypselentoma</u> , horn corals, crinoids, fenestrate bryozoans, and ramose bryozoans; about..... | 2.0 |
| Shale; light gray with medium bluish-gray overtones; clayey to slightly silty; about..... | 5.7 |
| Limestone (ostracode coaly lime mudstone); light brownish-gray; argillaceous to silty; interlaminated carbonaceous material, limestone, and clay to silt; basal contact gradational; ostracodes, gastropods, sparse brachiopods; about..... | 0.8 |
| Tonganoxie Ss. Mbr. | |
| Shale; greenish-gray to yellowish-brown; silty; about..... | 2.7 |
| Shale and siltstone interbedded; light brownish-gray to yellowish-brown; sh, silty, micaceous; siltstone, platy beds, in part calcareous, about..... | 3.2 |
| Total thickness of the Tonganoxie Ss. Mbr..... | 5.9 |
| Iatan Ls. Mbr. | |
| See Pl. 17 and p. 78 to p. 81 for detailed description. | |

16.--Creek bank exposure in NW $\frac{1}{4}$ SE $\frac{1}{2}$ NE $\frac{1}{4}$ sec. 12, T. 54 N., R. 37 W., Platte Co., Mo. See Pl. 34D. Measured and described in Nov., 1959.

Douglas Grp.

Lawrence Fm.

Robbins-Ireland Mbr.

| | |
|--|------|
| Shale; greenish-gray, silty to clayey; thickest at east end of exposure; maximum exposed thickness, about..... | 10.0 |
| Limestone; yellowish-brown; cross-stratified; abundant crinoids and sparse brachiopods in a predominantly sparry calcite matrix; pinches out at east end of exposure; thickness variable; feathered edge to about..... | 2.0 |

| | Thickness, feet |
|---|--------------------|
| Shale; greenish-gray to light brownish-gray; vague lamination; silty; weathers into subcubical blocks as much as 0.4 foot in long dimension; about..... | 10.5 |
| Limestone; light brownish-gray; a single bed; crinoid and brachiopod fragments in a lime mud matrix; about..... | 1.0 |
| Shale to mudstone; greenish-gray; silty; micaceous; about..... | 14.0 |
| Limestone; yellowish-brown; a zone of extremely ferruginous concretions; about..... | 0.3 |
| Note - the probable correlation of the succeeding five units with the Cass Ls. of Nebraska terminology is shown on Pl. 34. | |
| Shale; greenish-gray to olive gray; clayey to silty; about..... | 1.0 |
| Haskell Ls. Mbr. | |
| Limestone; light gray with greenish-gray overtones; an 0.1 foot thick reddish-brown rind atop unit; crinoids, brachiopods including <u>Rhipidomella</u> ; about.... | 0.8 |
| Vinland Sh. Mbr. | |
| Mudstone; greenish-gray; extremely calcareous; sparsely fossiliferous, myalinid pelecypods in uppermost 0.5 foot; contacts gradational; about..... | 4.0 |
| Limestone; light gray; argillaceous; weathers to a rubble of irregularly-shaped fragments; abundantly fossiliferous, brachiopods, bryozoans, crinoids; about..... | 0.7 |
| Shale; medium gray with medium bluish-gray overtones; locally a mudstone that lacks lamination; silty; thickness exposed, about..... | 6.0 |

17.--Ravine exposure along east line SW $\frac{1}{4}$ sec. 33, T. 56 N., R. 36 W., Buchanan Co., Mo. Measured and described in Nov., 1959.

Shawnee Grp.

Oread Ls. Fm.

Toronto Ls. Mbr. base

Douglas Grp.

Lawrence Fm.

Wathena Sh. Mbr.

| | |
|--|------|
| Shale; greenish-gray to light brownish-gray; silty; in part calcareous; about..... | 3.0 |
| Mudstone; grayish-red mottled greenish-gray; weathers into irregularly-shaped to subcubical blocks as much as 0.3 foot in long dimension; about..... | 5.0 |
| Shale; greenish-gray and yellowish-gray; locally a mudstone; silty; about..... | 47.0 |

Thickness,
feet

| | |
|---|------|
| Siltstone; yellowish-brown; very thin-bedded; mica- ceous; carbonaceous; ?plant remains; about..... | 10.0 |
| Amazonia Ls. Mbr. | |
| Limestone; light gray; very finely crystalline; sparsely fossiliferous, brachiopods, crinoids, ?lin- ear algae; about..... | 6.0 |
| Note - near center sec. 33, T. 56 N., R. 36 W., the Amazonia Ls. is, in greater part, cross- stratified. | |
| Robbins-Ireland Mbr. | |
| Sh.; greenish-gray to yellowish-brown upward; locally mudstone; clayey to silty upward; thickness exposed, about..... | 43.0 |
| 18.--Road cut exposure in NW $\frac{1}{4}$ sec. 29, T. 57 N., R. 35 W., Buchanan Co., Mo. Measured and described in Nov., 1959. | |
| Douglas Grp. | |
| Lawrence Fm. | |
| Wathena Sh. Mbr. | |
| Shale; greenish-gray; clayey to silty; thickness ex- posed below loess, about..... | 1.0 |
| Amazonia Ls. Mbr. | |
| Limestone and shale interbedded; limestone, light gray, argillaceous, 0.2 foot thick bed, sparsely fossiliferous; shale, greenish-gray, calcareous, sparsely fossiliferous, about..... | 1.0 |
| Limestone; light gray; indistinct and discontinuous bedding; very finely crystalline; sparsely fossili- ferous; about..... | 7.0 |
| Robbins-Ireland Mbr. | |
| Shale; greenish-gray to yellowish-brown; locally a mudstone; calcareous and sparsely fossiliferous in uppermost foot; about..... | 48.0 |
| Limestone and shale interbedded, light gray to greenish-gray; limestone, very thin-to thin-bedded; shale, extremely calcareous, lamination indistinct; both limestone and shale abundantly fossiliferous, brachiopods including <u>Chonetes</u> , <u>Crurithyris planocon-</u> <u>vexa</u> , <u>Linoproductus</u> , <u>Punctospirifer</u> , and <u>Rhipidomella</u> <u>carbonaria</u> , gastropods, pelecypods including <u>Myalina</u> , and crinoids; about..... | 3.4 |
| Shale; greenish-gray; clayey to silty; about..... | 6.0 |
| Covered interval; about..... | 10.0 |

| | Thickness, feet |
|--|--------------------|
| Limestone; light gray with yellowish-brown overtones; bedding indistinct and discontinuous; finely crystalline; prominent vertical joints; crinoids, productid brachiopods, sponges; about..... | 2.0 |
| Note - succeeding three units probably correlate with the Cass Ls. of Nebraska terminology. | |
| Shale; light gray; calcareous in upper part; thickness exposed; about..... | 1.0 |
| 19.--Quarry exposure in SE $\frac{1}{4}$ SE $\frac{1}{2}$ SW $\frac{1}{4}$ sec. 31, T. 58 N., R. 35 W., Buchanan Co., Mo. | |
| Shawnee Grp. | |
| Oread Ls. Fm. | |
| Toronto Ls. Mbr. base | |
| Douglas Grp. | |
| Lawrence Fm. | |
| Wathena Sh. Mbr. | |
| Shale; greenish-gray; silty; about..... | 3.5 |
| Mudstone; grayish-red mottled greenish-gray in marginal parts; silty; about..... | 6.0 |
| Siltstone; yellowish-brown; very thin-bedded; calcareous; about..... | 2.0 |
| Shale; olive gray to greenish-gray; silty; micaceous; about..... | 8.0 |
| Total thickness of the Wathena Sh. Mbr..... | 19.5 |
| Amazonia Ls. Mbr. | |
| Limestone; light gray to medium light gray; thin to thick indistinct and discontinuous beds; very finely crystalline; sparsely fossiliferous, brachiopods, bryozoans, crinoids; basal contact covered; thickness exposed, about..... | 11.0 |
| 20.--Quarry exposure near SE corner SW $\frac{1}{4}$ sec. 19, T. 58 N., R. 35 W., Andrew Co., Mo. See Fig. 35D. Measured and described in Nov., 1959. | |
| Shawnee Grp. | |
| Oread Ls. Fm. | |
| Leavenworth Ls. Mbr. base | |
| Snyderville Sh. Mbr. | |
| Shale; greenish-gray; locally mudstone; silty; about. | 30.0 |
| Conglomerate and shale interbedded; conglomerate, light gray to medium light gray, in part cross-stratified, in part graded bedding, beds bifurcate and are intercalated with shale, sand- to cobble-size | |

Thickness,
feet

| | |
|--|-------------|
| limestone fragments, matrix comprises both sparry calcite and lime mud, grains extremely closely packed, skeletal grains in part rounded and polished, brachiopods, crinoids, fusulinids, thickness variable, where measured, about..... | 7.0 |
| Shale to mudstone; greenish-gray; silty; micaceous; in part calcareous; interbedded cross-stratified siltstone that is truncated by overlying conglomerate; fossiliferous (see listing in Table 6, locality 4); thickness variable; where measured, about... | 7.0 |
| Conglomerate; light gray to medium light gray; thick indistinct and discontinuous bedding; coarse fraction includes sand- to boulder-size limestone fragments (see Pl. 54B), sparse shale pebbles, pebbles of an extremely irregular shape (see Fig. 38 C, D, G, and H and Pl. 54C); sparry calcite and lime mud matrix; fossiliferous (see Table 6, locality 4; Fig. 37, and Pl. 54A); skeletal grains rounded and polished; thickness where measured, about..... | <u>10.2</u> |
| Total thickness of Snyderville Sh. Mbr..... | 54.2 |

Disconformity

Douglas Grp.

Lawrence Fm.

Amazonia Ls. Mbr.

| | |
|---|-----|
| Limestone; medium light gray; very finely crystalline; sparsely fossiliferous, crinoids, brachiopods; not exposed; excavated in ravine at northwest edge of quarry face; about..... | 0.8 |
|---|-----|

Note - the remnant of Amazonia Ls. and the overlying conglomerate unit were traced laterally into uneroded Amazonia Ls. Near the center south line SE $\frac{1}{4}$ sec. 19, T. 58 N., R. 35 W., about 60 feet of section that extends downward to the lower part of the Robbins Shale are exposed. These outcrops contain the two post-Haskell, pre-Ama-zonia limestones described in stratigraphic section 18.

21.--Railroad cutbank exposure near SE corner SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 59 N., R. 36 W., Andrew Co., Mo. See Pl. 29. Measured and described in Nov., 1959.

Shawnee Grp.

Oread Ls. Fm.

Toronto Ls. Mbr. base

Thickness,
feet

Lawrence Fm.

Wathena Sh. Mbr.

Shale; greenish-gray to yellowish-brown in uppermost and lowermost parts, grayish-red mudstone mottled greenish-gray in upper 10 feet (mostly covered, exact stratigraphic position of mudstone not determined); about.....

26.0

Amazonia Ls. Mbr.

See Pl. 29 and p. 150 to p. 153 for detailed description, about.....

7.2

Robbins-Ireland Mbr.

Shale; greenish-gray to light brownish-gray; silty; micaceous; interbedded siltstone in central part; thickness exposed, about.....

33.0

22.--Clay pit exposure near center east line NW $\frac{1}{4}$ sec. 14, T. 54 N., R. 35 W., Platte Co., Mo. Measured and described in Nov., 1958.

Douglas Grp.

Lawrence Fm.

Haskell Ls. Mbr.

Limestone; light gray to light brownish-gray; very thin-bedded; argillaceous; weathers to a rubble; contacts gradational; abundantly fossiliferous, crinoids, brachiopods, bryozoans, sparse fusulinids; thickness exposed, about.....

1.3

Stranger Fm.

Tonganoxie-Vinland Mbr.

Shale; greenish-gray; calcareous; micaceous; an extremely argillaceous limestone in lower 0.7 foot; abundantly fossiliferous, the pelecypods, Myalina subquadrata, Astartella, Aviculopinna, and Aviculopecten, the gastropods, Bellerophon, Retaspira, Pharkidonotus, and Amphiscapha, the brachiopods Chonetes granulifer, Meekella striatocostata, and Derbyia, and crinoids; about.....

2.7

Mudstone; greenish-gray to olive gray; upper part calcareous; weathers into subcubical blocks as much as 0.2 foot in long dimension; about.....

9.7

Mudstone; grayish-red; as first above; about.....

1.3

Shale to mudstone; greenish-gray to light brownish-gray; lower part calcareous; micaceous; about.....

2.0

Iatan Ls. Mbr.

Limestone; light brownish-gray; even beds 0.2 foot to 4 feet thick; discontinuous bedding developed within thicker beds; interbedded calcareous shale

Thickness,
feet

partings; finely crystalline; pyrite crystals in uppermost foot; sparsely fossiliferous, crinoids, brachiopods, bryozoans, fusulinids; basal contact gradational; about..... 9.5

Weston Sh. Mbr.

Shale; light gray with greenish-gray and light bluish-gray overtones; upper 5 feet calcareous and contains brachiopods and crinoids; locally a mudstone when exposed during quarrying operation, but weathers to shale; thickness exposed; about..... 50.0

Note - according to plant manager, drillings have established that the Weston Sh. is approximately 100 feet thick at this locality.

23.--Streambank exposure in NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 24, T. 56 N., R. 35 W., Buchanan Co., Mo. See Pl. 18B (for illustration of Iatan Ls. lithology), Pl. 26B (for illustration of Haskell Ls. lithology), and Pl. 34C. Measured and described in Nov., 1958.

Douglas Grp.

Lawrence Fm.

?Ireland Ss. Mbr.

Sandstone; yellowish-brown; massive splitting; microscopic cross lamination; very fine-grained to siltstone; grains subrounded to subangular and equant; grains partially covered with a ferruginous (?limonitic) stain; thickness exposed, about..... 5.0

Note - the Amazonia Ls. Mbr. is not exposed at this locality. Channeling at base of the Snyderville Sh. Mbr. (Oread Ls. Fm., Shawnee Grp.) is known in northwest Missouri exposures (e.g. stratigraphic section 20). The sandstone exposed at this locality may be younger than the Ireland Ss.; therefore the stratigraphic identification is queried.

Robbins Sh. Mbr.

Shale and mudstone; olive gray to greenish-gray; silty; carbonaceous; about..... 29.0

Limestone (crinoidal lime wackestone); light brownish-gray; a single bed; prominent vertical joints; fractures conchoidally; abundant crinoids, sparse to common brachiopods and bryozoans; matrix comprises predominantly sparry calcite and some lime mud (texture illustrated on Pl. 34C); contacts sharp; about..... 1.5

Shale and mudstone; light greenish-gray to olive gray; silty; micaceous; upper 1 foot calcareous; sparse pectinoid pelecypod molds; about..... 25.0

Thickness,
feet

| | |
|--|------|
| Limestone; medium bluish-gray with yellowish-brown overtones; nodular; very finely crystalline; extremely ferruginous; sparse ?brachiopod fragments; about..... | 0.3 |
| Note - succeeding three units probably correlate with the Cass Ls. of Nebraska terminology. | |
| Shale; grayish-black; fissile to platy; phosphatic nodules, concodonts including <u>Ozarkodina</u> and <u>Hindeodella</u> ; about..... | 1.7 |
| Note - basal Robbins Sh. of Kansas-Missouri nomenclature correlates with the Little Pawnee Sh. of Nebraska terminology. | |
| Haskell Ls. Mbr. | |
| Limestone (mixed-fossil lime packstone); light brownish-gray; a single bed; skeletal grains include fragmented crinoids, productid and other brachiopods, bryozoans, sparse fusulinids, and other foraminifers; <u>Osagia</u> coatings on grains common; matrix predominantly sparry calcite with some lime mud; basal contact gradational; about..... | 0.6 |
| Stranger Fm. | |
| Tonganoxie-Vinland Mbr. | |
| Limestone; light brownish-gray; bedding poorly defined; extremely argillaceous; weathers to a rubble; gastropods, pelecypods, crinoids, brachiopods, about.. | 0.6 |
| Shale to mudstone; olive gray to yellowish-brown; silty to clayey upward; micaceous; about..... | 16.0 |
| Iatan Ls. Mbr. | |
| Limestone; light gray to light brownish-gray; see Pl. 18B for vertical variation in bedding, textural, and faunal characteristics; genera identified include the brachiopods <u>Hustedia</u> and <u>Neospirifer</u> ; about..... | 5.3 |
| Weston Sh. Mbr. | |
| Shale; greenish-gray; lamination indistinct locally; clayey to slightly silty; micaceous; thickness exposed, about..... | 8.0 |
| Note - since this section was studied, construction of the Little Ozark Lake dam has obliterated the best exposure of the Haskell Ls.-Little Pawnee Sh. part of the section. A good exposure of these strata was studied 0.5 mile west of stratigraphic section 23 and is described below as a supplementary section. | |

23A.--Streambank exposure in SE $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 23, T. 56 N., R. 35 W., Buchanan Co., Mo. See Pl. 34B. Section by S. M. Ball and G. F. Stewart. Measured and described in Dec., 1963.

| | Thickness, feet |
|--|--------------------|
| Douglas Grp. | |
| Lawrence Fm. | |
| Robbins Sh. Mbr. | |
| Limestone (crinoidal lime packstone); light brownish-gray, with medium bluish-gray overtones; single bed; prominent vertical joints; profuse crinoid debris, sparse to common brachiopods, bryozoans, and foraminifers; skeletal grains extensively abraded and closely packed; matrix predominantly sparry calcite with some lime mud; exposed below Pleistocene deposits, about..... | 0.6 |
| Limestone; as above but argillaceous; basal contact gradational; about..... | 0.2 |
| Note - this limestone probably correlates with the basal part of the Cass Ls. of Nebraska terminology. | |
| Mudstone; greenish-gray; weathers into irregular to subcubical fragments as much as 0.5 foot in long dimension; contains some discontinuous stringers of black, fissile shale; basal contact gradational; about..... | 0.5 |
| Shale; black; fissile; basal contact gradational; about..... | 0.15 |
| Shale to mudstone; greenish-gray; about..... | 0.1 |
| Note - the succeeding three units correlate with the Little Pawnee Sh. of Nebraska terminology. | |
| Haskell Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone); light brownish-gray; a single bed; argillaceous; crinoids, brachiopods, bryozoans, foraminifers, gastropods; basal contact gradational; thickness variable..... | 0.3-0.5 |
| Stranger Fm. | |
| Vinland Sh. Mbr. | |
| Limestone; greenish-gray; extremely argillaceous; weathers to a rubble; abundantly fossiliferous, productid brachiopods, other brachiopods, gastropods, pelecypods; thickness variable..... | 0.5-0.9 |
| Mudstone; greenish-gray; calcareous; fossils common to abundant, mainly pelecypods, gastropods, and brachiopods; a single specimen of <u>Myalina</u> was observed in life position; a 0.3-0.7-foot thick zone, the top of which is about 5.5 feet below Haskell Ls. base, contains abundant <u>Derbyia crassa</u> ; thickness exposed.. | 6.0 |

24.--Composite of streambank exposures in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10 (Weston Sh. Mbr. to Tonganoxie-Vinland Mbr. of Stranger Fm.) and in NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 11 (Vinland Sh. Mbr. of Stranger Fm. to Robbins Sh. Mbr. of Lawrence Fm.), T. 58 N., R. 33 W., De Kalb Co., Mo. See Pl. 18B and Pl. 26A. Measured and described in Nov., 1959.

| | Thickness, feet |
|---|--------------------|
| Douglas Grp. | |
| Lawrence Fm. | |
| Robbins Sh. Mbr. | |
| Shale; black; fissile; conodonts; about..... | 0.3 |
| Haskell Ls. Mbr. | |
| Limestone (mixed-fossil lime packstone); medium light gray; single bed; vertically-jointed; crinoids, brachiopods, gastropods, pelecypods, bryozoans, echinoids; most of the skeletal grains are fragmented and many are coated with <u>Osagia</u> ; about..... | 0.3 |
| Stranger Fm. | |
| Tonganoxie-Vinland Sh. Mbr. | |
| Mudstone; greenish-gray; extremely calcareous; molluscan fauna; about..... | 1.2 |
| Limestone (mixed-fossil lime mudstone); top bed 0.7 foot thick, lower 0.9 foot comprises very thin beds; argillaceous and weathers to a rubble in lower half; productid brachiopods, foraminifers, ostracodes; specks of carbonaceous material; about..... | 1.6 |
| Covered interval; thickness estimated; approximately. | 10.0 |
| Shale to mudstone; olive gray with medium bluish-gray overtones; clayey to slightly silty; micaceous; about | 7.0 |
| Iatan Ls. Mbr. | |
| Limestone; light brownish-gray; see Pl. 18B for vertical variations of fauna, bedding, and texture; about..... | 4.5 |
| Weston Sh. Mbr. | |
| Shale; medium bluish-gray to greenish-gray upward; calcareous and fossiliferous in upper 0.3 foot; crinoids; thickness exposed..... | 11.0 |

Kansas

25.--Railroad cutbank exposure in SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 9 S., R. 23 E., Leavenworth Co., Kansas. See Fig. 9, section 2. Measured and described in Jul., 1958.

| | Thickness, feet |
|--|--------------------|
| Douglas Grp. | |
| Stranger Fm. | |
| Weston Sh. Mbr. | |
| Shale; greenish-gray with medium bluish-gray overtones; clayey to slightly silty; several horizons of clay-ironstone concretions; exposed below Pleistocene deposits; about..... | 40.0 |
| Note - an 0.5 foot thick crinoidal limestone exposed locally and about 34.0 above Lansing Group top. | |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone, see Pl. 14A); light brownish-gray with light bluish-gray overtones; single bed; the brachiopods <u>Chonetes</u> and <u>Crurithyris planoconvexa</u> , crinoids, fusulinids; 0.05-foot thick streaks of sublithographic limestone in upper part; yellowish-brown ferruginous crust atop unit; about... | 1.2 |
| Siltstone; yellowish-brown; fossiliferous; about..... | 1.0 |
| Limestone (mixed fossil lime wackestone); chocolate brown; single bed; <u>Chonetes</u> , <u>Linoproductus</u> , fenestrate bryozoans, fusulinids; about..... | 0.5 |
| Siltstone; as second above; about..... | 0.2 |
| Limestone (mixed-fossil lime wackestone); medium bluish-gray mottled yellowish-brown; single bed; brittle; abundant <u>Chonetes</u> in uppermost part, fusulinids; about..... | 0.7 |
| Limestone (quartzose molluscan lime wackestone); yellowish-brown; very thin beds; <u>Myalina</u> common, sparse gastropods, fenestrate bryozoans, ramose bryozoans, brachiopods, fusulinids; extremely arenaceous; very fine sand- to silt-size angular to subrounded quartz grains, about..... | 1.3 |
| Total thickness of South Bend Ls. Mbr..... | 4.9 |
| Note - Rock Lake Sh. Mbr. and upper 10 feet of Stoner Ls. Mbr. are exposed at this locality. Graphic illustration of these members is included in Fig. 9 (section 2) for the purpose of documenting correlation. Descriptions of the Rock Lake and the Stoner Members are not judged to be necessary to this report. | |

26.--Quarry exposure near center south line SW $\frac{1}{4}$ sec. 30, T. 9 S., R. 23 E., Leavenworth Co., Kansas. See Fig. 9, section 3. Measured and described in Jul., 1958.

| | Thickness, feet |
|--|--------------------|
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone to mudstone); light bluish-gray to medium bluish-gray; beds 0.3 to 1 foot thick; <u>Chonetes</u> , <u>Meekella striatocostata</u> , marginiferids, fusulinds, crinoids, echinoids; yellowish-brown ferruginous crust atop unit; about..... | 2.5 |
| Limestone (quartzose molluscan lime wackestone); light brownish-gray to yellowish-brown; very fine sand- to silt- size quartz; grains subangular to subrounded; <u>Aviculopecten</u> , <u>Aviculopinna</u> , <u>Bellerophon</u> , <u>Composita</u> , fusulinids, crinoids, echinoids; about..... | 1.5 |
| Total thickness of South Bend Ls. Mbr..... | 4.0 |
| Note - Rock Lake Sh., Stoner Ls., and Eudora Sh. (in part) Members are exposed at this locality. See Fig. 9 (section 3) for graphic illustration of these units. | |

27.--Road cut exposure near center west line NW $\frac{1}{4}$ sec. 8, T. 11 S., R. 23 E., Wyandotte Co., Kansas. See Fig. 9, section 4 and Fig. 35A. Measured and described in Jul., 1958.

| | |
|--|-----|
| Douglas Grp. | |
| Stranger Fm. | |
| Tonganoxie Ss. Mbr. | |
| Sandstone; yellowish-brown to dark yellowish-orange; trough-type cross stratification; very fine- to fine-grained; quartz particles subangular to subrounded and elongate to equant; ferruginous (?limonitic) and siliceous cement; micaceous; mica flakes sand-sized; friable; about..... | 9.0 |
| Conglomerate; light gray, medium bluish-gray, and yellowish-brown; massive splitting; see Table 5 (quartzose conglomerate), Pl. 52A, and p. 285 for detailed description; thickness variable; feathered edge to about..... | 4.0 |
| Disconformity | |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone); medium bluish-gray mottled light brownish-gray; thin to thick and even beds; <u>Composita</u> , <u>Chonetes</u> , <u>Derbyia</u> , | |

Thickness,
feet

| | |
|--|-----|
| <u>Pulchratia</u> , <u>Neospirifer</u> , <u>Meekella striatocostata</u> , marginiferids, Erisocrinus, fusulinids, fenestrate bryozoans, ramose bryozoans, echinoids, planispiral gastropods; see Pl. 14B for illustration of lithology; thickness variable; featheredge (west end of exposure) to as much as..... | 3.0 |
| Shale; yellowish-brown; calcareous; micaceous; about. | 0.2 |
| Limestone (quartzose molluscan lime wackestone); light bluish-gray to medium bluish-gray; carbonaceous material common; <u>Aviculopinna</u> , <u>Bellerophon</u> , <u>Myalina</u> ; see Pl. 13A for illustration of lithology; thickness variable; featheredge (west end of exposure) to about..... | 3.0 |
| Note - Rock Lake Sh., Stoner Ls., Eudora Sh., and Captain Creek Ls. (in part) Members are ex- posed at this locality. See Fig. 9 (section 4) for graphic illustration of these units. | |

28.--Quarry exposure near center south line NW $\frac{1}{4}$ sec. 13, T. 14 S., R. 22 E.,
Johnson Co., Kansas. See Fig. 9, section 5. Measured and described
in Jul., 1958.

Douglas Grp.

Stranger Fm.

?Weston Sh. Mbr.

| | |
|--|-----|
| Shale; greenish-gray; micaceous; highly weathered; exposed below soil, about..... | 1.0 |
|--|-----|

Note - this unit may be Recent surficial
material.

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr.

| | |
|--|-----|
| Limestone (mixed-fossil lime wackestone, see Pl. 14C); light bluish-gray to medium bluish-gray; single bed; vertical joints that have been enlarged by solution; yellowish-brown weathering rind atop unit; <u>Chonetes</u> , <u>Derbyia</u> , <u>Neospirifer</u> , <u>Meekella striatocostata</u> , cri- noids, fusulinids; about..... | 1.0 |
|--|-----|

| | |
|---|-----|
| Limestone; as first above but contains <u>Myalina</u> and is mottled with grayish-black splotches in lower part; about..... | 6.0 |
|---|-----|

Conglomerate; light gray to light bluish-gray with
yellowish-brown overtones; sand- to small pebble-
sized limestone fragments, carbonaceous matter,
fossil fragments, and very fine-grained quartz particles

Thickness,
feet

in a calcareous matrix; Myalina, Aviculopecten,
brachiopods, crinoids, echinoids; thickness variable;
featheredge to about..... 1.5

Note - the Rock Lake Sh. and Stoner Ls. (in
greater part) Members are exposed at this
locality. See Fig. 9 (section 5) for graphic
illustration of these units.

29.--Quarry exposure at the NW corner sec. 22, T. 16 S., R. 20 E., Franklin
Co., Kansas. See Fig. 9, section 6 for graphic illustration and Ball
and others (1963, p. 48) for description of this section.

30.--Quarry exposure in NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5, T. 17 S., R. 20 E., Franklin Co.,
Kans. See Fig. 9, section 7. Measured and described in June., 1957.

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr.

Limestone (mixed-fossil lime wackestone, see Pl. 14D);
light brownish-gray mottled with medium bluish-gray
splotches; thin beds; Composita, Chonetes, Derbyia,
Linoproductus, Meekella striatocostata, Neospirifer,
Punctospirifer, crinoids, echinoids, ramose bryozoans,
lophophyllid corals, fusulinids, pelecypods; slightly
to moderately quartzose in lower foot; about..... 2.5

Note - Rock Lake Sh., Stoner Ls., and Eudora Sh.
Members exposed at this locality. See Fig. 9
(section 7) for graphic illustration of these
units.

31.--Road cut exposure near center south line sec. 32, T. 19 S., R. 19 E.,
Anderson Co., Kans. See Fig. 9, section 8. Measured and described
in Jul., 1958.

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr.

Limestone (mixed-fossil lime wackestone); medium
bluish-gray with brownish-gray overtones; thin beds;
Meekella striatocostata, other brachiopods, sparse
fusulinids, crinoids, fenestrate bryozoans; exposed
below soil, about..... 3.0

Thickness,
feet

Limestone (quartzose molluscan lime wackestone, see Pl. 13C); very thin- to thin-bedded; silty to sandy; abundantly fossiliferous, myalinid pelecypods, gastropods, nautiloid cephalopods, brachiopods, crinoids, bryozoans; about..... 2.0

Note - Rock Lake Sh., Stoner Ls., Eudora Sh. and Captail Creek Ls. Members are exposed at this locality. These units are illustrated graphically as Fig. 9 (section 8).

32.--Quarry exposure near NE corner sec. 19, T. 21 S., R. 19 E., Anderson Co., Kans. Measured and described in Jul., 1958.

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr.

Limestone (mixed-fossil lime wackestone); light brownish-gray mottled with medium bluish-gray splotches; thin even beds; arenaceous in lower part; Composita, Chonetes, Derbyia, Echinaria, Meekella striatocostata, dictyoclostids, Euomphalus, and crinoids; about..... 1.2

Limestone (quartzose molluscan lime wackestone); light brownish-gray to yellowish-brown; thin beds; silty to sandy; Myalina, Aviculopecten, crinoids, brachiopods; conglomeratic with vague cross-stratification in lowermost part; about..... 2.8

Note - Rock Lake Sh. and Stoner Ls. (in part) Members are exposed at this locality. See Fig. 9 (section 9) for graphic illustration of these units.

33.--Quarry exposure near NW corner SW $\frac{1}{4}$ sec. 33, T. 21 S., R. 19 E., Anderson Co., Kans. See Fig. 9, section 10. Measured and described in Jul., 1958.

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr.

Limestone (mixed-fossil lime wackestone); light brownish-gray with medium bluish-gray overtones; thin even beds; prominent vertical joints; relatively large upper surface exposed showing 3 joint sets, some of the joints are arcuate in plan view; Meekella striatocostata, fusulinids, crinoids; Osagia coatings on skeletal grains common; ferruginous (?hematite) rind atop unit; about..... 2.5

Thickness,
feet

| | |
|--|-----|
| Limestone (pelletal lime packstone to pelletal, mixed-fossil lime wackestone); light brownish-gray; locally cross-stratified; sandy; mollusks, brachiopods; about..... | 1.5 |
| Limestone (quartzose molluscan lime wackestone); yellowish-brown; cross-stratified locally; extremely arenaceous, a calcareous sandstone to siltstone in lower part; pelletal to oolitic locally; <u>Aviculopecten</u> , <u>Myalina</u> , <u>Metacoceras</u> , <u>Calamites</u> ; basal contact erosional and high irregular (see Pl. 47C); thickness variable; where measured, about..... | 4.0 |
| Note - Rock Lake Sh. and Stoner Ls. (in part) Members are exposed at this locality. See Pl. 9 (section 10) for graphic illustration of these units. | |

34.--Quarry exposure in SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 12, T. 23 S., R. 17 E., Anderson Co., Kans. See Fig. 9, section 11. Measured and described in Jul., 1958.

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr.

Limestone (mixed-fossil lime wackestone, see Pl. 14F); light brownish-gray; thin to thick even beds; Chonetes, Meekella striatocostata, Linoproductus, Euomphalus, crinoids; Osagia-coated skeletal grains common; sandy to silty and locally pelletal in lower 2 feet; about....

7.0

Limestone (pelletal lime packstone); light brownish-gray mottled yellowish-brown; cross-stratified; arenaceous; dominantly molluscan fauna with Aviculopinna, Allorisma, Myalina, and gastropods, brachiopods, crinoids; extensive recrystallization of skeletal debris; in part ?dolomitized, about.....

4.0

Note - Rock Lake Sh. and Stoner Ls. (in part)
Members are exposed at this locality. See Fig. 9 (section 10) for graphic illustration of these units.

35.--Road cut exposure near SW corner sec. 31, T. 21 S., R. 19 E., Anderson Co., Kansas. Measured and described in Jul., 1958.

Lansing Grp.

Stanton Ls. Fm.

South Bend Ls. Mbr.

Limestone; light gray mottled light bluish-gray locally; cross-stratified; conglomeratic in part; arenaceous; angular to subrounded silt- to very fine sand-size

Thickness,
feet

quartz particles; gastropods abundant, brachiopods, crinoids, echinoids, bryozoans, foraminifers including sparse fusulinids; skeletal grains extensively abraded and in many cases rounded; pelletal to oolitic; matrix comprises both sparry calcite and lime mud; about..... 5.0

Note - Rock Lake Sh. and Stoner Ls. (just north of road in abandoned quarry) are exposed at this locality.

- 36.--Streambank exposure near center NE $\frac{1}{4}$ sec. 17, T. 21 S., R. 19 E., Anderson Co., Kans. See Pl. 36. Section by S. M. Ball and Don Scafe. Measured and described in Dec., 1962.

Lansing Grp.

Stanton Ls. Fm.

Stoner Ls. Mbr.

Limestone (?algal lime boundstone); very light gray to pinkish-gray; yellowish-brown splotches peripheral to vugs (?limonite stain); a single bed in parts of the exposure but apparently very thin wavy beds in other parts of the exposure; platy structures (?an alga) form a partially interconnected labyrinth in a lime mud matrix; many of the plates or blades are arranged contrary to gravity, sparry calcite mosaics form the interiors of these structures; no algal structure was definitely identified; about..... 10.0

Note - this unit is at least 18 feet thick in a streambank exposure 150 yards southeast of the measured section locality and weathers like a massive sandstone.

Limestone (crystalline carbonate); light brownish-gray with abundant irregularly-shaped spar stringers that appear medium bluish-gray; thin wavy beds; lime mud matrix; sparse identifiable ramose bryozoans, crinoids, and brachiopods; skeletal grains partially recrystallized, gradation from lime mud to coarse spar evident in thin section; about..... 12.0

Limestone (bryozoan lime wackestone); light gray with medium bluish-gray overtones; very thin to thin wavy beds; dark stain (?hydrocarbon) on both grains and matrix; lime-mud matrix; bryozoans, productid brachiopods, crinoids, echinoids; about..... 4.0

Shale and limestone interbedded; shale, light gray to medium light gray, calcareous, abundantly fossiliferous, bryozoans, brachiopods, crinoids; limestone (mixed-fossil lime wackestone), medium bluish-gray to yellowish-

| | Thickness, feet |
|---|--------------------|
| brown, nodular, abundantly fossiliferous, fauna similar to first above, mostly nodular limestone in lower foot; about..... | 5.0 |
| Limestone (mixed-fossil lime mudstone); light brownish-gray; single thick bed; contacts gradational; brachiopods, bryozoans, crinoids; about..... | 3.0 |
| Eudora Sh. Mbr. | |
| Mudstone; greenish-gray; extremely calcareous; abundantly fossiliferous, <u>Wellerella osagensis</u> , <u>Rhipidomella carbonaria</u> , <u>Cancrinella boonensis</u> , <u>Composita</u> , <u>Crurithyris planoconvexa</u> , ramose bryozoans; about.... | 0.2 |
| Shale; grayish-black; fissile to platy; vertical joints; fractures into blocks; phosphatic nodules; conodonts, inarticulate brachiopods; about..... | 6.0 |
| Shale; greenish-gray; calcareous, micaceous; covered; about..... | <u>0.2</u> |
| Total thickness of the Eudora Sh. Mbr..... | <u>6.4</u> |
| Captain Creek Ls. Mbr. top - exposed about 40 yards north of measured section locality at water level of stream. | |

Note - this outcrop is: (1) the southernmost exposure observed in which black fissile shale is continuous and well developed in the Eudora Sh. Mbr.; (2) the southernmost exposure observed in which all member contacts within the Stanton Ls. Fm. are readily identifiable; and (3) the northernmost exposure observed in which a reefoid facies is developed in the Stanton Fm.

- 37.--Streambank exposure near center north line sec. 33, T. 26 S., R. 13 E., Woodson Co., Kans. Section by N. D. Newell. Measured and described in Aug., 1938. Section description in Basic Geology Division, State Geological Survey of Kansas files. South Bend Ls. Mbr., Rock Lake Sh. Mbr., and upper part of Stoner Ls. Mbr. (Stanton Ls. Fm., Lansing Grp.).
- 38.--Quarry exposure near center south line NE $\frac{1}{4}$ sec. 24, T. 29 S., R. 14 E., Wilson Co., Kans. Section by N. D. Newell. Date of study not known. Section description in Basic Geology Division, State Geological Survey of Kansas files. Stanton Ls. Fm. and upper part of Vilas Sh. Fm. (Lansing Grp.).

39.--Road cut exposure near NE corner sec. 26, to near center north line sec. 25, T. 34 S., R. 13 E., Montgomery Co., Kans.

| | Thickness, feet |
|---|--------------------|
| Douglas Grp. | |
| Stranger Fm. | |
| Weston Sh. Mbr. | |
| Siltstone to sandstone; light brownish-gray, weathers yellowish-brown; predominantly coarse silt-size quartz; about..... | 2.0 |
| Shale; greenish-gray to yellowish-brown; clayey to silty; four samples were taken at 15, 30, 45, and 60 feet below the overlying siltstone and were analyzed for clay-mineral content; illite, illite-mixed layer clay, kaolinite, ?vermiculite; crinoids and brachiopods sparse to common in lower 25 feet, pectinoid clams from 25 to 35 feet below top; about..... | 70.0 |
| Lansing Grp. | |
| Stanton Ls. Fm. | |
| South Bend Ls. Mbr. | |
| Limestone (quartzose molluscan lime wackestone, see Pl. 13E, in lower foot; mixed-fossil lime wackestone in upper 0.5 foot); bluish-gray mottled light brownish-gray; single bed; gradational basal contact; <u>Composita</u> , <u>Chonetes</u> , <u>Meekella striatocostata</u> , and crinoids throughout, bellerophontid gastropods, <u>Retispira</u> , <u>Aviculopecten</u> , and <u>Myalina</u> in lower part; about..... | 1.5 |
| Limestone; yellowish-brown; very thin beds; extremely arenaceous; in part conglomeratic; ?cross-stratified; molluscan fauna; thickness exposed..... | 1.0 |

40.--Composite section of a clay pit in NW $\frac{1}{4}$ sec. 23 (Tonganoxie Ss. Mbr.) and a road cut exposure near center west line SW $\frac{1}{4}$ sec. 14 (Weston Sh. Mbr.), T. 17 S., R. 19 E., Franklin Co., Kans. Measured and described in Jun., 1957. Section by S. M. Ball, M. M. Ball, and D. J. Laughlin.

| | |
|---|------|
| Douglas Grp. | |
| Stranger Fm. | |
| Tonganoxie Ss. Mbr. | |
| See Ball and others (1963, p. 23-25, Fig. 6, Pl. 8, Pl. 9) for detailed description; about..... | 19.0 |
| Weston Sh. Mbr. | |
| Shale; light gray, greenish-gray, and medium bluish-gray; very finely laminated; predominantly clayey; slightly silty to silty in upper 10 feet; 0.2-foot thick nodular, silty, light brownish-gray limestone apparently devoid of fossils 10 feet below top; | |

Thickness,
feet

illite, illite-mixed layer clay, kaolinite, ?vermiculite; apparently more kaolinite in upper, siltier part of member but no attempt was made to quantify by constituent percentages; thickness exposed..... 50.0

Note - Ten samples were analyzed for clay-mineral content. The samples were taken at 5 foot intervals from 10 feet above base of exposure to 5 feet below top of the Weston.

41.--Streambank exposures near SW corner NE $\frac{1}{4}$ sec. 4, T. 8 S., R. 22 E., Leavenworth Co., Kans. Section by A. L. Bowsher. Measured and described in Jul., 1942. Section description in Basic Geology Division, State Geological Survey of Kansas files. Tonganoxie Ss. Mbr. of Stranger Fm. to Haskell Ls. Mbr. of Lawrence Fm. See Pl. 34F for graphic illustration of the rocks exposed at this locality. The Westphalia Ls. Mbr. shown on the graphic section by me is discontinuous at this locality. The Westphalia was absent where Mr. Bowsher studied the section. See also Fig. 39.

42.--Road cut exposures along east line sec. 32, T. 26 S., R. 16 E., Woodson Co., Kans. Section by N. D. Newell. Measured and described in Aug., 1938. Section description in Basic Geology Division, State Geological Survey of Kansas files. Stoner Ls. Mbr. of Stanton Ls. Fm. (Lansing Grp.) to Tonganoxie Ss. Mbr. of Stranger Fm. (Douglas Grp.)

43.--Road cut exposure near center south line SW $\frac{1}{4}$ sec. 35, T. 26 S., R. 14 E., Woodson Co., Kans. Section by S. M. Ball and R. R. West. Measured and described in Aug., 1961.

Douglas Grp.

Lawrence Fm.

Robbins Sh. Mbr.

Shale; light gray to greenish-gray upward; clayey to silty upward; lamination less distinct upward; weathers to subcubical fragments as much as 0.2 foot in long dimension in upper part; thickness exposed... 35.0

Haskell Ls. Mbr.

Limestone (mixed-fossil lime wackestone); olive gray with medium bluish-gray overtones; a single bed; prominent vertical joints enlarged by solution; very finely crystalline; fractures conchoidally; crinoids, echinoid spines, brachiopods including Composita, sparse fusulinids, Ottonosia-like algae; about..... 1.4

Thickness,
feet

| | |
|---|------|
| Limestone; light brownish-gray stained yellowish-brown; very thin wavy beds; argillaceous; brachiopods, crinoids, fusulinids; basal contact gradational through 0.1 foot; about..... | 0.3 |
| Total thickness of the Haskell Ls. Mbr..... | 1.7 |
| Stranger Fm. | |
| Vinland Sh. Mbr. | |
| Shale; greenish-gray in upper 0.5 foot and in lower 0.5 foot; micaceous; mostly covered; <u>Myalina</u> and crinoids in uppermost part; about..... | 6.0 |
| Westphalia Ls. Mbr. | |
| Limestone (coated-grain lime packstone to wackestone); yellowish-brown; single bed; contacts irregular and apparently sharp; fragmented skeletal grains include brachiopods, crinoids, bryozoans, and sparse fusulinids; about..... | 1.0 |
| Tonganoxie Ss. Mbr. | |
| Shale and siltstone interbedded; shale, yellowish-brown, silty, micaceous; siltstone, yellowish-brown, very thin beds, micaceous, about..... | 1.0 |
| Siltstone to sandstone; light brownish-gray stained yellowish-brown; relatively even thin beds; medium silt- to very fine sand-size quartz particles; quartz grains subangular to subrounded and elongate to equant; about..... | 7.0 |
| Shale and siltstone interbedded; as second above; about..... | 4.0 |
| Shale, siltstone, and sandstone interbedded; greenish-gray to yellowish-brown; as second and third above; thickness exposed..... | 35.0 |

44.--Quarry exposure in NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, T. 9 S., R. 23 E., Leavenworth Co., Kans. See Fig. 35B. Section by S. M. Ball and H. A. Mendoza. Measured and described in Jun., 1959.

Douglas Grp.

Stranger Fm.

Tonganoxie Ss. Mbr.

Shale, siltstone, and limestone conglomerate interbedded; shale, greenish-gray to light brownish-gray, silty, micaceous, carbonaceous matter, ?plant fossils, sample from lower part (see position of diamond in Fig. 35B) contained sparse spine and valve fragments of productid brachiopods and sparse fragments of Composita; siltstone, olive gray, quartzose, part calcareous cement, part siliceous cement, carbonaceous

Thickness,
feet

matter; limestone conglomerate, yellowish-brown, thin to very thin beds, beds lenticular, small-scale cross stratification of trough type locally, rounded and polished fragments of fusulinids, productid and other brachiopods, crinoids, and bryozoans, matrix comprises both sparry calcite and ferruginous (?limonitic) material, grains are predominantly sand-sized but limestone pebbles occur in lowermost parts of some beds, sparse clay pebbles, sparse siltstone pebbles, sparse wood fragments; exposed below Pleistocene deposits, as much as.....

9.0

Note - See Fig. 35B for disposition of rock types in a part of the quarry face. Limestone pebbles derived from both the South Bend and Stoner

Members of the Stanton Ls. Fm. were observed.

Conglomerate; light gray to light brownish-gray, in part stained yellowish-brown; weathers into thick, in part discontinuous beds, locally cross-stratified, beds locally graded; coarse fraction includes limestone sand, pebbles, granules, and cobbles, fossils, sparse clay pebbles, sparse siltstone pebbles, and extremely sparse quartz grains; pebbles and cobbles are largely of an extremely irregular shape; pebbles of the upper part of the South Bend Ls. Mbr. (bluish-gray), of the lower part of the South Bend (brownish-gray to bluish-gray and silty), of the uppermost part of the Stoner Ls. Mbr. (yellowish-brown and ferruginous, ?limonitic), and of the lower part of the Stoner (light gray to medium light gray) were observed; many of the pebbles are pitted; matrix a mosaic of coarse sparry calcite; matrix-pebble contacts locally stylolitic; thickness variable; from a featheredge (west end of quarry) to (east end of quarry).....

9.5

Disconformity

Lansing Grp.

Stanton Ls.

Stoner Ls. Mbr.

Limestone (mixed-fossil lime wacestone in upper 0.7 foot, oolite and coated-grain lime packstone in lower 1.1 feet); medium light gray with medium bluish-gray overtones; single bed; grains commonly fragmented and many are coated with Osagia; fusulinids, brachiopods, crinoids, bryozoans, gastropods, pelecypods; basal contact gradational; thickness variable, as much as.....

1.8

Thickness,
feet

Note - the Stoner Ls. was measured and described at the east end of the quarry. The above description does not apply to the upper part of the Stoner, which is exposed at the west end of the quarry.

Eudora Sh. Mbr.

| | |
|--|-----|
| Shale; greenish-gray; calcareous; abundant <u>Derbyia</u> , sparse to common <u>Myalina</u> , <u>Aviculopinna</u> , and <u>Pleurophorus</u> ; about..... | 0.5 |
| Shale; black; fissile to platy; conodonts; thickness exposed..... | 1.0 |

Note - the Eudora Mbr. is exposed only at the east end of the quarry.

45.--Composite of road cut exposures near center south line NW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27 (Haskell Ls. Mbr. of Lawrence Fm. to Toronto Ls. Mbr. of Oread Ls. Fm.) and near SW corner sec. 15, T. 14 S., R. 20 E., Vinland Sh. and Westphalia Ls. Members of Stranger Fm.), Douglas Co., Kans. Section by S. M. Ball, P. C. Franks, Don Scafe, and Ada Swineford. Measured and described in Feb., 1962.

Shawnee Grp.

Oread Ls. Fm.

Toronto Ls. Mbr.

| | |
|--|---------|
| Limestone (mixed-fossil lime wackestone); very light gray mottled light greenish-gray; a single bed; skeletal grains comprise crinoid, echinoid, productid and other brachiopod, and foraminifer (including fusulinid) debris; many grains show effects of abrasion and many are <u>Osagia</u> -coated; nonskeletal grains include approximately 1-2 percent fine to medium silt-size, subangular to subrounded, equant to elongate quartz particles, and clay minerals in trace amounts; matrix predominantly lime mud, sparry calcite-filled fossil interiors common and about 3-5 percent spar in irregularly-shaped and randomly-disposed blebs; bounded above by a light greenish-gray calcareous shale parting as much as 0.1 foot thick; basal contact gradational..... | 0.4-0.6 |
| Limestone (quartzose mixed-fossil lime wackestone); light gray; skeletal grains include fusulinid, brachiopod, and crinoid remains; <u>Osagia</u> -coated shell fragments common; <u>Derbyia crassa</u> common; medium silt- to very fine sand-size subangular to subrounded, elongate to equant quartz particles (coarse silt- and very fine sand-size grades predominant, quartz content varies | |

Thickness,
feet

laterally, rock locally a calcareous siltstone); approximately 3-5 percent white mica; contains included blebs of greenish-gray clay; lime mud matrix, spar restricted to fillings of fossil voids; upper contact irregular and gradational; basal contact weathers as if sharp but this rock type is intermediate relative to bounding rock types; thickness variable..... 0.1-0.3

Note - only basal 0.5-0.7 foot of Toronto Ls. is described. Strata up to the Plattsmouth Ls. Mbr. (basal part) of the Oread Ls. are exposed in this road cut.

Lawrence Fm.

Wathena Sh. Mbr.

Siltstone; light greenish-gray; laminated to thinly-laminated downward, lamination poorly defined in upper part; shaly to blocky parting; calcareous; less than 5 percent disseminated minute flakes of white mica, abundant interstitial clay in silty parts; upper contact highly irregular; thickness variable... 2.3-2.8

Limestone; greenish-gray to light greenish-gray, locally streaked with medium light gray to medium gray laminae and ellipsoidal blebs of calcareous siltstone; nodular; microcrystalline; moderately argillaceous; less than 5 percent disseminated flakes of white mica; nodules as much as 0.4 foot long by 0.2 foot thick; zone of nodules of variable thickness..... 0.1-0.3

Shale; greenish-gray, weathers pale olive gray and pale olive; thin-laminated, lamination indistinct in lower part; clayey to moderately silty downward; calcareous; jointed with ?limonite stains along fractures; about. 7.5

Coal; dark gray; a shaly smut; thin argillaceous and coaly interlaminae; clay laminae greenish-gray; coal laminae grade from coal to carbonaceous shale; contacts gradational; about..... 0.05-0.2

Mudstone; dark greenish-gray; locally contains rounded to ellipsoidal, light olive gray, limestone nodules 0.1 foot by 0.2 foot in maximum dimension; irregular to blocky fracture, fragments as much as 0.2 foot in long dimension and slickensided; moderately calcareous; silty; less than 5 percent disseminated flakes of white mica; contacts gradational; about..... 4.2

Mudstone; greenish-gray to moderate olive, weathers light olive gray; as first above; thickness variable. 2.7-3.4

Thickness,
feet

Mudstone; dark grayish-red, locally mottled medium light gray in central part and greenish-gray marginally; locally the red color predominates throughout, whereas the lower 0.3 to 1 foot is generally greenish-gray in larger part; blocky fracture, largest fragments less than 0.1 foot long; calcareous; thickness variable..... 1.4-1.8
Total thickness of Wathena Sh. Mbr., approximately. 19.0-20.0

Note - preliminary clay-mineral analysis indicates an illite, illite-mixed layer clay, kaolinite, and ?vermiculite assemblage. The only vertical variation noted was the apparent increase in kaolinite content above the coal smut. No attempt was made to quantify by constituent percentages.

?Amazonia Ls. Mbr.

Siltstone; light gray, weathers light pale olive to yellowish-brown; thin-bedded to laminated; flaggy parting, commonly along light greenish-gray films; Lingula carbonaria abundant in upper part and rare in lower part, abundant bottom markings similar to so-called "fucoidal markings"; contains as much as 40 percent carbonate, which is largely dolomite judging from weak effervescence, thin section study, and an x-ray diffractometer pattern; somewhat argillaceous; contains less than 5 percent white mica and biotite; basal contact gradational; thickness variable..... 2.0-2.5

Siltstone; light gray with yellowish-green overtones; laminated to thin-laminated, lamination is wavy; shaly parting; abundant argillaceous films. calcareous; abundant flakes of white mica up to 1 mm in diameter with the coarser flakes concentrated along bedding surfaces; abundant ?carbonaceous flecks; trace amounts of biotite; small masses of argillaceous limestone up to 6 cm by 1.5 cm, limestone transected by veinlets of moderate yellowish-brown sparry calcite; thickness variable..... 0.5-1.0

Total thickness of ?Amazonia Ls. Mbr..... 2.5-3.5

Ireland Ss. Mbr.

Shale; greenish-gray; thinly-laminated; shaly to papery parting; moderately calcareous; slightly silty to silty downward; micaceous, less than 2 percent disseminated minute flakes of white mica; interbedded greenish-gray siltstone in lower part; mostly covered; about..... 78.0

Thickness,
feet

Note - preliminary clay-mineral analysis indicates the presence of illite, illite-mixed layer clay, kaolinite, and ?vermiculite. Five equally-spaced samples were taken from 9 to 45 feet below top of unit.

| | |
|---|-------|
| Sandstone to siltstone; yellowish-brown; very thin- to thin-bedded, beds even to slightly wavy; medium silt- to very fine sand-size, angular to subrounded, elongate to equant quartz particles; micaceous; cement mostly siliceous, but locally calcareous; poorly exposed; about..... | 20.0 |
| Shale; as second above but more silty; about..... | 6.0 |
| Siltstone to sandstone; as second above but siltstone predominates over sandstone; about..... | 18.0 |
| Total thickness of Ireland Ss. Mbr..... | 123.0 |

Robbins Sh. Mbr.

| | |
|--|-----|
| Mudstone; greenish-gray; indistinct lamination locally; micaceous; slightly calcareous; silty in upper part; preliminary clay mineral analysis indicates illite, illite-mixed layer clay, kaolinite, and ?vermiculite; arenaceous foraminifers, ostracodes; about..... | 2.8 |
|--|-----|

Note - slumping of Robbins Sh. into small-scale ?solution cavities in top of underlying Haskell Ls. Mbr.

Haskell Ls. Mbr.

| | |
|---|------|
| Limestone (mixed-fossil lime wackestone); light brownish-gray to medium bluish-gray; crinoids, brachiopods, <u>Ottonosia</u> -like algae; only uppermost part exposed; about..... | 0.3 |
| Covered interval; thickness estimated; about..... | 10.0 |

Note - interval contains Stranger-Lawrence Fm. boundary and upper part of Vinland Sh. Mbr.

Stranger Fm.

Vinland Sh. Mbr.

| | |
|--|------|
| Shale; facies as in type section, stratigraphic section 47; not washed for microfossils nor analyzed for clay minerals; about..... | 15.0 |
|--|------|

Westphalia Ls. Mbr.

| | |
|--|-----|
| Limestone (ostracode coaly lime mudstone; see Pl. 21C); medium bluish-gray weathers light brownish-gray; very finely-laminated; ostracodes; carbonaceous material; basal contact gradational; about..... | 1.5 |
|--|-----|

Note - this outcrop exposes the thickest section observed of the ostracode coaly lime mudstone facies of the Westphalia.

Upper Sibley coal bed - not measured or described.

- 46.--Composite section of exposures near center south line SE $\frac{1}{4}$ sec. 17 (Toronto Ls. Mbr. of Oread Ls. Fm., Shawnee Grp.) to center south line sec. 18 (Tonganoxie Ss. Mbr. of Stranger Fm.), T. 19 S., R. 18 E., Franklin Co., Kans. Section by S. M. Ball, M. M. Ball, and D. J. Laughlin. Measured and described in Oct., 1956. See Ball and others, 1963, p. 48, section C1 for detailed description.
- 47.--Road cut exposure near center east line SE $\frac{1}{4}$ sec. 2, T. 14 S., R. 20 E., Douglas Co., Kans. Section by S. M. Ball and R. R. West. Measured and described in Apr., 1962. Type section of Vinland Sh. Mbr. of Stranger Fm. See Fig. 20 and p. 109 to p. 111 for detailed description.
- 48.--Road cut exposure near center east line sec. 11, T. 7 S., R. 21 E., Atchison Co., Kans. Section by S. M. Ball and R. R. West. Measured and described in Jul., 1961.

| | Thickness, feet |
|--|--------------------|
| Douglas Grp. | |
| Lawrence Fm. | |
| Robbins-Ireland Mbr. | |
| Shale; greenish-gray; clayey to slightly silty; micaceous; exposed below surficial material..... | 17.5 |
| Limestone (crinoid lime packstone); light brownish-gray; single vertically-jointed bed; crinoids, brachiopods, corals, foraminifers; about..... | 0.6 |
| Note - this limestone probably correlates with a part of the Cass Ls. of Nebraska terminology. | |
| Shale; medium light gray to olive gray; locally lacks lamination and weathers to irregular blocks; micaceous; part calcareous; contains septarian limestone concretions and argillaceous limestone nodules, the latter are sparsely fossiliferous with brachiopods; nodules and septaria are medium bluish-gray; basal contact gradational; about..... | 9.0 |
| Haskell Ls. Mbr. | |
| Limestone (crinoid lime packstone); light brownish-gray, medium bluish-gray overtones; argillaceous, especially so marginally; shaly parting; contacts gradational; thickness variable..... | 0.3-0.5 |
| Stranger Fm. | |
| Tonganoxie-Vinland Mbr. | |
| Limestone; light gray to medium bluish-gray; extremely argillaceous; shaly parting; abundantly fossiliferous; abundant <u>Crurithyris planoconvexa</u> , abundant <u>Derbyia</u> , <u>Linoproductus</u> common, sparse <u>Composita</u> , sparse <u>Punctospirifer kentuckyensis</u> , abundant <u>Rhipodomella carbonaria</u> , other brachiopod genera, abundant | |

Thickness,
feet

| | |
|--|---------|
| <u>Pharkidonotus</u> , <u>Treospira</u> common, abundant <u>Retispira</u> , abundant <u>Amphiscapha</u> , other gastropod genera, abundant nuculid pelecypods, sparse myalinid pelecypods, lophophyllid corals, crinoid columnals, ramose bryozoans; thickness variable..... | 0.6-0.8 |
| Mudstone; medium light gray to greenish-gray; calcareous; sparse productid brachiopods, other brachiopods, sparse ?pelecypod fragments; about..... | 4.0 |
| Mudstone; yellowish-brown; weathers into irregular to subcubical blocks as much as 0.3 foot in long dimension; contains silty limestone nodules in central part; nodules as much as 1 foot by 2 feet, fossiliferous with sparse productid brachiopod, crinoid and ?plant fragments; about..... | 5.0 |
| Shale to mudstone; greenish-gray to yellowish-brown; vague lamination locally; silty; about..... | 5.5 |
| Siltstone and shale interbedded; siltstone, greenish-gray to light brownish-gray, current ripplemarks, ?plant fossils; shale, as second above but more silty; thickness exposed..... | 8.0 |
| Note - recent slumping of cutbanks makes thicknesses of thicker units tenuous. | |

49.--Road cut exposure near NE corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 5, T. 13 S., R. 20 E., Douglas County, Kansas. Type section of Haskell Ls. Mbr. of Lawrence Fm. Measured and described in Oct., 1960.

Douglas Grp.

Lawrence Fm.

Robbins Sh. Mbr.

| | |
|---|-----|
| Shale; light brownish-gray; contains clay-ironstone concretions that comprise principally goethite, kaolinite, and small amounts of lepidocrocite; shale contains illite, kaolinite, and 1 or 2 mixed-layer clays, very fine-grained quartz, calcite, marcasite or pyrite; fossiliferous; thickness exposed below surficial material..... | 1.0 |
| Goethite bed; reddish-brown; contains quartz, calcite, kaolinite, illite, and a 14 angstrom mineral; fossiliferous; about..... | 0.2 |
| Shale; light brownish-gray to greenish-gray; illite, kaolinite, 1 or 2 mixed-layer clays, small amount of goethite, calcite, quartz, and a trace of pyrite or marcasite; contains fossiliferous phosphatic nodules at base, nodules comprise irregular blebs of apatite, | |

Thickness,
feet

bone matter replaced by granular calcite, small amount of quartz, some collophane, volatile sulphur compounds, and minute blotches of organic matter; about..... 0.3-0.4

Note - detailed lithology of the Robbins Sh. Mbr. was taken largely from Miller and Swineford (1957).

Haskell Ls. Mbr. - see Pl. 24 and p. 120 to p. 122 for detailed description.

Stranger Fm.

Tonganoxie-Vinland Mbr.

Siltstone to sandstone; light brownish-gray; very thin, irregular, discontinuous bedding; slightly calcareous; about..... 1.0

Shale; light brownish-gray; clayey to silty; micaceous; thickness variable..... 0.6-1.0

Siltstone; as second above; thickness variable..... 0.1-1.0

Shale; light gray; silty to clayey; carbonaceous; abundant fragmented plant fossils; thickness variable. 0.5-2.0

Shale to mudstone; light brownish-gray; silty to clayey; carbonaceous; about..... 2.0

Shale; dark gray; carbonaceous, thickness variable... 0.6-1.0

Shale; yellowish-brown; carbonaceous, numerous casts and molds of plant fossils; featheredge up to..... 1.0

Coal and shale interlaminated..... 0.1-0.2

Coal; bituminous; about..... 0.6

Shale; light brownish-gray; silty; thickness variable 0.6-0.7

Sandstone to siltstone; brown; thin-bedded, quartzose; calcite cement; micaceous; thickness variable..... 0.7-0.8

Sandstone to siltstone; brown; thin-bedded; coarse silt- to very fine sand-size quartz particles; friable; micaceous; contacts gradational; thickness variable.. 0.1-4.0

Sandstone; apparently a single bed; as first above... 0.1-0.8

Shale; light brownish-gray; silty; micaceous; thickness variable..... 0.1-0.3

Sandstone to siltstone; as third above but apparently structureless with massive splitting; about..... 5.5

Shale; yellowish-brown; sandy to silty downward; micaceous; thickness exposed..... 0.1-1.0

Note - description of Tonganoxie-Vinland Mbr. slightly modified from a section by A. L. Bowsher (in Basic Geology Division, State Geological Survey of Kansas files).

50.--Quarry exposure near center NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 28 S., R. 14 E., Wilson Co., Kans. See Pl. 25G (illustration of Haskell Ls. facies) and Pl. 20B and C (illustration of Westphalia Ls. facies). Measured and described in Aug., 1959.

| | Thickness, feet |
|--|--------------------|
| Douglas Grp. | |
| Lawrence Fm. | |
| Haskell Ls. Mbr. | |
| Limestone (mixed-fossil lime mudstone to wackestone); light gray to medium light gray with light brownish-gray overtones; thin, wavy bedding; abundant stringers, angular fragments, and irregular blebs of sparry calcite, many of which are algal-coated (for the most part, the algal coating are disposed on only one side, that is, the upper side of the spar), sparse crinoids, sparse fusulinids in upper part, sparse to common brachiopods including <u>Composita</u> , <u>Crurithyris planoconvexa</u> , <u>Chonetes</u> , and <u>Meekella striatocostata</u> ; skeletal grains and coated spar in a lime mud matrix; shaly in lower part; basal contact gradational; exposed below soil..... | 5.0-6.0 |
| Stranger Fm. | |
| Vinland Sh. Mbr. | |
| Limestone and shale interbedded; limestone, light brownish-gray, nodular, arenaceous to argillaceous, fossiliferous; shale, greenish-gray, slightly silty, micaceous, ?fossiliferous; contacts gradational; about..... | 0.7 |
| Shale; greenish-gray; calcareous; extremely fossiliferous; crinoids, brachiopods, nautiloid cephalopods, gastropods, pelecypods; about..... | 1.0 |
| Limestone and shale interbedded; as third above; brachiopods, <u>Myalina</u> ; basal contact gradational; about..... | 0.5 |
| Mudstone; light brownish-gray in basal 0.5 foot, medium bluish-gray (wet) above; weathers blocky; slightly calcareous in upper part; finely disseminated carbonaceous matter in upper half; upper half of slope covered with fossils that are probably not indigenous; about..... | 8.5 |
| Total thickness of Vinland Sh. Mbr..... | 10.7 |
| Westphalia Ls. Mbr. | |
| Limestone (coated-grain lime packstone to wackestone); light gray to medium light gray; thin- to thick-bedded; surfaces weather vuggy; skeletal grains include gastropods, brachiopods, fusulinids, <u>Myalina</u> , bryozoans, crinoids, echinoids, and <u>Osagia</u> ; fusulinids common to abundant in upper part; sparse quartz particles; grain | |

Thickness,
feet

coatings of Osagia as much as 2 mm thick; predominantly sparry calcite matrix in lower part, matrix predominantly lime mud in upper part; lamellar spar crystals arranged perpendicular to skeletal grain boundaries common; exposed above water level in quarry..... 2.8

51.--Composite of a road cut exposure near SW corner sec. 31 (upper 22 feet of section), a quarry exposure in SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 31 (thick limestone), a road cut exposure along south line SE $\frac{1}{4}$ sec. 32 (shale-siltstone-sandstone-section), T. 32 S., R. 13 E.; and a road cut exposure in SW $\frac{1}{4}$ sec. 4, T. 33 S., R. 13 E. (Haskell Ls. Mbr. and lower part of Robbins Sh. Mbr.), Chautauqua Co., Kans. Measured and described in Jul., 1961

Douglas Grp.

Lawrence Fm.

Shale; greenish-gray; silty to clayey; micaceous; poorly exposed; about..... 11.0

Note - this unit is overlain by a thick (about 50 feet) massive sandstone section.

Siltstone; yellowish-brown; quartzose; calcareous; brachiopods, fusulinids, pelecypods; discontinuous; locally argillaceous; poorly exposed; about..... 0.6

Shale; as second above but less silty; about..... 11.0

Note - best exposure of lower part of this unit is in west face of quarry in which the underlying limestone was studied.

Limestone; see Pl. 40 and p. 212 to p. 214 for detailed description; basal contact gradational; about.. 14.0

Shale; medium gray; calcareous; large crinoid stem fragments, productid brachiopods; contacts gradational; about..... 2.0

Shale; greenish-gray; micaceous; about..... 3.0

Siltstone; greenish-gray to light brownish-gray; calcareous; micaceous; about..... 0.5

Shale; as second above; about..... 10.0

Shale, siltstone, and sandstone interbedded; shale, greenish-gray, silty, micaceous; siltstone, as second above; and sandstone, light brownish-gray to yellowish brown, coarse silt- to very fine sand-size quartz particles, grains subangular to subrounded and elongate to equant, micaceous, very thin- to thick-bedded, small-scale cross stratification locally, this sandstone development displays abrupt facies change into silty shale

Thickness,
feet

northeast of this locality; thickness variable;
featheredge to..... 30.0

Note - this unit displays inverse thickness
relationships to the underlying shale.

Shale; olive gray to greenish-gray; clayey to silty;
4 zones of clay-ironstone concretions in the upper
half; micaceous; sparse pelecypod and brachiopod im-
pressions, no shell material was observed; thickness
variable..... 35.0-50.0

Note - this shale definitely represents the lower
part of the Robbins Sh. Mbr. Preliminary clay-
mineral analysis indicates an illite, illite-
mixed layer clay, kaolinite, and ?vermiculite
assemblage. Four samples spaced at 10-foot
intervals from 5 to 35 feet above the underlying
Haskell Ls. Mbr. were analyzed. Robbins Sh. top
was not definitely recognized at this locality.
Whether the 14-foot thick limestone represents the
Amazonia Ls. farther north or an additional lime-
stone of slightly younger age was not verified
during the course of this study.

Haskell Ls. Mbr.

Limestone (mixed-fossil lime wackestone to packstone);
light brownish-gray with medium bluish-gray overtones;
crinoids, brachiopods, bryozoans, sparse fusulinids;
thickness variable..... 0.3-0.5

Stranger Fm.

Vinland Sh. Mbr.

Shale; greenish-gray; slightly micaceous; clayey to
silty downward; abundantly fossiliferous in upper 2
to 3 feet; crinoids, brachiopods, bryozoans, gastro-
pods, cephalopods, abundant Myalina; thickness ex-
posed..... 17.0

52.--Composite of a quarry exposure near NE corner sec. 15 (Haskell Ls. to
Robbins Sh. Members of Lawrence Fm.), a streambank exposure in SE¼
sec. 17 (Vinland Sh. Mbr. of Stranger Fm. to Haskell Ls. Mbr. of
Lawrence Fm.), and a log of stratigraphic test drilling near SW corner
sec. 17, T. 34 S., R. 12 E., Chautauqua Co., Kans. Section by S. M.
Ball and H. A. Mendoza. Measured and described in Jul., 1958. Drilling
completed in Feb., 1959 by E. L. Reavis and William Gellinger. Logged
on site by S. M. Ball.

Douglas Grp.

Lawrence Fm.

Robbins Sh. Mbr.

Shale; greenish-gray; clayey to silty; micaceous;
exposed below soil..... 1.5

Thickness,
feet

Sandstone; yellowish-brown; coarse silt- to very fine sand-size quartz particles; grains angular to subrounded and elongate to equant; micaceous; moderately calcareous; about..... 0.6
Shale; greenish-gray; clayey to slightly silty; micaceous; about..... 18.0

Note - samples taken at 0.5 foot, 5 feet, 10 feet, and 15 feet above the underlying Haskell Ls. Mbr. were analyzed for clay minerals. Preliminary analysis indicates the presence of illite, illite-mixed-layer clay, kaolinite, and ?vermiculite.

Haskell Ls. Mbr.

Limestone; light gray to medium light gray; thin wavy bedding; finely crystalline; abundant stringers, angular "fragments", and irregular blebs of sparry calcite that are ?algal; brachiopods, crinoids, echinoids, corals, sparse fusulinids; shaly parting and argillaceous to silty in lower 2 feet; basal contact gradational; thickness variable in the vicinity of this locality.. 12.0-14.0

Stranger Fm.

Vinland Sh. Mbr.

Shale and siltstone interbedded; shale, greenish-gray with medium bluish-gray overtones, silty, micaceous; siltstone, light brownish-gray with greenish-gray overtones; very thin-bedded; micaceous; about... 7.5
Mudstone; medium bluish-gray; clayey to silty; exposed above water level in stream..... 2.0

Note - this mudstone is the oldest unit exposed in this section. The description below is a log of rotary samples collected during stratigraphic test drilling.

Siltstone to sandstone; light brownish-gray, silt- to very fine sand-size quartz particles; calcareous cement; sparse fragments of brachiopods; about..... 33.0
Shale to siltstone; greenish-gray; slightly calcareous; slightly micaceous; about..... 36.0

Note - the upper 60 feet of the stratigraphic test hole penetrated the exposed part of this stratigraphic section. The drill hole was cored about 36 feet above Haskell Ls. top.

53.--Streambank exposure and spillway cutbank exposure in SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 26 S., R. 14 E., Woodson Co., Kans. Type section of Robbins Sh. Mbr. of Lawrence Fm. Section by S. M. Ball and G. F. Stewart. Measured and described in Jun., 1963.

| | Thickness, feet |
|--|--------------------|
| Douglas Grp. | |
| Lawrence Fm. | |
| Ireland Ss. Mbr. | |
| Sandstone; yellowish-brown; platy to flaggy parting; thick-bedded; abundant bottom markings; "rolled" sandstone masses; furrow-flow casts; interference ripple marks on upper surfaces of some blocks; silt- to fine sand-size quartz particles; grains subangular to sub-rounded and elongate to equant; contains clay-ironstone concretions and plant remains, <u>Calamites</u> ; thickness exposed..... | 4.0 |
| Robbins Sh. Mbr.-see Fig. 22 and p. 134 to p. 136 for detailed description. | |
| Haskell Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone to mudstone); medium bluish-gray; a single, vertically-jointed bed within which discontinuous bedding is developed; bottom markings on upper surface; skeletal grains include brachiopods, crinoids, fusulinids, sparse <u>Myalina</u> , and sparse <u>Wewokella</u> ; grains in lower 0.1 to 0.3 are commonly <u>Osagia</u> -coated; shaly parting and slightly argillaceous near contacts; contacts gradational; about... | 2.8 |
| Stranger Fm. | |
| Vinland Sh. Mbr. | |
| Shale; greenish-gray to light brownish-gray; clayey to silty upward; a mudstone locally in lower part; fossils common to abundant upward; lower 1.2 feet contains abundant productid brachiopod spine and valve fragments, arenaceous foraminifers, ostracods, fusulinids, echinoid spines, and crinoid stem and calyx plate fragments; middle 2.4 feet contains sparse arenaceous foraminifers including <u>Ammovertella</u> , sparse pelecypod fragments, sparse ?plant remains, mica flakes, pyrite crystals, and medium silt-size quartz particles; upper 1.2 feet contains stringers and nodules of fossil hash in which productid and other brachiopods including <u>Composita</u> , bryozoans, sparse echinoid spines, crinoids, and sparse arenaceous foraminifers including <u>Ammodiscus</u> are extremely fragmented and commonly <u>Osagia</u> -coated; about..... | 4.8 |
| Note - four samples taken at base, 1.5, 3, and 4.5 feet above the underlying Westphalia Ls. Mbr. were analyzed for clay minerals. Preliminary analysis indicates the presence of illite, | |

Thickness,
feet

illite-mixed layer clay, kaolinite, and ?vermiculite. The kaolinite content is apparently higher in the upper, siltier part of the member but no attempt was made to quantify by constituent percentages.

Westphalia Ls. Mbr.

Limestone (algal-fusulinid lime packstone); light brownish-gray; predominantly lime mud matrix; a single ledge with discontinuous bedding locally; extremely abundant fusulinids, brachiopods common, bryozoans common, crinoids common, and pelecypods common; a zone of abundant brachiopods including Derbyia, Pulchratia, and Linoproductus from 0.5 to 0.7 foot above base; most of the skeletal remains are coated with calcium carbonate; many of the coatings are the algal-foramiferal consortium Osagia; the orientation of fusulinids was, in part, controlled by burrowing pelecypods, 3 of which are arranged in life position (see Pl. 44A); lobate lower contact with irregular apophyses of underlying shale (mudlumps) protruding into the Westphalia (see Pl. 44B); about.....

4.0

Tonganoxie Ss. Mbr.

Shale; light greenish-gray to light bluish-gray; finely laminated; clayey to slightly silty; very finely micaceous relative to size of mica flakes found in Douglas Group sandstones; nodules of argillaceous to silty limestone in upper 0.5 foot; sample taken 1.5 feet below top contained sparse to common fossils including Ammovertella, ostracodes, productid brachiopod spines, Naticopsis, and echinoid spines; thickness exposed.....

3.0

Note - the sample collected for washing was halved and analyzed for clay minerals. Preliminary analysis indicates a clay-mineral assemblage similar to those of the Vinland and Robbins Members at this locality.

54.--Quarry exposure in NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 33, T. 3 S., R. 22 E., Doniphan Co., Kans. Type section of the Wathena Shale Mbr. of the Lawrence Fm. Measured and described in Jul., 1959.

Shawnee Grp.

Oread Ls. Fm.

Heebner Sh. Mbr.; remnant exposed below loess.

Leavenworth Ls. Mbr.; about.....

1.8

Snyderville Sh. Mbr.

Shale; abundantly fossiliferous; about.....

0.5

| | Thickness, feet |
|--|--------------------|
| Limestone; abundantly fossiliferous; about..... | 0.6 |
| Shale to mudstone; about..... | <u>12.0</u> |
| Total thickness of Snyderville Sh. Mbr..... | 13.1 |
| Toronto Ls. Mbr.; about..... | 5.1 |
| Note - Oread rocks not described. | |
| Douglas Grp. | |
| Lawrence Fm. | |
| Wathena Sh. Mbr. - see Fig. 25 and p. 158 to p. 160 for detailed description. | |
| Amazonia Ls. Mbr. | |
| Limestone (mixed-fossil lime mudstone to wackestone); light gray to medium light gray; thin to thick and discontinuous bedding; very finely crystalline; sparsely fossiliferous; brachiopods, crinoids, ?linear algae; poorly exposed in greater part of quarry; thickness exposed..... | 9.5 |
| 55.--Road cut exposure in NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 21 T, 12 S., R. 19 E., Douglas Co., Kans. Section by S. M. Ball, P. C. Franks, Don Scafe, and Ada Swine- ford. Measured and described in Jun., 1962. | |
| Shawnee Grp. | |
| Oread Ls. Fm. | |
| Toronto Ls. Mbr. | |
| Limestone (mixed-fossil lime wackestone); "fresh" rock surfaces pale yellowish-brown, weathers grayish- orange; speckled by ?Mn-oxide dendrites on "fresh" surfaces; skeletal grains, commonly fragmented and coated, include fusulinid, brachiopod (mainly pro- ductid), fenestrate and ramose bryozoan, crinoid, and gastropod debris; <u>Cancrinella</u> and <u>Neospirifer</u> identi- fied; lime mud matrix extensively weathered; thickness described..... | 0.5 |
| Douglas Grp. | |
| Lawrence Fm. | |
| Wathena Sh. Mbr. | |
| Siltstone; grayish-orange where rich in limonitic stain to yellowish-gray, argillaceous films and laminae are light gray; irregularly to thinly laminated; parting tends to be shaly or irregularly flaggy; contains abundant interstitial clay and locally as much as 40 percent intercalated mudstone as films, pods, and contorted wavy laminae; abundant flakes of white mica and biotite concentrated mainly in silty laminae and along bedding surfaces; locally | |

Thickness,
feet

| | |
|---|---------|
| speckled by "limonite" in silty layers; trace amounts of nearly microscopic pyrite crystals; sparse small clam fragments and molds; grades into unit next below; about..... | 1.5 |
| Siltstone; greenish-gray in more argillaceous parts, very light gray in siltier parts; thin-laminated to laminated, laminae both wavy and contorted, pods and streaks of silt intercalated with the more argillaceous parts of the rock, bedding similar to that ascribed to tidal flats; shaly parting and tendency to break into irregular blocks as much as 15 cm long parallel to bedding and 6 cm thick; intercalated mudstone approximates 30 to 40 percent of the rock, somewhat plastic; about 5 percent flakes of white mica; less than 5 percent pyrite as nearly spherical crystalline aggregates as much as 0.5 cm in diameter; abundant interstitial clay; grades into units next below and above, about.. | 1.5 |
| Siltstone; light gray with greenish overtones, weathers grayish-orange; thin-laminated to laminated; laminae are wavy and lenticular; shaly to flaggy parting; composed mainly of sandy siltstone with about 20 percent intercalated argillaceous laminae and films; intercalated clay is somewhat plastic; less than 10 percent flakes of white mica and biotite, trace amounts of pyrite in anhedral aggregates less than 1mm in long diameter; somewhat calcareous; abundant interstitial clay; grades into units next below and above through 0.5 foot intervals or less; about..... | 2.5 |
| Shale; light gray with greenish overtones; thin-laminated, laminae somewhat wavy in basal parts; shaly parting; somewhat plastic; locally sandy at base, generally silty; less than 5 percent mica, the larger flakes of which are concentrated mainly along silty films and laminae; trace amounts of pyrite as spheroidal aggregates measuring less than 2 mm in diameter and composed of small crystals; grades upward from coal next below with decreasing waviness of laminae and decreasing abundance of brown to dark gray carbonaceous films in the lower foot; grades into unit next above, thickness variable..... | 2.9-3.5 |
| Coal; dark gray; slightly wavy thin laminae with thin interlaminae of greenish-gray clay; trace amounts of microcrystalline pyrite as minute blebs less than 1 mm long; grades into unit next above, about..... | 0.02 |
| Mudstone; greenish-gray becoming medium light gray with greenish overtones toward the top; indistinct | |

Thickness,
feet

| | |
|---|---------|
| <p>lamination best seen in the upper 0.5 feet; breaks into rounded and irregularly-shaped blocks measuring as much as about 10 cm in long dimension, tends to break along slickensided surfaces; may contain sparse flecks of ?carbonaceous matter throughout, fragments and discontinuous films of carbonaceous matter common near top as are round light gray blebs of calcite up to 1 mm in diameter; grades into unit next below through a 0.5 foot interval; thickness variable.....</p> | 3.5-4.0 |
| <p>Mudstone; mottled grayish-red and greenish-gray, sparse olive brown limonitic specks and stringers; weathers mainly grayish-red and moderate yellowish-orange; breaks into irregular and rounded blocks up to about 7 cm in long dimension, commonly parts on slickensided surfaces filmed with hematite; no obvious lamination except in lower 0.3 foot where shaly parting is developed locally in dominantly greenish-gray mudstone; similarly the upper 0.5 feet tend to be mainly greenish-gray; greenish-gray and olive parts carry less than 5 percent minute flakes of white mica, trace amounts of mica elsewhere; base marked by numerous argillaceous calcareous nodules as much as 15 cm long and 6 cm thick, moderate grayish-yellow and pale olive to light olive gray mottled grayish-red; nodules contain trace amounts of minute pyrite crystals less than 1 mm long and locally are cut by veinlets and stringers of coarsely crystalline light gray to yellowish-brown calcite, veinlets and stringers are as much as 2 mm thick, diversely oriented, and commonly arcuate; nodules rest directly on unit next below; grades into unit above; thickness variable.....</p> | 2.5-3.0 |
| <p>Shale; greenish-gray; thin-laminated; shaly to papery parting; sparse chonchoidal fracture; generally silty and containing sparse hard silty films and thin laminae; generally calcareous; less than 5 percent minute flakes of white mica and biotite, the coarser ones of which tend to be concentrated mainly in the silty films and laminae; trace amounts of pyrite as anhedral blebs locally distributed along laminae; thickness variable.....</p> | 0.5-1.0 |
| <p>?Amazonia Ls. Mbr. Limestone; varicolored, medium gray, yellowish-gray and greenish-gray; weathers pale yellow-brown and greenish-gray; forms a single nodular bed as much as 1 foot thick and embedded in calcareous shale like that above and below; locally forms a zone of irregular slabby to nodular beds totaling about 1.5 feet</p> | |

Thickness,
feet

thick, also pinches out locally into calcareous shale like that above and below and containing nodules of the limestone; generally argillaceous; less argillaceous parts within the rock are medium gray; rudely rectangular and irregular masses of calcite that are subrounded to angular and measure up to 5 cm in long dimension, yellowish-gray; angular, rectangular to irregular masses of microcrystalline calcite that measure from 1 mm to 3 cm in long dimension, are cut by veinlets and stringers of coarsely crystalline calcite, and some of which show faint, arcuate lamination that is concave upward; the medium gray masses are more abundant; the masses are embedded in a more argillaceous matrix composed of stringers, veinlets, and clots of greenish-gray argillaceous limestone and moderate yellowish-brown to light gray coarsely crystalline calcite; about 5 percent crystalline pyrite as scattered subspherical aggregates measuring up to 2 mm in diameter and concentrated on the upper and lower surfaces and in the matrix; the rock may be largely an algal limestone in which dessication cracks and voids within and between algal heads are filled by more argillaceous material; thickness variable.....

1.0-1.5

Ireland Mbr.

Shale; greenish-gray; thin-laminated; shaly to papery parting; sparse hard silty films and thin laminae; less than 5 percent minute white mica and biotite flakes, the coarser ones of which tend to be concentrated mainly in the silty films and laminae; trace amounts of pyrite as anhedral blebs locally distributed along laminae; locally calcareous; base not exposed.....

3.0

Note - preliminary clay-mineral analysis of the Wathena Sh. Mbr. indicates illite, kaolinite, ?vermiculite, and 1 or 2 mixed-layer clays.

56.--Road cut exposure near center east line SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 25, T. 12 S., R. 19 E., Douglas Co., Kans. Section by S. M. Ball, P. C. Franks, Don Scafe, and Ada Swineford. Measured and described in Jun., 1962.

Shawnee Grp.

Oread Ls. Fm.

Toronto Ls. Mbr.

Limestone (mixed-fossil lime wackestone); mottled yellowish-gray and grayish-orange; skeletal grains include crinoid, brachiopod (mainly productid), fusulinid, bryozoan, echinoid, and tiny (maximum of 0.7 mm in height) gastropod remains; coatings of the

Thickness,
feet

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| <p>algal-foraminiferal consortium <u>Osagia</u> on fragmented grains common; other grains consist of about 3 percent very fine to coarse silt-size, subangular to subrounded, equant to elongate quartz particles and about 1-2 percent clay minerals; grains embedded in 8-14 micron lime mud matrix; spar restricted to fossil void fillings and recrystallized fossil fragments; upper contact even and marked by a grayish-orange clay parting that weathers as a recess in the exposed rock surface; basal contact irregular and gradational; about.....</p> | 0.4 |
| <p>Siltstone; grayish-yellow-green streaked light olive brown; medium silt- to very fine sand-size, subangular to subrounded, equant to elongate quartz particles; medium silt size grade predominant; contains crinoid, brachiopod, and fusulinid remains; <u>Neospirifer</u> identified; about 3-5 percent flakes of white mica; about 2 percent clay minerals; carbonate cement; upper contact gradational; basal contact irregular and weathers to an apparent sharpness, however this rock type is gradational relative to adjacent units; about.....</p> | 0.1-0.2 |
| Lawrence Fm. | |
| Wathena Sh. Mbr. | |
| <p>Siltstone; yellowish-gray, grayish-orange to yellowish-orange where rich in limonite; argillaceous films and laminae are light gray; irregular to wavy thin laminae; parting tends to be shaly, but is locally irregularly flaggy; contains locally abundant interstitial clay and as much as 20 percent intercalated mudstone as films, pods, and contorted wavy laminae; about 5 percent white mica as disseminated minute flakes, the coarser of which tend to be concentrated in siltstone laminae and on bedding surfaces; stained and speckled by "limonite" in silty parts; basal contact gradational through 0.2 foot interval; about.....</p> | 1.4 |
| <p>Siltstone; light gray with greenish overtones; sparse moderate reddish-brown "limonitic" streaks parallel lamination; thin-laminated to laminated, laminae both wavy and contorted, pods and streaks of silt intercalated with more argillaceous parts of siltstone; irregular shaly to flaggy parting; abundant interstitial clay; approximately 5 percent or less disseminated flakes of white mica, sparse flecks of carbonaceous matter; basal contact gradational through 0.2 foot interval; about.....</p> | 1.7 |

Thickness,
feet

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| Siltstone; argillaceous; light gray with greenish overtones, spotted yellowish-orange locally; indistinct lamination emphasized upon weathering; irregular blocky to lumpy fracture, blocks measure as much as 4 cm in long dimension; less than 5 percent white mica as disseminated flakes; locally calcareous; sparse carbonaceous flecks; abundant interstitial clay; grades into unit next below through 0.2- to 0.5-foot interval; thickness variable..... | 1.9-2.1 |
| Shale; light gray with yellowish-gray overtones; thinly laminated, sparse silty interlaminae intercalated with less silty argillaceous laminae; shaly parting; less than 5 percent white mica as minute flakes the coarsest of which are as much as 1 mm in long dimension and concentrated along interfaces between silty and argillaceous laminae; trace amounts of ?biotite as minute flakes; sparse carbonaceous flakes; locally calcareous; thickness variable..... | 2.9-3.1 |
| Coal; dark gray; very thinly interlaminated argillaceous and coaly smut; coaly laminae grade from coal to carbonaceous shale..... | 0.01-0.05 |
| Mudstone; gray-green; breaks commonly along slickensided surfaces into irregular blocks generally less than 3 cm in long dimension; less than 2 percent white mica as disseminated minute flakes; irregularly disseminated flecks and films of carbonaceous matter; calcareous; grades into unit next below through 0.3-foot interval; thickness variable..... | 1.0-1.2 |
| Mudstone; moderate greenish-gray; irregular to blocky fracture, fragments measure as much as 0.4 cm in long dimension; about 1 percent disseminated minute flakes of white mica; highly calcareous; thickness variable..... | 1.2-1.5 |
| Mudstone; mottled grayish-red and moderate olive in upper parts to brownish-gray with dusky yellow spots and blebs in basal parts; fractures into irregular lumps and blocks as much as 5 cm in long dimension; calcareous; grades into unit next below through 0.2-foot interval; thickness variable..... | 1.7-1.9 |
| Mudstone; greenish-gray; blocky to conchoidal fracture, irregular blocks as much as 3 cm in long dimension; shaly parting in lower 0.3 foot; slickensided surfaces; calcareous, sparse calcite pellets forming nodules 0.5 cm. or less in diameter; trace amounts of white mica as minute disseminated flakes; basal contact gradational through 0.3 foot interval; thickness variable..... | 1.6-1.9 |

| | Thickness, feet |
|--|--------------------|
| Shale; mottled grayish-red and greenish-gray, locally stained dusky yellow; thin-laminated; shaly parting with slight tendency toward conchoidal fracture; calcareous; less than 5 percent white mica as disseminated flakes; grades into unit next below through 0.2-foot interval; thickness variable..... | 0.5-0.7 |
| Shale; predominantly light gray with greenish overtones, locally mottled grayish-red in lower 0.5 foot; laminated to thin - laminated; sparse thin silty laminae increasing in abundance downward; shaly parting; calcareous; trace amounts of pyrite as subspherical aggregates; less than 5 percent disseminated minute flakes of white mica and biotite; thickness variable. | 1.3-1.5 |
| ?Amazonia Ls. Mbr. | |
| Limestone; facies as in stratigraphic section 55; thickness variable..... | 0.3-0.5 |
| Shale; predominantly light gray, locally mottled greenish-gray and grayish-red; thin-laminated, weathers papery; calcareous; less than 5 percent minute flakes of white mica; basal contact gradational through 0.5-foot interval; thickness variable..... | 1.0-1.5 |
| Shale; predominantly a uniform grayish-red locally mottled greenish-gray near top and basal contacts; laminated to thin-laminated; shaly to papery parting with slight tendency toward conchoidal fracture; silty laminae intercalated with more argillaceous laminae, very sparse streaks, specks, and blebs of dusky yellow and dark greenish-yellow "limonite" stains; less than 3 percent minute flakes of white mica; highly calcareous; grades into contiguous units through 0.5-foot intervals; thickness variable..... | 3.7-4.0 |
| Shale; greenish-gray, locally mottled grayish-red; thin-laminated, weathers papery; alternating silty and more argillaceous laminae; less than 5 percent minute flakes of white mica; calcareous; contacts gradational through 0.5-foot intervals; about..... | 1.6 |
| Shale; predominantly greenish-gray, weathers medium light gray, an 0.05 foot dusky yellow-green band 0.2 foot above base of unit; clayey to silty; 5 percent or less white mica as minute disseminated flakes; slightly calcareous; thickness variable..... | 1.5-1.8 |
| Limestone; as fifth above; thickness variable; featheredge to as much as..... | 0.8 |
| Ireland Ss. Mbr. | |
| Shale; light gray with greenish overtones; thin-laminated; slightly silty; sparse minute aggregates of pyrite; moderately calcareous; approximately 5 percent disseminated minute flakes of white mica, trace amounts of ?biotite; basal contact covered; exposed.. | 5.0 |

Thickness,
feet

Note - preliminary clay-mineral analysis indicates presence of illite, illite-mixed layer clay, kaolinite, and ?vermiculite in the Wathena Sh. Mbr. of the Lawrence Fm. at this locality.

57.--Quarry exposure near NE corner NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 25 S., R. 13 E., Woodson Co., Kansas. Type section of Toronto Ls. Mbr. of Oread Ls. Fm. Section by S. M. Ball and R. R. West. Measured and described in Aug., 1961.

Shawnee Grp.

Oread Ls. Fm.

Snderville Sh. Mbr.

| | |
|--|-----|
| Siltstone to sandstone; light brownish-gray to yellowish-brown; thin-bedded; medium silt- to very fine sand-size quartz particles; grains subangular to rounded and irregular to equant; ferruginous (?limonite) stain on many quartz grains; argillaceous partings; exposed below soil..... | 7.2 |
| Siltstone and silty shale interbedded; yellowish-brown and greenish-gray; siltstone as first above; about..... | 3.5 |
| Mudstone; grayish-red mottled greenish-gray; weathers to a blocky fracture; about..... | 1.0 |
| Mudstone; grayish-red; greenish-gray stringers locally; about..... | 4.7 |
| Shale; light brownish-gray; slightly silty; micaceous; about..... | 0.6 |
| Shale; yellowish-brown; as first above; about..... | 1.0 |
| Shale to mudstone; light brownish-gray with greenish-gray overtones; in part blocky; as second above; about..... | 3.2 |
| Siltstone; yellowish-brown; a ferruginous "boxwork" filled with yellowish-green clay; concretionary; about..... | 0.2 |
| Shale to mudstone; light brownish-gray to greenish-gray; clayey to slightly silty; weathers blocky in upper part locally; basal contact apparently sharp; about..... | 4.9 |
| Toronto Ls. Mbr. - see Pl. 31 and p. 168 to p. 172 for detailed description. | |

Douglas Grp.

Lawrence Fm.

Wathena Sh. Mbr.

| | |
|--|-----|
| Shale; greenish-gray; micaceous; fossiliferous; about..... | 0.6 |
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Thickness,
feet

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|---|-----|
| Limestone; yellowish-brown to medium bluish-gray; very thin-bedded; argillaceous with shaly parting; abundantly fossiliferous; brachiopods including <u>Derbyia crassa</u> , crinoids, pelecypods including <u>Aviculopecten</u> ; silty; micaceous; about..... | 2.0 |
| Limestone; medium bluish-gray to grayish-black; very thin-bedded; shaly parting; fossiliferous with crinoids, brachiopods, plant remains; carbonaceous; micaceous; silty; basal contact gradational into underlying Upper Williamsburg coal bed; about..... | 1.0 |
| Note - this limestone apparently grades laterally into the calcareous, locally fossiliferous, cross-stratified siltstone exposed in the highway cut 60 yards north of the quarry. | |

58.--Road cut exposure near center south line NE $\frac{1}{4}$ sec. 12, T. 33 S., R. 11 E., Chautauqua Co., Kans. Measured and described in Sept., 1958.

Shawnee Grp.

Oread Ls. Fm.

| | |
|--|------------------|
| Leavenworth Ls. Mbr.; not described; about..... | 2.1 |
| Snyderville Sh. Mbr. | |
| Shale; greenish-gray; clayey to silty downward; micaceous; about..... | 11.0 |
| Sandstone; yellowish-brown; very fine- to fine-grained quartz particles; thin to thick poorly defined beds; locally cross-stratified; about..... | 28.0 |
| Shale; yellowish-brown and greenish-gray; silty, micaceous; about..... | 8.0 |
| Sandstone; as second above; basal contact erosional; about..... | 32.5 |
| Shale; greenish-gray; calcareous; thickness variable; featheredge to as much as..... | 1.0 |
| Total thickness of Snyderville Sh. Mbr..... | <u>79.5-80.5</u> |

Toronto Ls. Mbr.

| | |
|--|---------|
| Limestone (mixed-fossil lime wackestone to packstone); light brownish-gray with medium bluish-gray overtones; a single bed, indistinct and discontinuous very thin beds locally; shaly parting near contacts; slightly argillaceous to silty; abundant brachiopod, bryozoan, and crinoid remains, sparse fusulinids; ?cut out below sandstone in the Snyderville on west side of road; best exposure on east side of road; thickness variable. | 0.5-0.7 |
|--|---------|

Douglas Grp.

Lawrence Fm.

| | Thickness, feet |
|--|--------------------|
| Shale; greenish-gray; silty; abundantly fossiliferous in upper 1 to 2 feet; profuse crinoid columnals and calyx plates, abundant brachiopods including <u>Chonetes</u> , <u>Composita</u> , <u>Punctospirifer kentuckyensis</u> , and <u>Rhipidomella carbonaria</u> , fenestrate bryozoans, ramose bryozoans, sparse lophophyllid corals; abundant myalinid pelecypods from about 7 to 9 feet below base of Toronto Ls.; about..... | 17.0 |
| Mudstone; grayish-red; thickness variable..... | 2.0-3.0 |
| Shale; greenish-gray; silty; micaceous; about..... | 1.0 |
| Mudstone; as second above; contains reddish-brown limestone nodules; nodules are sparsely fossiliferous with minute brachiopods; thickness variable..... | 2.0-3.0 |
| Note - an additional 48 feet of alternating shale, mudstone, siltstone, and sandstone section is exposed at this locality but was not described. | |

Oklahoma

59.--Composite of an escarpment exposure near center west line NW $\frac{1}{4}$ sec. 29 (Plattsmouth Ls. Mbr. to Snyderville Sh. Mbr. of Oread Ls. Fm.), road cut exposures from near center south line SE $\frac{1}{4}$ sec. 29 to near center west line NW $\frac{1}{4}$ sec. 33 (thick sandstone-shale section that includes the Jonesburg Sandstone in its lower part), and a road cut exposure near the center east line SE $\frac{1}{4}$ sec. 34 (Cheshewalla Sandstone to sandstone above Bowring Limestone), T. 29 N., R. 10 E., Osage Co., Okla. Thicknesses of the thick covered intervals were measured with plane table, alidade, and stadia rod. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

Shawnee Grp.

Oread Ls. Fm.

Plattsmouth Ls. Mbr.

| | |
|---|------|
| Limestone; light gray to medium light gray; thin wavy bedding; finely crystalline with stringers and blebs of sparry calcite; brachiopods including <u>Linoproductus</u> , fusulinids, crinoids, echinoids, abundant horn corals in lower 5 feet; exposed below soil..... | 15.0 |
|---|------|

Heebner Sh. Mbr.

| | |
|---|-----|
| Mudstone; light brownish-gray to medium bluish-gray; contains minute calcareous nodules; clayey to slightly silty; slightly micaceous; about..... | 8.0 |
| Siltstone; yellowish-brown; very thin-bedded; micaceous, about..... | 3.0 |

Thickness,
feet

| | |
|---|------|
| Shale to mudstone; as second above but lamination is better developed and contains brachiopods and crinoids; about..... | 5.0 |
| Total thickness of the Heebner Sh. Mbr..... | 16.0 |
| Leavenworth Ls. Mbr. | |
| Limestone; medium bluish-gray; thick, single, vertically-jointed bed; fractures conchoidally; crinoids, brachiopods, abundant small fusulinids, base poorly exposed; about..... | 1.5 |
| Note - at about the horizon of Leavenworth Ls. base, an 0.2-foot thick, grayish-black limestone pebble conglomerate exists but was not observed in place. | |
| Covered interval; about..... | 57.5 |
| Note - the Lawrence-Oread contact probably occurs within the lower part of this covered interval. However, the basal member of the Oread, that is, the Toronto Ls., is a thin discontinuous bed in this area. Even if the entire section was exposed, the Lawrence-Oread formational boundary might not be identifiable. | |
| Stranger-Lawrence Fm. | |
| Sandstone, shale, and mudstone interbedded; sandstone, yellowish-brown, thin to thick relatively even bedding, locally cross-stratified, micaceous, sparse pelecypods, <u>Linoproductus oklahomae</u> common about 18 feet below top; shale and mudstone, greenish-gray and light brownish-gray, clayey to silty, micaceous; about..... | 77.0 |
| Note - the lower part of this unit represents the Jonesburg Sandstone of Goldman (1920) | |
| Covered interval; shale-sandstone section (predominatly shale) where exposed locally; about..... | 75.0 |
| Sandstone; yellowish-brown; thin-bedded; fine-grained; upper contact concealed; thickness exposed..... | 2.0 |
| Shale; greenish-gray; silty; micaceous; about..... | 1.0 |
| Westphalia (Bowring) Ls. Mbr. | |
| Limestone; yellowish-brown; very thin wavy bedding; crinoids; brachiopods, abundant fusulinids; about..... | 3.0 |
| Shale; greenish-gray; silty; micaceous; mostly covered; about..... | 7.5 |
| ?Cheshewalla Ss. Mbr. | |
| Sandstone; yellowish-brown; very fine- to fine-grained; quartz grains subangular to subrounded and elongate to equant; base concealed; thickness exposed..... | 11.0 |
| Note - all strata included in this stratigraphic section are grouped within the Vamoosa Fm. of Oklahoma terminology. | |

60.--Composite of road cut exposures near center south line sec. 14 (base of section) to near NE corner SE $\frac{1}{4}$ sec. 15 to NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16 (top of section), T. 28 N., R. 11 E., Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | Thickness, feet |
|---|--------------------|
| Douglas Grp. | |
| Covered interval; sandstone rubble and vegetation are indicative of sandstone section; about..... | 20.0 |
| Sandstone; light brownish-gray and yellowish-brown; fine- to medium-grained; quartz particles subangular to subrounded; about..... | 11.0 |
| Covered interval; shale-sandstone section is indicated by small exposures in drainage ditches along slope; about..... | 60.0 |
| Sandstone and shale interbedded; sandstone, as second above; shale, greenish-gray to light brownish-gray, silty, micaceous; about..... | 13.0 |
| Sandstone; yellowish-brown; thin- to thick-bedded; fine-grained; quartz particles angular to subangular and equant; grains stained with a ferruginous (?limonite) material; micaceous; about..... | 3.0 |
| Shale; olive gray; clayey to silty upward; micaceous; lamination vague locally and weathers blocky; about.. | 7.0 |
| Westphalia (Bowring) Ls. Mbr. | |
| Limestone (fusulinid lime packstone, see Pl. 20E and F); medium bluish-gray, weathers yellowish-brown; very thin-bedded, weathers slabby; crinoids, productid brachiopods, pelecypods, the alga <u>Epimastopora</u> , and profuse fusulinids; many of the skeletal grains are abraded and some are rounded and polished; both lime mud and sparry calcite form the matrix; about..... | 5.0 |
| Tonganoxie Ss. Mbr. | |
| Sandstone and shale interbedded; sandstone, yellowish-brown, massive splitting, thin to thick beds, very fine- to fine-grained, calcareous, micaceous, plant remains, fusulinids in uppermost foot; shale, greenish-gray to light brownish-gray, silty, micaceous, plant fossils; about..... | 48.0 |
| Sandstone and shale interbedded; as first above but does not contain fusulinids; thickness exposed, about. | 30.0 |
| Note - strata exposed at this locality are included within the Vamoosa Fm. of Oklahoma classification. | |

61.--Composite of road cut exposures from near center sec. 33, T. 28 N., R. 11 E., (base of section) to near SE corner NW $\frac{1}{4}$ sec. 9, T. 27 N., R. 11 E., Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | Thickness, feet |
|--|--------------------|
| Vamoosa Fm. | |
| Sandstone; float blocks on slope above Labadie (Haskell) Ls. Mbr.; exact stratigraphic position not determined | |
| Covered interval; probably shale; about..... | 4.0 |
| Labadie (Haskell) Ls. Mbr. | |
| Limestone; light gray to medium light gray; thin wavy bedding; fine to medium crystalline; ?in part dolomitized; weathers to a rubble on slope; <u>Composita</u> , <u>Crurithyris planoconvexa</u> , crinoids; about..... | 17.0 |
| Vinland Sh. Mbr. | |
| Shale; greenish-gray; clayey to slightly silty; micaceous; <u>Rhipidomella carbonaria</u> , <u>Trepostira</u> , <u>Euomphalus</u> , lophophyllid corals, crinoids; fossils concentrated in upper 6 feet; about..... | 27.0 |
| Shale and sandstone interbedded; shale, greenish-gray, clayey to silty, micaceous; sandstone, light brownish-gray to yellowish-brown, thin to thick slightly irregular beds, very fine- to fine-grained, grains angular to subrounded and elongate to equant, micaceous; upper half mostly covered; about..... | 44.0 |
| Mudstone; greenish-gray; weathers into irregularly-shaped to subcubical blocks as much as 0.2 foot in long dimension; extremely clayey, plastic; sparse crinoid remains in lowermost part; about..... | 1.0 |
| Total thickness of Vinland Sh. Mbr..... | 72.0 |
| Westphalia (Bowring) Ls. Mbr. | |
| Limestone (fusulinid lime packstone); medium bluish-gray; a single bed; arenaceous; abundant fusulinids and crinoids, sparse brachiopods; basal contact gradational; exposed for a 10-foot lateral distance along each side of road; about..... | 0.7 |
| Tonganoxie Ss. Mbr. | |
| Sandstone and shale interbedded; sandstone, light brownish-gray to yellowish-brown upward, thin to thick bedding, massive splitting, fine-grained, micaceous, tiny spired gastropods and abundant <u>Lino-productus oklahomae</u> about 39 to 40 feet below the overlying Westphalia Ls.; shale, greenish-gray, silty, micaceous; unit predominantly sandstone; about..... | 41.0 |
| Shale, siltstone, and sandstone interbedded (predominantly shale); shale and sandstone as first above; | |

Thickness,
feet

siltstone, greenish-gray argillaceous, micaceous, calcareous and contains abundant Linoproductus oklahomae in upper 2.5 feet; sparse plant fossils in lower part; thickness exposed, about..... 33.0

Note - according to my correlations the Tonganoxie Ss. of northern Midcontinent classification comprises the Bigheart Ss. Mbr. of the Tallant Fm. to the Cheshewalla Ss. Mbr. of the Vamoosa Fm. part of the Oklahoma section.

62.--Composite of a road cut exposure near center east line NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27 (upper part of section) and a quarry exposure near center east line NW $\frac{1}{4}$ sec. 17, T. 27 N., R. 10 E., Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

Vamoosa Fm.

Sandstone; yellowish-brown; thin to thick bedding; massive splitting; trough-type cross-stratification; lower contact erosional; very fine- to medium-grained; quartz particles subangular to subrounded and elongate to equant; plant fossils; thickness exposed, about... 10.0

Siltstone and mudstone interbedded; siltstone, greenish-gray to light brownish-gray, very thin beds, micaceous; mudstone, greenish-gray and grayish-red, clayey to slightly silty, slightly micaceous, moderately calcareous locally; about..... 25.0

Sandstone; yellowish-brown; thin- to thick-bedded; fine-grained; vertical "tubular" structures (?weathering features) that some have described as clam burrows; moderately calcareous in upper part; micaceous; about..... 5.0

Shale; greenish-gray; silty; micaceous; about..... 1.0

Limestone; olive gray to light brownish-gray; thin-bedded; arenaceous; pelecypods, crinoids; about..... 4.0

Shale; as second above; about..... 1.0

Limestone- see Pl. 41B and p. 214 to p. 216 for detailed description; thickness exposed, about..... 25.0

- 63.--Composite of road cut exposures from near center north line SW $\frac{1}{4}$ sec. 18, T. 27 N., R. 11 E., (top of section) to just east of center SE $\frac{1}{4}$ sec. 24, T. 27 N., R. 10 E. (base of section), Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | Thickness, feet |
|---|--------------------|
| Vamoosa Fm. | |
| Limestone; light gray to medium light gray; thin to very thin wavy beds; fine to medium crystalline; brachiopods, crinoids, sparse corals; Labadie (Haskell) Ls. Mbr.; about..... | 14.0 |
| Shale and siltstone interbedded; shale, olive gray, silty, micaceous; siltstone, greenish-gray, micaceous, sparse minute fossil fragments; about..... | 20.0 |
| Sandstone; yellowish-brown; very thin to thick bedding; massive splitting; fine-grained; micaceous; <u>Linoproductus oklahomae</u> , pelecypods, especially fossiliferous in the lower part; silty shale partings; about..... | 40.0 |
| Shale; greenish-gray; silty; micaceous; about..... | 4.0 |
| Limestone; light brownish-gray; very thin-bedded; arenaceous to argillaceous; brachiopods, crinoids, gastropods; float blocks with fusulinids at about this position but did not observe in place; contacts gradational; about..... | 1.0 |
| Shale; as second above; about..... | 5.0 |
| Sandstone; as fourth above; calcareous; <u>Linoproductus oklahomae</u> , crinoids, <u>Chonetes</u> ; ripplemarked; about..... | 4.0 |
| Shale; as fourth above; about..... | 10.0 |
| Limestone; light brownish-gray; nodular; argillaceous; abundant crinoids, sparse brachiopods; about..... | 0.7 |
| Note - about 75 additional feet of shale-siltstone-sandstone section is exposed at this locality but was not described. | |

- 64.--Road cut exposure near center section 3, T. 26 N., R. 10 E., Osage Co., Okla. Standard reference section of the Labadie Ls. Mbr. of the Vamoosa Fm. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | |
|---|------|
| Vamoosa Fm. | |
| Siltstone to sandstone; yellowish-brown; thin- to thick-bedded; medium silt- to fine sand-size quartz grains upward; particles subangular to subrounded and elongate to equant; ferruginous (?limonite) stain on grains; micaceous; thickness exposed, about..... | 7.0 |
| Shale; light brownish-gray to medium bluish-gray; clayey to silty; micaceous; about..... | 10.0 |

| | Thickness, feet |
|--|--------------------|
| Labadie Ls. Mbr. - see Pl. 38 and p. 203 to p. 205 for detailed description; about..... | 13.0 |
| Shale; as second above with crinoids in uppermost foot; about..... | 12.0 |
| Sandstone and shale interbedded; sandstone, as fourth above; shale, light brownish-gray, clayey to silty, micaceous, lamination vague locally and weathers blocky; about..... | 8.0 |
| Covered interval; about..... | 23.0 |
| Sandstone; as fifth above; thickness exposed, about.. | 7.0 |
| | |
| 65.--Composite of road cut exposures from just west of center east line NW $\frac{1}{4}$ sec. 10, T. 26 N., R. 11 E. (Bigheart Ss. Mbr. of Tallant Fm.) to center west line SE $\frac{1}{4}$ sec. 6 T. 25 N., R. 11 E. (Labadie Ls. Mbr. of Vamoosa Fm.), Osage Co., Okla. Section along U. S. Highway 60 by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958. | |
| | |
| Vamoosa Fm. | |
| Limestone; medium light gray, weathers yellowish- brown; partly dolomitized, the chocolate brown dolo- mitic unit, which is well exposed in the abandoned quarry to the west on U. S. Highway 60, is present at this locality; very thin to thin, slightly irregular beds; <u>Composita</u> , crinoids, pelecypods, spired gastro- pods, horn corals; Labadie (Haskell) Ls. Mbr.; thick- ness exposed, about..... | 33.0 |
| Sandstone and shale interbedded; most covered; from base of Vamoosa Fm. as mapped by Tanner (1956a, Pl. 1, in pocket) to base of Labadie, about..... | 35.0 |
| Covered interval; mostly shale and sandstone section; measured to road that leads to Okesa (SE $\frac{1}{4}$ sec. 9, T. 26 N., R. 11 E.); about..... | 115.0 |
| Shale; light brownish-gray; silty; micaceous, about.. | 6.0 |
| Sandstone; yellowish-brown; thick-bedded; massive splitting; very fine- to fine-grained; micaceous; about..... | 15.0 |
| Shale and siltstone interbedded; shale, light brown- ish-gray, silty, micaceous, plant fossils; siltstone; light brownish-gray, moderately calcareous, cross- stratified, <u>Linoproductus oklahomae</u> ; about..... | 10.0 |
| Sandstone; as second above but contains <u>Linoproductus</u> <u>oklahomae</u> ; about..... | 6.0 |

Thickness,
feet

| | |
|--|-----|
| Shale; light brownish-gray; moderately calcareous; contains siltstone nodules; contains a coal smut, 0.5 in thick and discontinuous; this unit pinches out 30 feet west of where described; about..... | 0.7 |
| Sandstone; yellowish-brown; thin- to thick bedded upward; massive splitting in upper 4.5 feet; micaceous; coarse silt- to medium sand-size grains; quartz particles subangular to rounded and display a ferruginous (?limonite) stain; abundantly fossiliferous in lower 2 feet, zones of relatively few fossils grade laterally into zones of plentiful fossils; abundant <u>Linoproductus oklahomae</u> , <u>Neospirifer</u> , crinoids, pelecypods, about.. | 7.0 |
| <p>Note - the lower part of the section described above forms the basal part of the Bigheart Ss. Mbr. of the Tallant Fm. Numerous geologists have identified other named sandstones in this section. However, I was unable to do so. The fossils observed in these sandstones are apparently idigenous and their preservation is exceptionally good.</p> | |
| Shale to mudstone; olive gray; clayey to silty; weathers blocky; moderately calcareous locally; <u>Linoproductus oklahomae</u> , contains calcareous siltstone nodules in western part of exposure; thickness exposed, about... | 5.0 |

66.--Composite of a spillway cutbank (Lake Hudson) exposure near SW corner NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20 (lower part of section) and an exposure at the west end of the dam (Lake Hudson) in NW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 20, T. 27 N., R. 12 E. (upper part of section), Osage Co., Okla. Section by S. M. Ball and R. R. Bower. Measured and described in Aug., 1960.

Tallant Fm.

| | |
|--|------|
| Shale and siltstone interbedded; shale, greenish-gray to light brownish-gray, clayey to silty, micaceous; siltstone, light brownish-gray calcareous, brachiopods, pelecypods; thickness exposed, about..... | 15.0 |
| Shale; as first above; about..... | 27.0 |
| Limestone; light brownish-gray; contains abundant <u>Linoproductus oklahomae</u> ; about..... | 0.2 |
| Shale; greenish-gray; clayey to slightly silty; micaceous; gastropods, sparse crinoids, <u>Linoproductus oklahomae</u> ; about..... | 2.3 |
| Sandstone; yellowish-brown; thin to thick, relatively even beds; massive splitting; fine- to medium-grained; micaceous; sparse to common gastropods and <u>Linoproductus oklahomae</u> in upper 15 feet of unit--limestone tongue or | |

Thickness,
feet

| | |
|---|------|
| lens (2 feet by 8 feet) is completely enclosed in sandstone in upper 3 feet of unit at an exposure about 75 yards southwest of the west end of dam; limestone-sandstone contacts are gradational and interfingering; thin section study of the limestone shows that it is mixed-fossil lime grainstone, grains include 30-40 percent quartz particles, trace amounts of plagioclase feldspar, trace amounts of microcline, trace amounts of clay minerals, and sparse to common fusulinids, productid brachiopod spines, crinoid fragments, gastropod fragments, and echinoid fragments; the arenaceous limestone displays a sparry calcite matrix--the lower part of the sandstone changes facies to silty shale in the spillway exposure at the east end of the dam; about..... | 27.0 |
| <p>Note - at least the lower part of the section described above is the Bigheart Ss. Mbr. of the Tallant Fm. According to my correlation, the Bigheart Ss. Mbr. correlates with the lower part of the Tonganoxie Ss. Mbr. of the Stranger Fm. of northern Midcontinent classification.</p> | |
| Shale and limestone interbedded; shale, greenish-gray to light brownish-gray, silty, micaceous; limestone, light brownish-gray with medium bluish-gray overtones, very thin even beds, in part nodular; sparse brachiopods; about..... | 17.0 |
| Limestone; medium bluish-gray; single even bed; vertically-jointed; silty; <u>Crurithyris planoconvexa</u> sparse, <u>Neospirifer</u> , <u>Linoproductus</u> , gastropods, crinoids; about..... | 1.2 |
| Shale; light brownish-gray; clayey to silty, micaceous; moderately calcareous; brachiopods; about..... | 4.0 |
| Sandstone; brownish-gray; very thin beds; fine-grained; micaceous; moderately calcareous locally; sparse brachiopods; about..... | 0.4 |
| Shale; as second above; about..... | 4.0 |
| Shale and limestone interbedded; as third and fourth above but more abundant fossils, especially in lower half; abundant <u>Crurithyris planoconvexa</u> , <u>Linoproductus</u> , <u>Neospirifer</u> , <u>Composita</u> , gastropods, crinoids, bottom markings; thickness exposed; about..... | 21.0 |
| <p>Note - the base of this section extends 2.5 feet below the top of the level part of the concrete retaining wall that forms the spillway sides.</p> | |

67.--Exposure near NE corner SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 3, T. 26 N., R. 12 E., Osage Co., Okla. Section exposed on the mound just west of Bartlesville, Oklahoma and just north of U. S. Highway 60. Measured and described in Aug., 1960.

| | Thickness, feet |
|---|--------------------|
| Barnsdall Fm. | |
| Sandstone; yellowish-brown; thin-thick even beds; very fine- to fine-grained; calcareous cement; micaceous; sparse brachiopods, poorly preserved plant fossils; thickness exposed, about..... | 5.0 |
| Covered interval; mostly shale; sandstone float covers upper half of slope; about..... | 64.0 |
| Sandstone; yellowish-brown; thin even beds; calcareous; micaceous; sparse to common casts and molds of <u>Linoproductus oklahomae</u> , gastropods, and pelecypods; about..... | 3.6 |
| Shale; greenish-gray; silty; micaceous; about..... | 0.3 |
| Limestone and shale interbedded; limestone, light brownish-gray, very thin to thin beds, abundant crinoids, ramose bryozoans, fenestrate bryozoans, brachiopods, pelecypods, gastropods, fusulinids; shale, greenish-gray, calcareous, in part silty, fauna similar to that of limestone beds; about..... | 10.2 |
| Shale; greenish-gray to light brownish-gray; clayey to slightly silty; micaceous; crinoids, brachiopods; about..... | 2.0 |
| Limestone; brownish-gray; interbedded calcareous shale in upper 2.8 feet; brachiopods, crinoids, bryozoans, pelecypods; about..... | 5.4 |
| Shale; light brownish-gray to greenish-gray; calcareous in lower half; clayey to silty; micaceous; especially fossiliferous in lower half; crinoids, pelecypods, fenestrate bryozoans, brachiopods; about..... | 5.1 |
| Limestone: brownish-gray; very thin wavy beds; shaly parting, weathers to a rubble; silty; abundantly fossiliferous, especially crinoids and brachiopods; about..... | 1.1 |
| Shale; as second above; abundantly fossiliferous, pelecypods, fenestrate bryozoans, crinoids, brachiopods including <u>Linoproductus</u> and <u>Chonetina</u> ; thickness exposed, about..... | 5.4 |

Note - lower part of this section probably correlates with the Stanton Ls. Fm. of northern Mid-continent classification and contains the Birch Creek Ls. Mbr. of the Barnsdall Fm. of Oklahoma terminology.

68.--Composite of road cut exposures from near center north line SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 15, T. 26 N., R. 11 E., (base of section) to near center sec. 25, T. 26 N., R. 10 E. (top of section), Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | Thickness, feet |
|---|--------------------|
| Tallant-Vamoosa Fm. | |
| Limestone; greenish-gray to light brownish-gray upward; very thin wavy bedding; dolomitic; brachiopods, crinoids, fusulinids; thickness exposed, about..... | 7.0 |
| Note - this unit is the Labadie (Haskell) Ls. Mbr. | |
| Sandstone, shale, and mudstone interbedded; mostly covered; grayish-red mudstone in upper half; sandstone float blocks contain <u>Linoproductus oklahomae</u> , <u>Aviculopecten</u> , and gastropods; about..... | 70.0 |
| Shale; greenish-gray; clayey to silty; micaceous; about..... | 7.0 |
| Covered interval; apparently sandstone in greater part; about..... | 31.0 |
| Sandstone; yellowish-brown; thick-bedded; massive splitting; fine-grained; <u>Neospirifer</u> , <u>Linoproductus oklahomae</u> , fusulinids, crinoids; thickness exposed, about..... | 8.0 |
| Note - this 8-foot thick unit is the lower part of the Bigheart Ss. Mbr. of the Tallant Fm. | |
| Barnsdall Fm. | |
| Shale and siltstone interbedded; shale, light brownish-gray to olive gray, clayey to silty, micaceous, in part weathers blocky; siltstone, greenish-gray, thin-bedded, calcareous; about..... | 50.0 |
| Sandstone to siltstone; yellowish-brown; thin even bedding; silt- to fine sand-size quartz particles; calcareous; brachiopods, pelecypods; about..... | 4.0 |
| Shale; as second above; about..... | 55.0 |
| Birch Creek Ls. Mbr. | |
| Limestone; medium light gray; very thin to thin even bedding; greenish-gray shale break in upper foot; reddish-brown, 0.2-foot thick rind at top of unit; fusulinids, brachiopods, crinoids; about..... | 5.7 |

69.--Railroad cutbank exposure near center NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 35, T. 26 N., R. 10 E., Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | Thickness, feet |
|---|--------------------|
| Vamoosa Fm. | |
| Shale and siltstone interbedded; greenish-gray; micaceous; sandy in lower foot; thickness exposed, about..... | 4.0 |
| Shale; medium bluish-gray to greenish-gray upward; in part weathers blocky; silty to clayey; poorly preserved plant fossils in upper foot; about..... | 4.0 |
| Siltstone; medium light gray; very thin-bedded; shaly parting, weathers to a rubble; about..... | 1.7 |
| Mudstone; greenish-gray to medium bluish-gray; silty; ?phosphatic nodules; about..... | 1.9 |
| Limestone; medium bluish-gray; very thin-bedded; argillaceous, weathers to a rubble; abundant fusulinids; about..... | 1.0 |
| Shale to mudstone; greenish-gray to dark greenish-gray; silty to clayey; micaceous; gastropods, pelecypods, crinoids, fusulinids, and brachiopods; phosphatic nodules around fossil nuclei; about..... | 3.9 |
| Limestone; as second above with crinoids and brachiopods; about..... | 2.4 |
| Note - the succeeding 3 units comprise the Labadie (Haskell) Ls. Mbr. | |
| Shale; medium dark gray to greenish-gray upward; clayey to slightly silty; micaceous; gastropods, brachiopods including <u>Rhipidomella carbonaria</u> and <u>Orbiculoidea missouriensis</u> ; about..... | 3.8 |
| Mudstone; medium bluish-gray; extremely argillaceous; shaly parting near contacts; contacts gradational; <u>Orbiculoidea missouriensis</u> ; about..... | 1.4 |
| Shale; greenish-gray and medium bluish-gray; clayey to silty; micaceous; thickness exposed, about..... | 3.0 |

70.--Railroad cutbank exposure near NE corner sec. 3, T. 25 N., R. 10 E., Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | |
|--|------|
| Vamoosa Fm. | |
| Sandstone; yellowish-brown; trough-type cross stratification; very fine-grained to siltstone; micaceous; small-scale slump faulting; basal contact erosional (see Pl. 45B); about..... | 14.0 |
| Shale; dark olive gray; clayey to silty; lamination vague locally and weathers blocky; micaceous; about... | 1.5 |

| | Thickness, feet |
|---|--------------------|
| Limestone; medium bluish-gray to light brownish-gray; argillaceous to silty; shaly parting; crinoids; fusulinids; thickness variable, featheredge to about..... | 1.0 |
| Shale; as second above with fusulinids, pelecypods, and sparse brachiopods; about..... | 2.0 |
| Limestone; as second above with abundant fusulinids; featheredge to about..... | 1.0 |
| Note - the succeeding three units form the southernmost definite exposure of the Labadie (Haskell) Ls. Mbr. | |
| Shale; greenish-gray; clayey to silty; weathers blocky in part; micaceous; upper contact gradational where overlain by sandstone; thickness exposed, about. | 7.0 |

71.--Composite of a road cut exposure near SW corner sec. 29, T. 24 N., R. 11 E., (Birch Creek Ls. Mbr. of Barnsdall Fm.) and a covered interval measured from this outcrop to near center sec. 7, T. 23 N., R. 11 E. (base of Bigheart Ss. Mbr. of Tallant Fm.), Osage Co., Okla. Section by S. M. Ball and R. R. Bower. Measured and described in Aug., 1960.

Tallant Fm.

Bigheart Ss. Mbr. base

Barnsdall Fm.

Covered interval; measured with plane table, alidade, and stadia rod; about..... 116.0

Birch Creek Ls. Mbr.

Dolostone; medium light gray mottled dark yellowish-orange; very thin beds; dolomitized; recognizable crinoids, brachiopods, gastropods; about..... 1.0

Limestone (crinoid lime wackestone); medium light gray; single bed; silty; crinoids, productid brachiopods, bellerophontid gastropods; about..... 0.3

Limestone (mixed-fossil lime packstone); light brownish-gray with dark yellowish-orange overtones; single thick bed; abundant crinoids, bellerophontid gastropods including Bellerophon, and productid brachiopods including Linoproductus, sparse to common fusulinids in upper foot; about..... 2.0

Limestone (mixed-fossil lime wackestone); basal part of the overlying bed; as first above but fewer fossils and siltier; about..... 0.6

Note - base of Birch Creek Ls. is covered but was excavated and is underlain by shale-siltstone section.

72.--Road cut exposure from near center south line SW $\frac{1}{4}$ sec. 34, (base of section) to near SE corner sec. 33 (top of section), T. 23 N., R. 10 E., Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | Thickness, feet |
|---|--------------------|
| Sandstone and shale interbedded; sandstone, yellowish-brown; thin- to thick bedded; fine-grained; micaceous; shale, greenish-gray, silty, micaceous; sandstone the predominant rock type; about..... | 25.0 |
| Shale; olive gray; silty; micaceous; plant fossils; about..... | 11.0 |
| Limestone; light gray to medium bluish-gray in lower 7 feet, chocolate brown and dolomitized in upper 8 feet; thin wavy bedding; sparse crinoids in upper 8 feet; crinoids, echinoids, marginiferid brachiopods, <u>Rhipodomella carbonaria</u> , fenestrate bryozoans, ramose bryozoans, and lophophyllid corals in lower 7 feet; about..... | 15.0 |
| Note - this unit is the Wildhorse dolostone of Oklahoma terminology. | |
| Shale; olive gray to greenish-gray; clayey to silty; micaceous; about..... | 35.0 |
| Sandstone and shale interbedded; most covered; about. | 45.0 |

73.--Composite of exposures from near center south line SE $\frac{1}{4}$ sec. 27 (Avant Ls.) to SE $\frac{1}{4}$ sec. 22 (Bigheart Ss. Mbr.), T. 22 N., R. 11 E., to near center west line sec. 21 (Wildhorse dolostone), T. 22 N., R. 10 E., Osage Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | |
|---|------|
| Dolostone; see Pl. 39 and p. 207 to p. 209 for detailed description; about..... | 17.0 |
| Note - this unit is the Wildhorse dolostone of Oklahoma terminology. | |
| Shale; medium bluish-gray to light brownish-gray upward; clayey to silty upward; micaceous; abundantly fossiliferous in lower half; profuse <u>Trepostira</u> , <u>Worthenia</u> , other gastropods, nuculid and other pelecypods, <u>Punctospirifer kentuckyensis</u> , <u>Composita</u> , dictyoclostids and other productid brachiopods, <u>Orbiculoidea missouriensis</u> , <u>Conularia</u> ; about..... | 25.0 |
| Limestone; medium light gray; extremely argillaceous, shaly parting, crinoids, brachiopods, fenestrate bryozoans, ramose bryozoans; about..... | 0.6 |

| | Thickness, feet |
|---|--------------------|
| Shale to mudstone; medium bluish-gray; weathers blocky; clayey to silty; <u>Linoproductus</u> , crinoids, sparse myalinid pelecypods, especially fossiliferous in upper 1.5 feet; about..... | 7.0 |
| Shale; greenish-gray; clayey to silty; micaceous; about..... | 5.0 |
| Sandstone; light brownish-gray to yellowish-brown; thin- to thick-bedded; massive splitting; micaceous; about..... | 9.0 |
| Shale and sandstone interbedded; as first and second above; about..... | 33.0 |
| Sandstone; as second above with a 2-foot thick, greenish-gray, silty shale break in its central part; about..... | 35.0 |
| Shale; mostly covered; about..... | 10.0 |
| Sandstone; light brownish-gray to yellowish-brown; very thin to thick relatively even beds; massive splitting; fine-grained; micaceous; a zone of <u>Lino-productus oklahomae</u> from about 14 to 20 feet above base, plant fossils; about..... | 25.0 |
| <p style="margin-left: 40px;">Note - according to my correlations, this sandstone is the Bigheart Ss. Mbr. of the Tallant Fm. Some Oklahoma geologists, who believe that the Wildhorse dolostone is older than the Bigheart Ss., disagree (see discussion on p. 209 to p. 212).</p> | |
| Measured interval; mostly shale with some siltstone and sandstone; not described in detail; about..... | 147.0 |
| Avant Ls. | |
| Limestone; medium light gray; very thin-bedded; shaly parting, weathers to a rubble; abundantly fossiliferous; crinoids, <u>Chonetes</u> ; about..... | 2.0 |
| Mudstone; light brownish-gray to greenish-gray; calcareous; slightly micaceous; about..... | 2.5 |
| Limestone; light gray; very thin-bedded; abundant bryozoans; about..... | 1.0 |
| Shale; light brownish-gray; upper half covered; contains crinoids in lower half; about..... | 8.0 |
| Limestone; light gray; thin wavy bedding; brachiopods, crinoids, ?linear algae; thickness exposed, about.... | 5.0 |

74.--Road cut exposure near center south line SW $\frac{1}{4}$ sec. 1, T. 14 N., R. 8 E., Creek Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

Vamoosa Fm.

Sandstone-chert conglomerate; sandstone, reddish-brown and grayish-red, medium- to coarse-grained; chert,

Thickness,
feet

| | |
|---|------|
| light brownish-gray and light gray, sand- to cobble-sized fragments; fragment angular to subrounded, many chert fragments are extensively weathered; not bedded, rather intercalated and mixed; basal contact irregular and erosional (See Pl. 51C); about..... | 30.0 |
| Mudstone; greenish-gray and reddish-brown; weathers blocky; contains a 0.6-foot thick grayish-red siltstone 4 feet above base; about..... | 9.5 |
| Sandstone; light gray speckled black, weathers brownish-red; thick bed, massive splitting; fine-grained; thickness exposed, about..... | 8.0 |

75.--Composite of road cut exposures from near NW corner sec. 21, T. 13 N., R. 8 E. (base of section) to near center north line sec. 8, T. 13 N., R. 7 E. (top of section), Okfuskee Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

Vamoosa Fm.

| | |
|---|------|
| Sandstone-chert conglomerate; rock type as developed in stratigraphic section 74; about..... | 50.0 |
| Shale; greenish-gray; silty to clayey; micaceous; about..... | 15.0 |
| Sandstone; brownish-red; thin- to thick-bedded; medium-grained; a 6-foot thick, light gray siltstone in the central part; about..... | 25.0 |
| Covered interval; nodular siltstone in upper 3 feet; about..... | 10.0 |
| Sandstone; as first above but fine- to medium-grained; about..... | 10.0 |
| Shale; as fourth above; about..... | 5.0 |
| Sandstone; yellowish-brown to light brownish-gray upward; thin- to thick-bedded; massive splitting; medium- to coarse-grained; contains sand-size weathered chert fragments in lower 8 feet; fine-grained with little or no chert in uppermost 3 feet; about..... | 11.0 |
| Shale and siltstone interbedded; shale, reddish-brown and brownish-gray; silty, micaceous; siltstone, grayish-red, micaceous; about..... | 25.0 |
| Sandstone-chert conglomerate; fine to medium sand-size quartz particles; sand- to large pebble-size chert fragments; chert subangular to subrounded; about..... | 20.0 |

Note - about 3 feet of greenish-gray shale is exposed below the sandstone-chert conglomerate.

76.--Road cut exposure near center south line sec. 21, T. 12 N., R. 8 E., Okfuskee Co., Okla. Section by S. M. Ball and H. A. Mendoza. Measured and described during Summer, 1958.

| | Thickness, feet |
|--|--------------------|
| Vamoosa Fm. | |
| Sandstone-chert conglomerate; same development as that described for this rock type in stratigraphic section 74; about..... | 25.0 |
| Mudstone to shale; grayish-red; weathers blocky; vague lamination locally; about..... | 7.0 |
| Sandstone-chert conglomerate (Boley Cgl. Mbr.); sandstone, medium light gray to reddish-brown; bedding contorted and discontinuous; massive splitting; medium- to coarse grained; chert, light gray, light brownish-gray, medium bluish-gray, sand- to large cobble-size angular to rounded chert fragments, some fragments of banded chert, sparse ?crinoid and bryozoan in chert pebbles; about..... | 15.0 |
| Shale to mudstone; as second above; about..... | 7.0 |
| Sandstone; light brownish-gray, weathers reddish-brown; thin- to thick-bedded; fine- to medium-grained; micaceous; clay pebble conglomerate in lower 0.5 foot; about..... | 1.5 |
| Note - about 15 feet of greenish-gray silty shale is exposed below this unit but was not studied. | |

77.--Road cut exposures in SW $\frac{1}{4}$ sec. 17, T. 7 N., R. 7 E., Seminole Co., Okla. Section by S. M. Ball and R. R. Bower. Measured and described in Aug., 1960.

Belle City Ls.

| | |
|--|------|
| Limestone; light gray to medium light gray; thin to thick and wavy bedding; finely crystalline; abundant fusulinids concentrated on bedding surfaces in upper half, sparse <u>Composita</u> , sparse small spired gastropods, sparse echinoid spines, sparse fenestrate bryozoans; sandy and yellowish-brown in lower 3 feet; grades downward into sandstone-chert conglomerate; about.... | 24.0 |
| Note - section both above and below contains numerous sandstone-chert conglomerate "zones". | |

Logs of Cable Tool Cuttings

Sample logs prepared during this study are described below. Abbreviations are used on the logs and are listed below.

Abbreviations
(from Maher, 1959)

| | | | |
|------------------------------|-----------|----------------------------|-------|
| About..... | abt. | Green..... | gn. |
| Above..... | abv. | Hard..... | hd. |
| Abundant..... | abnt. | Included, including..... | incl. |
| Amount..... | amt. | Irregular..... | ireg. |
| Angular..... | ang. | Large, larger..... | lrg. |
| Anhydrite, anhydritic..... | anhy. | Light, lighter..... | lt. |
| Argillaceous..... | arg. | Limestone..... | ls. |
| Black..... | blk. | Limy..... | lmy. |
| Blue, bluish..... | bl. | Lithographic..... | lith. |
| Brachiopod..... | Brac. | Little..... | ltl. |
| Brown..... | brn. | Long..... | lg. |
| Bryozoa..... | Bry. | Loose..... | lse. |
| Calcite, calcareous..... | calc. | Material, matter..... | mat. |
| Carbonaceous..... | carb. | Matrix..... | mtx. |
| Cavings..... | cav. | Medium..... | m. |
| Cement, cemented..... | cmt. | Mica, micaceous..... | mica. |
| Cephalopod..... | Ceph. | Moderate..... | mod. |
| Chert..... | cht. | Mottled, mottling..... | mot. |
| Clay, clayey..... | cl. | Olive..... | olv. |
| Clay-ironstone..... | cl.-fest. | Oolite, oolitic..... | ool. |
| Coarse, coarsely..... | c. | Oolite, oolitic..... | ool. |
| Concretion, concretions..... | concr. | Orange..... | orng. |
| Conglomerate..... | cgl. | Ostracode..... | Ost. |
| Conodonts..... | Con. | Part, partly..... | pt. |
| Crinoid, crinoidal..... | Crin. | Pebble..... | pbl. |
| Crystal, crystalline..... | xl. | Pelecypod..... | Plcy. |
| Dark..... | dk. | Pellet..... | pel. |
| Dense..... | dns. | Phosphate, phosphatic..... | phos. |
| Dolomite, dolomitic..... | dol. | Pink..... | pk. |
| Fine, finely..... | f. | Porosity, porous..... | por. |
| Fissile..... | fis. | Probable, probably..... | prob. |
| Flaky..... | flky. | Pyrite, pyritized..... | pyr. |
| Foraminifera..... | Foram. | Quartz..... | qtz. |
| Fossil, fossiliferous..... | fos. | Quartzose..... | qtzs. |
| Fragment, fragmental..... | frag. | Round, rounded..... | rd. |
| Friable..... | fri. | Sample..... | spl. |
| Fusulinid..... | Fus. | Sandstone..... | ss. |
| Gastropod..... | Gast. | Sandy..... | sd. |
| Good..... | g. | Scattered..... | scat. |
| Grain, grained..... | gr. | Shale..... | sh. |
| Gray..... | gy. | Shaly..... | shy. |

Silica, siliceous.....sil.
 Siltstone.....sltst.
 Silty.....slty.
 Slight, slightly.....sl.
 Small.....s.
 Smooth.....sm.
 Soft.....sft.
 Speck, speckled.....spec.
 Stain, stained, staining....stn.
 Streak.....str.

Stringer.....strg.
 Subangular.....sbang.
 Subrounded.....sbrd.
 Trace.....tr.
 Very.....v.
 Vug, vuggy, vugular.....vug.
 White.....wh.
 With...../
 Yellow.....yel.

LOG 1 (See Plate 2, Well 5)

NATHAN AND BRIAN

NO. 1 DECKER

Near cen. NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 1, T. 61 N., R. 38 W.

Holt County, Missouri

Altitude: 1062 feet

Footage described: 390- to 650-foot depth

Oread Ls. Fm.

- 390-400 Ls., lt. gn.-gy. to m. gy., f. xl., pt. sft. and mod. arg.,
v. arg. in lowermost pt., pt. sl. pyr., Fus., Brac.,
Bry., Crin. / ang. frag. of gn.-gy. to m. dk. gy. to dk.
gn.-gy., fos. cht.
- 400-02 Sh., m. gy., fis., cly. to sl. slty., fos.
- 402-16 Ls., as 2nd abv.
- 416-20 Sh., olv. gy. to gy.-blk., fis., cly., sl. mica., gy.-blk.,
pt. / calc. str. (Heebner Sh. Mbr.)
- 420-22 Ls., lt. gn.-gy. to m. gy., mot. gy.-blk., v. f. xl., hd.,
sl. arg., Brac. and Fus.
- 422-29 Mdst., gn.-gy., calc., cly. to sl. slty., mica.
- 429-35 Ls., v. lt. gy. to lt. gn.-gy., f. xl., sft. and mod. arg.,
Crin. and Brac.
- 435-40 Ls., as 1st abv., less arg., fos., / Fus.
- 440-41 Ls., as 2nd abv., mod. arg. to slty.

Lawrence Fm.

- 441-54 Mdst., gn.-gy. and gy.-red, intbd., cly., sl. mica., calc.
- 445-50 Ls., brn.-gy., v. f. xl., fos.
- 454-60 Sh. to sltst., gn.-gy., qtzs., mica., sltst. / dol. cmt.
- 460-66 Mdst., gn.-gy. and gy.-red., intbd., cly., mica., calc., pyr.,
spr. frag. of ls. (prob. cav.)
- 466-73 Ls., lt. gn.-gy. to gn.-gy. to m. gy., f. xl., pt. sft. and
mod. arg., pt. pyr., abnt. fos. / Crin., fenestrate Bry.,
and Brac. (Amazonia Ls. Mbr.)
- 473-81 Sh. and sltst., intbd.; sh., m. gy. to gn.-gy., fis., cly.
to slty., mica.; sltst., gn.-gy., qtzs., mica., calc. carb.
- 481-95 Ss., gn.-gy., v. f. gr., qtzs., mica., calc., / intbd. gn.-gy.,
slty. sh.
- 495-500 Sh. and sltst., intbd., m. gy., carb., mica., calc.
- 500-41 As 1st abv. / intbd. v. f. gr., calc. ss., spr. ls. frag.
(prob. cav.)
- 541-58 Sh., olv. gy. to m. gy., fis., cly. to sl. slty., sl. mica.
- 558-59 Sh., gy.-blk., fis., cly. / calc. str.
- 559-61 Ls., brn.-gy. to m. dk. gy., ar. to slty., pyr., pt. fos. /
Ost., Crin., Brac. incl. Crurithyris planoconvexa (Haskell
Ls. Mbr.)

Stranger Fm.

- 561-70 Slstst. to v. f. gr. ss., gn.-gy., qtzs., mica., carb.; and
sh., gn.-gy., cly., mica., sl. slty., intbd.
- 570-90 Sh. and sltst. to v. f. gr. ss., intbd., gn.-gy., mica., fos. /
Crin. and Plcy.
- 590-94 Ls., gn.-gy. to brn., f. xl., pt. shy. to slty., fos. (Iatan
Ls. Mbr.)

- 594-614 Sh., m. gy., fis., cly., sl. mica., / ang. frag., cl.-fest.
Stanton Ls. Fm.
- 614-24 Ls., lt. gn.-gy. to lt. brn.-gy. to m. gy., f. xl., pt. sft.
and mod. arg., Crin., Brac., intbd. sltst. to v. f. gr. ss.
- 624-45 Ls., v. lt. gy. to dk. gn.-gy., f. xl., pt. sft. and mod.
arg., pt. ool., Brac., Crin., intbd. gn.-gy. to m. gy.,
calc., sltst. to slty. sh., carb., mica.
- 645-47 Sh., m. gy., cly., mica.
- 647-49 Sh., gy.-blk., fis.
- 649-50 Ls., brn.-gy. to dk. gn.-gy., f. xl., mod. arg., fos.

LOG 2 (See Plate 2, Well 6)

J. A. KILBY AND FLORY

NO. 1 NINA SUE MEYER

SE $\frac{1}{2}$ NE $\frac{1}{2}$ NW $\frac{1}{2}$ sec. 29, T. 62 N., R. 39 W.

Holt County, Missouri

Altitude: 862 feet

Footage described: 300- to 586-foot depth

Oread Ls. Fm.

- 300-09 Ls., lt. gn.-gy., f. xl., pt. sdy., ooc., Fus. and Crin.
- 309-15 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl. / abnt. c. xl.
calc., ool., ooc., hd. sdy., pt. fos. / Brac., Bry.
(fenestrate), Fus., Crin., Echin. spines
- 315-30 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
arg., Fus., Bry., Crin. and Brac. incl. Crurithyris
planoconvexa, Rhipidomella carbonaria, and Composita /
intb. car., fos., sh. brks. and abnt. lt. gn.-gy. to m.
gy., ang. fos., cht. frag.
- 330-33 Sh., m.-gy. and gy.-blk., m. gy. pt. fis., slty., mica.;
gy.-blk. pt. fis., sl. mica. / calc. strs. (Heebner Sh. Mbr)
- 333-35 Ls., m.-gy. mot. gy.-blk., v. f. xl., hd., Fus. and Brac.
- 335-48 Mdst., gn.-gy., cly., sl. slty., sl. mica., calc., pt. pyr.,
spr. cav. of 1st and 2nd abv.
- 348-55 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
arg., Ost., Brac., Crin. and Fus.

Lawrence Fm.

- 355-65 Mdst., gn.-gy. to lt. brn.-gy. to gy.-red, calc.
- 365-70 Ls., gn.-gy. to brn.-gy., v. f. xl., pyr., fos.
- 370-75 Slstst. to v. f. gr. ss., lt. gn.-gy., qtzs., mica., carb.,
pyr., calc. pt. fos. / productid spines and Crin.
- 375-96 Ls., as 2nd abv., pt. arg.; sltst., m. gy., calc., carb.,
pt. pyr.; and sh., gn.-gy., slty., mica., intbd. (Amazonia
Ls. Mbr., 365-381)
- 396-402 Sh., m. gy. to gn.-gy., slty., mica.; and sltst. to v. f.
gr. ss., gn.-gy., calc., carb., abnt. c. xl. calc., pyr.,
intbd.
- 402-22 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., carb.,
calc. / spr. ls. frag. (prob. cav.)

- 422-28 Sh. and sltst. intbd., as 2nd abv.
 428-37 Ss., as 2nd abv., v. f. gr., pyr.
 437-66 Sh. and sltst. intbd., as 4th abv.
 447-60 Sltst. to v. f. gr. ss., dol. cmt.
 466-74 Sh., m. gy., fis., slty. to cly., mod. carb.
 474-76 Sh., gy.-blk., fis., / calc. strks.
 476-78 Ls., gn.-gy., arg., Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
 478-85 Sh., gn.-gy., plty., cly. to sl. slty., sl. mica., sl. carb.,
 Crin., Ost. and Gast.
 485-87 Mdst., gn.-gy., calc., pyr.
 487-94 Ls., v. lt. gy. to lt. gn.-gy. to lt. brn.-gy., f. xl., pt.
 sft. and mod. arg., pt. slty., Crin. (Iatan Ls. Mbr.)
 494-502 Sh., lt. gn.-gy., fis., slty., calc.
 495-500 Intbd. sltst.
 502-10 Ss., v. lt. gy. to lt. gn.-gy., qtzs., v. f. gr., pyr.,
 sil. cmt., abnt. frag. of a gn. min.
 510-19 Sh. and sltst. intbd., lt. gn.-gy., mica., carb.
 519-21 Sltst. to v. f. gr. ss., as 2nd abv., abnt. frag. of a gn.
 min.
 521-38 Sh., olv. gy. to m. dk. gy., fis., cly., sl. carb., spr.
 cav. of 1st abv.
 527-38 Ang. frag. of brn.-gy., cl.-fest.
- Stanton Ls. Fm.
 538-45 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod.
 arg., Crin., Fus. and Brac.
 545-48 Sh., m. dk. gy. to gy.-blk., fis., pt. fos. / Crin.
 548-52 Ls., gn.-gy. mot. gy.-blk., f. xl., pt. arg. and slty.,
 Crin., Brac. and Bry.
 552-54 Sltst., m. gy., calc., fos.
 554-79 Ls., v. lt. gy. to lt. gn.-gy. to lt. brn.-gy., f. xl., pt.
 hd., pt. sft. and arg., pt. pyr.
 579-83 Sh., gy.-blk., fis., cly.
 583-86 Ls., lt. gn.-gy., sft., arg., Crin., Brac.

LOG 3 (See Plate 2, Well 9)

DAN SHORT ET AL.

NO. 1 GIFFIN

Near cen. nor. line SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 15, T. 65 N., R. 40 W.

Atchison County, Missouri

Altitude: 1018 feet

Footage described: 425- to 650-foot depth

Oread Ls. Fm.

- 425-47 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
 arg., Crin., Brac. / ang. frag. of gn.-gy. and dk. gn.-gy.,
 fos. cht.
 430-47 V. ltl. spl.
 447-49 Sh., gy.-blk., fis. (Heebner Sh. Mbr.)

- 449-51 Ls., gn.-gy. mot. gy.-blk., hd., fos.
 451-60 Mdst., gn.-gy., calc., pt. pyr.
 460-71 Ls., v. lt. gy. to lt. gn.-gy. to lt. brn.-gy., f. xl.,
 pt. sft. and mod. arg., fos.

Lawrence Fm.

- 471-90 Mdst., gn.-gy. and gy.-red intbd., calc.
 475-90 Lmy. strs.
 490-500 Sh., gn.-gy., fis., cly. to sl. slty., pt. fos. / gy.-red
 strs. and a th. gn.-gy. to lt. brn.-gy., fos., arg. ls.
 (Amazonia Ls. Mbr.)
 500-68 Sh., gn.-gy., fis., cly. to sl. slty., sl. mica.
 520-27 V. ltl. spl.
 542-47 Slty. to sdy.
 547-53 Lmy. strs.
 553-58 Crin.
 558-68 Lmy. strs.
 568-70 Sh., gn.-gy. and gy.-blk., fis.
 570-72 Ls., m. gy. to gn.-gy., arg., Crin. (Haskell Ls. Mbr.)

Stranger Fm.

- 572-74 Sh., m. gy., calc., fos.
 574-80 Mdst., gn.-gy. and gy.-red intbd., cly., pt. slty., pt. calc.
 580-90 Mdst., gn.-gy., cly., calc.; and sh., dk. gn.-gy., fis.,
 sl. carb., mod. mica. cly. to sl. slty., intbd.
 590-619 Ls., gn.-gy. to lt. brn.-gy., fos., pt. shy. / sh. brk.,
 pr. spl. (South Bend Ls. Mbr. of Stanton Ls. to Iatan Ls.
 Mbr. of Stranger Fm.; Stanton Ls. Fm. top at about 609-foot
 depth)
 619-21 Mdst., gy.-red, cly., pt. calc.
 621-44 Ls., v. lt. gy. to lt. gn.-gy. to m. gy., f. xl., pt. sft.
 and arg., Bry., Brac., and Crin.
 627-32 Fus.
 627-44 M. gy. sh. brks.
 644-46 Sh., gn.-gy. and gy.-blk., fis., cly., calc. strs. in gy.-
 blk. pt.
 646-48 Ls., gn.-gy., arg., Crin.

Vilas Sh. Fm.

- 648-50 Sh., gn.-gy., mica., sl. slty.

LOG 4 (See Plate 4, Well 2)

MOSBACHER AND OTHERS

NO. 1 SLOAN

Near SW cor. NE $\frac{1}{4}$ sec. 16, T. 9 S., R. 22 E.

Leavenworth County, Kansas

Altitude: 959 feet

Footage described: 42- to 203-foot depth

Lawrence Fm.

- 42-45 Sh., m. gy., sft., cly. to sl. slty., mica., fis.
 45-48 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., mod. arg., Crin.
 (Haskell Ls. Mbr.)

Stranger Formation

- 48-50 Ls., shy. or sh., calc.; lt. gn.-gy. to lt. brn.-gy., abnt. fos., Crin., Brac. and Bry.
- 50-56 Sh., as 3rd abv.
- 56-90 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr. qtzs., pt. calc., pt. dol. cmt., pt. carb., qtz. gr. sbang. to sbrd. and eqnt.
- 75-85 Gn.-gy. sh., intbd.
- 90-107 Sh., m. gy. to lt. brn.-gy., v. slty., v. mica., fis., pt. carb.
- 107-24 Sh. and ss., intbd.; as 1st and 2nd abv., / a th. coal
- 124-37 Ls., v. lt. gy. to lt. gn.-gy., f. xl., Crin., Brac., Bry., and Fus., mod. arg. (Iatan Ls. Mbr.)
- 137-40 Sh., m. gy., sl. slty., mica., Brac. and Crin.
- 140-73 Sh., gn.-gy., slty., mica., pt. carb.
- Stanton Ls. Fm.
- 173-79 Ls., lt. brn.-gy. to brn.-gy., f. xl., Crin., Brac., Bry. and Fus.; abnt. Crin., pyr. Gast., and 2 pyr. ceph. (Coloceras) occur in intbd. gn.-gy. sh.
- 179-82 Sh., m. gy., slty., mica.
- 182-85 Ls., lt. gn.-gy., f. xl., Crin. and Brac.
- 185-90 No samples
- 190-98 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. mod. arg., Brac., Crin., Fus. and Bry.
- 198-200 Sh., blk., fis., mica., cly. to sl. slty., Cono.
- 200-03 Ls., gn.-gy. to f. xl., sl. slty., pt. arg., Crin., Brac., pt. ?ool.

LOG 5 (See Plate 4, Well 3)

APPERSON AND JACKSON

NO. 1 GEISEN

Near cen. N $\frac{1}{2}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T. 9 S., R. 21 E.

Leavenworth County, Kansas

Altitude: 1000 feet

Footage described: 2- to 243-foot depth

Oread Ls. Fm.

- 2-18 Ls., v. lt. gy., stn. mod. yel., f. xl., Crin. and Brac., recorded by driller as lime boulders
- 18-20 Sh., m. gy. and blk., cly. to sl. slty., sl. mica. (Heebner Sh. Mbr.)
- 20-22 Ls., m. gy., f. xl., Crin.
- 22-28 Sh., gn.-gy., slty., mica.
- 28-40 Ls., v. lt. gy. to lt. gn.-gy., f. xl., mod. arg. / Crin., Brac., Bry. and Fus.

Lawrence Fm.

- 40-57 Sh., gn.-gy., cly. to slty., mica.
- 57-66 Ls., lt. gn.-gy., f. xl. / Crin.
- 66-76 Sh., as 2nd abv.

- 76-154 Sh., m. gy. to lt. gn.-gy., slty., mica.
 75-100 Pt. carb.
 85-90 Intbd. lt. gy. sltst.
 90-95 Intbd. lt. gy. sltst., pt. carb., pt. calc.
 95-110 Intbd. lt. gy. sltst.
- 154-83 Sh., olv. gy., fis., cly. to sl. slty., mica., mod. calc.
 183-87 Ls., m. gy., arg., slty., abnt. fos. / Crin., Brac. and Bry.
 (Haskell Ls. Mbr.)
- Stranger Fm.
 187-90 Sltst., m. gy., mica., mod. arg., fos., pt. carb.
 190-210 Sh., lt. gy. to lt. gn.-gy. to olv. gy., cly. to slty., mica.,
 pt. carb. / a th. coal
 210-90 Sh., as 1st abv., not carb.
 232-35 Frag. of brn.-gy. fest. concretions
 240-55 Same
 275-80 Same
 280-85 Fos.
- Stanton Ls. Fm.
 290-93 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., sl. arg., Crin.
 and Brac.
 293-97 Ss., v. f. gr. to sltst., olv. gy., calc., fos.
 297-316 Ls., v. lt. gy. to lt. gy. to lt. gn.-gy., f. xl., pt. mod.
 arg., Brac., Bry., Crin. and Fus.
 316-21 Sh., m. gy. and blk., fis.
 321-24 Ls., lt. to m. gy., sl. slty., Crin. and Brac.
- LOG 6 (See Plate 4, Well 4)
 WANHOFF AND LEBSACK AND OTHERS
 NO. 1 MADUSKA
 Near cen. SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T. 8 S., R. 20 E.
 Leavenworth County, Kansas
 Altitude: 1068 feet
 Footage described: 102- to 440-foot depth
- Oread Ls. Fm.
 102-18 Ls., lt. gn.-gy., f. xl., mod. arg., pt. sft., pt. slty. to
 sdy., pt. pyr.
 105-15 Spr. frag. dk. gn.-gy. fos. cht.
 115-18 Slty.
 118-22 Sh., dk. gy. to gy.-blk., slty. to cly., fis. / calc. strs.
 (Heebner Sh. Mbr.)
 122-25 Ls., m. gy. to m. dk. gy., f. xl., pt. sl. slty., Crin.,
 Brac. and Bry., pt. shells replaced by pyr.
 125-36 Sh., calc., m. gy. to lt. gn.-gy., pt. fos. / Crin., Brac.
 incl. Rhipodomella carbonaria; some cav. of 1st and 2nd abv.
 136-50 Ls., lt. gy. to lt. gn.-gy., sft., arg., pt. sl. mica. / Crin.
 and Brac.
- Lawrence Fm.
 150-64 Ss., v. lt. gy., v. f. gr. to sltst., qtzs., mica., some frag.
 stn. yel.-brn., calc. cmt., mdst. gn.-gy. to gy.-red, intbd.

- 164-68 Ls., lt. olv. gy., v. f. xl. to sblith., spr. fos., pt. cht.
(Amazonia Ls. Mbr.)
- 168-82 Sltst., m. lt. gy., qtzs., mica., pt. calc., pt. pyr., pt.
carb., / intbd. red.-brn. sltst.
- 182-86 Sh., m. gy., mica., fis.
- 186-95 Ss., gn.-gy., v. f. gr. qtzs., mica., carb., pt. calc.
- 195-96 Coal
- 196-200 Sh. to sltst., gn.-gy., mica., carb., pt. calc.
- 200-77 Ss., sltst., and slty. sh., intbd.; gn.-gy. to dominantly lt.
olv. gy. in lwr. pt.; ss., v. f. gr., qtzs., mica., carb.,
pt. pyr.; sh., cly. to slty., mica., sft., fis.
- 210-15 Spr. Crin. frag. (prob. cav.)
- 260-65 Crin.
- 270-75 Crin., Brac., Plcy.
- 277-80 Ls., gn.-gy. to m. gy., arg., sl. arg., abnt. fos. / Crin.,
Brac., Bry., Fus. (Haskell Ls. Mbr.)
- Stranger Fm.
- 280-90 Sltst. and v. f. gr. ss., lt. gn.-gy. to m. gy., v. calc.,
mica., carb., abnt. fos. / Brac., Gast., Plcy.
- 290-95 Sltst., pt. red.-brn.
- 295-312 Sltst. and sh., intbd.; sltst., as lst abv.; sh., gn.-gy.,
cly. to slty., mica.
- 305-12 Abnt. ang. frag. gy.-brn. fest.
- 312-13 Th. coal
- 313-19 Sh., gn.-gy., cly., mica., pt. pyr.
- 319-22 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. arg., Crin.
(Iatan Ls. Mbr.)
- 322-80 Sh., olv. gy., cly. to slty., mica., fis., a few frag. of
ls. (prob. cav.)
- 345-50 Frag. of red.-brn. fest.
- 355-60 In pt. red.-brn.
- 370-75 Sltst. to ss. frag., spr. (prob. cav.)
- 380-400 Sh., mdst., and sltst., intbd.; sh. as lst abv.; mdst., gy.-
red, calc.; sltst., lt. gn.-gy.
- Stanton Ls. Fm.
- 400-13 Ls., gn.-gy. to brn.-gy., f. xl. / c. xl. calc., arg., abnt.
fos. / Crin., Bry., Ost. incl. Bairdia, Brac. incl.
Crurithyris planoconvexa and Gast., some pyr.; / intbd.
gy., calc. sh. brks.
- 413-16 Ss., gn.-gy., v. f. gr. mica., qtzs., fos.
- 416-33 Ls., v. lt. gy. to lt. gn.-gy., f. xl., mod. arg., pt. sft.,
Brac., Crin., Fus.
- 433-37 Sh., olv. gy. to dk. gy. to gy.-blk., cly. to slty., sl. mica.,
fis.
- 437-40 Ls., m. dk. gy., f. xl. / abnt. c. xl. calc., pt. ool., arg.,
Bry., Brac., Crin.

LOG 7 (See Plate 4, Well 5)

MCLAUGHLIN SONS COMPANY

NO. 1 BODDE

Near NW cor. SW $\frac{1}{4}$ sec. 28, T. 8 S., R. 20 E.

Jefferson County, Kansas

Altitude: 1138 feet

Footage described: 225- to 557-foot depth

Oread Ls. Fm.

- 225-52 Ls., m. gy. to lt. gn.-gy., f. xl., mod. arg., Brac., Fus.,
Ost. incl. Bairdia, Bry., pt. pyr.
- 252-56 Sh., dk. gy. to gy.-blk., hd., sl. slty., sl. mica., calc.
strs., fis.
- 256-58 Ls., m. dk. gy., f. xl., hd., Crin. and Brac.
- 258-71 Sh., m. gy. to lt. gn.-gy., cly. to slty., sl. mica., pt.
calc.
- 271-87 Ls., v. lt. gy. to lt. gn.-gy., f. xl., mod. arg., pt. sft.,
Brac., Crin., Fus. and Bry., / a m. gy. calc. sh. brk.
in central pt.

Lawrence Fm.

- 287-96 Sh., m. gy. to gn.-gy., pt. calc., cly. to slty., sl. mica.
- 296-300 Ls., lt. gn.-gy., arg., sft., Crin. and Brac. (Amazonia Ls.
Mbr.)
- 300-50 Sh., sltst., and ss., intbd.; sh., m. gy. to gn.-gy., cly. to
slty., sl. mica.; sltst. and ss., lt. gn.-gy., qtzs.
- 320-30 Intbd. brn.-red sltst.
- 330-40 Predominantly v. f. gr. ss., some sltst., a few frag.
of Bry. (prob. cav.)
- 340-50 Predominantly lt. olv. gy., slty., mica., fis., sh.,
some intbd. v. f. gr., lt. gn.-gy. ss.
- 350-414 Sh., olv. gy., sl. slty., mica., pt. carb.
- 360-70 Intbd. gn.-gy., v. f. gr. ss. to sltst.
- 409-14 Fos. / abnt. frag. of Crin. col. and Brac.
- 414-421 Ls., shy., sl. slty., abnt. fos. / Crin., Brac., Bry., and
Ply.; intbd. sh. and sltst., v. f. gr. ss., m. gy. to
gn.-gy., pt. carb., mica. (Westphalia Ls. Mbr. of Stranger
Fm. to Haskell Ls. Mbr. of Lawrence Fm.; Stranger Fm. top
at about 416-foot depth.
- 421-28 Sh., sltst. and ss., intbd.; as 2nd abv.
- 428-34 Sh., gn.-gy. to olv. gy., fis., hd., slty., mica., cav. of
1st abv.
- 434-46 Slty. sh. and sltst., intbd., pt. carb., calc., spr. frag. of
Ply. (prob. cav.)
- 446-529 Sh., as 2nd abv., pt. carb.
- 470-80 Intbd. v. f. gr. ss., pt. carb., mica., calc.
- 480-90 Intbd. sltst., red.-brn.
- 500-10 Intbd. sltst., red.-brn., ls. frag. (prob. cav.)
- 510-20 Slstst., intbd., red.-brn., ls. frag. (prob. cav.)

Stanton Ls. Fm.

- 529-37 Ls., lt. gy. to lt. brn.-gy., f. xl., mod. arg., pt. pyr.,
Fus., Brac. and Crin.
- 537-40 Sltst., v. f. gr. ss., gn.-gy., calc., fos.
- 540-55 Ls., v. lt. gy. to lt. gn.-gy., f. xl., sl. arg., Crin.,
Bry., Brac. and Fus.
- 555-57 Sh., dk. gy. to gy.-blk., sl. slty., mica.

LOG 8 (See Plate 4, Well 6)

MCLAUGHLIN DEVELOPMENT COMPANY

NO. 1 GILLAN

SE $\frac{1}{2}$ NW $\frac{1}{2}$ SW $\frac{1}{2}$ sec. 2, T. 8 S., R. 18 E.

Jefferson County, Kansas

Altitude: 1046 feet

Footage described: 300- to 634-foot depth

Kanwaka Sh. Fm.

- 300-02 Sh. and sltst. intbd., gn.-gy., mica., pt. carb.

Oread Ls. Fm.

- 302-13 Ls., m. gy. to gn.-gy., f. xl., pt. mod. arg., pt. ool.,
pt. pyr., Ost., Fus., Crin., Brac. / intbd. m. gy. to
gn.-gy., slty. sh.
- 313-15 Sh., m. gy., fis., slty., sl. mica.
- 315-20 Ls., lt. gn.-gy. to m. gy. to m. dk. gy., f. xl., mod. arg.,
Fus., Crin., Brac. / Crurithyris planoconvexa
- 320-24 No samples.
- 324-28 Ls., v. lt. gy. to gn.-gy., f. xl., pt. mod. arg. and sft.,
Crin., Bry., Brac. / abnt. ang. frag. cht., lt. gy. to
m. gy. to gy.-blk., fos.
- 328-41 No samples.
- 341-46 Sh., gy.-blk., fis., sl. slty., calc. strcs. (Heebner Sh. Mbr.)
- 346-48 Ls., dk. gn.-gy., f. xl., fos.
- 348-57 Sh. to mdst., gy. to gn.-gy., cly. to slty., sl. mica.,
Brac., Plcy. / spr. cav. of 2nd abv.
- 357-67 Ls., v. lt. gy. to lt. gn.-gy. to mod. brn.-gy., f. xl.,
mod. arg., Fus., Crin., Brac., Bry.

Lawrence Fm.

- 367-71 Sltst. to v. f. gr. ss., lt. gn.-gy., mica., pt. pyr., dol.
cmt., / abnt. frag. of a gn. min.
- 371-83 Mdst., gn.-gy. and red.-brn. to gy.-red intbd., cly., pyr.,
Plcy. (pt. pyr.)
- 383-85 Ls., lt. gy., v. f. xl. fos.
- 385-95 Mdst., as 2nd abv.
- 395-402 Ls., gn.-gy. to lt. brn.-gry., pt. sft. and mod. arg., slty.,
Crin., Brac., Bry. (Amazonia Ls. Mbr.)
- 402-12 Ss., gn.-gy., v. f. gr., calc., mica., Crin.
- 412-13 Coal, shy.
- 413-25 Sh., gn.-gy., slty., sl. mica.; and sltst., gn.-gy., carb.,
dol. cmt. intbd.

- 425-45 Sh., gn.-gy. to m. olv. gy., slty. to cly., mica., carb.,
fis.
- 445-85 Sh., olv. gy., cly., sl. mica., fis.
450-54 Intbd. sltst., gn.-gy., carb.
454-58 Intbd. ss., gn.-gy., carb., v. f. gr., qtzs.
460-70 Spr. ls. frag. (prob. cav.)
470-80 Intbd. ss., v. f. gr., calc., carb.
- 485-87 Ls., m. gy. to dk. gy., arg., slty., abnt. fos. / Crin. and
Plcy. (Haskell Ls. Mbr.)
- Stranger Fm.
- 487-92 Sltst. and slty. sh. intbd., lt. gn.-gy., mica., pt. sl.
carb.
- 492-94 Ls., brn.-gy., arg. fos. (Westphalia Ls. Mbr.)
- 494-513 Sh. and sltst., as 2nd abv. and ss., gn.-gy., v. f. gr.,
qtzs., carb., dol. cmt., intbd. / scat. ls. frag.
(prob. cav.)
- 513-15 Sh., gn.-gy., fis., cly. to slty., mod. mica., pt. carb. /
intbd. th. gy.-red mdst.
- 515-23 Ss., as 2nd abv.
- 523-26 Sh., as 2nd abv.
- 526-30 No samples.
- 530-50 Sh. and ss. intbd., as 2nd and 3rd abv.
- 550-65 Sh., olv. gy., slty., mica., pt. carb.
- 565-75 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and arg.,
Brac., Crin., Fus., Bry., Ost. / ang. frag. of m. gy. fos.
cht. (Iatan Ls. Mbr.)
- 575-85 Sh., gn.-gy., pt. calc.; and sltst., lt. gn.-gy., pt. carb.,
mica. intbd.
- 585-96 Sh., m. gy., fis., cly. to slty., sl. mica.
- Stanton Ls. Fm.
- 596-600 Ls., m. gy., arg., Bry., Crin., Brac.
- 600-02 Sh., m. gy., sl. mica., fis., calc.
- 602-22 Ls., lt. gn.-gy., f. xl., mod. arg., Fus., Crin., Brac.
- 622-26 Sh., m. gy., plty., slty., mica.
- 626-30 Sh., gy.-blk., fis.
- 630-34 Ls., gn.-gy. to m. dk. gy., f. xl., arg., Crin., Brac.

LOG 9 (See Plate 4, Well 7)

HATCHER AND FISK, INC.

NO. 1 WARNER

Near cen. NW $\frac{1}{2}$ SW $\frac{1}{2}$ sec. 19, T. 7 S., R. 17 E.

Atchison County, Kansas

Altitude: 1064 feet

Footage described: 515- to 820-foot depth

Oread Ls. Fm.

- 515-38 Ls., v. lt. gy. to lt. gn.-gy. to gn.-gy., f. xl., arg., pt.
sft., pt. slty., Crin., Fus., Bry. and Brac. incl.
Rhipidomella carbonaria, Crurithyris planoconvexa, abnt.
ang. frag., gn.-gy. to olv. gy. to dk. gn.-gy., fos. cht.

- 538-43 Sh., m. gy., cly., mica., calc.
 543-47 Sh., blk., fis. / calc. strs. (Heebner Sh. Mbr., 538-547)
 547-50 Ls., m. gy., mot. dk. gn.-gy. to dk. gy., f. xl., hd., fos.
 550-60 No samples.
 560-71 Sh., sltst., and slty. ls., intbd.; sh., lt. gn.-gy. to m. lt. gy., fis., sl. calc., slty., mica.; sltst., gn.-gy., carb.; and slty. ls., lt. gn.-gy., Crin.
- Lawrence Fm.
- 571-81 Sltst. to v. f. gr. ss., gn.-gy., qtzs., calc., mica., pt. carb., abnt. frag. of gn. min.
 581-87 As 1st abv. / intbd. olv. gy. sh.
 587-90 Mdst., olv. gy. and gy.-red intbd., calc.
 590-96 Sh. and ss., intbd., sh., m. gy., fis., sl. calc., mica.; ss., v. f. gr., carb., mica., qtzs., calc.
 596-97 Coal, shy.
 597-605 Sh., gn.-gy., cly. to slty., mica.
 605-31 No samples.
 631-75 Sh., sltst., and ss., intbd.; sh., olv. gy., fis., hd., sl. slty., mica.; sltst., gn.-gy., mica., pt. carb., calc.; ss., lt. gn.-gy., v. f. gr. to f. gr., mica.
 650-55 Intbd. sltst. to v. f. gr. ss., dol. cmt.
 655-60 Intbd. sltst. to v. f. gr. ss.
 665-70 Intbd. sltst. to v. f. gr. ss., sil. cmt.
 670-75 Sltst., lt. gn.-gy.
 675-82 Ls. and mdst., intbd.; ls., lt. gn.-gy. to brn.-gy., f. xl. / abnt. c. xl. calc., mod. arg., Crin. and Brac.; mdst., lt. olv. gy., calc., cly., sl. mica. (Westphalia Ls. Mbr. of Stranger Fm. to Haskell Ls. Mbr. of Lawrence Fm.; Stranger Fm. top at about 677-foot depth.
 682-85 Sltst. to v. f. gr. ss. and slty. sh., intbd.; sltst., lt. gn. to lt. gy.; sh., m. gy.
 685-90 No samples.
 690-703 Ss., v. lt. gy., v. f. gr., qtzs., fri., mica., qtz. gr. sbang. to sbrd. and eqnt., pt. carb., spr. ls. frag. (prob. cav.)
 703-04 Coal, shy.
 704-19 Ss., as 2nd abv.
 719-21 Coal, shy.
 721-70 Sh., olv. gy. and brn.-gy. intbd., fis., cly. to sl. slty., pt. carb., sl. mica.
 760-70 Without brn.-gy. intbd.
 770-76 No samples.
 776-83 Sh., as 3rd abv.
- Stanton Ls. Fm.
- 783-88 Ls., gn.-gy. to brn.-gy., f. xl., pt. mod. arg., pt. ool., Bry., Brac., Fus. and Crin.
 788-93 Sltst. and sh., intbd.; sltst., gn.-gy.; sh., m. gy., calc., pt. carb.

- 793-95 Ls., lt. gn.-gy., f. xl., pt. mod. arg., pt. ool., Crin.,
Bry. and Brac.
795-99 Sh., m. gy., slty., mica., / a th. intbd. coal
799-813 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
arg., Crin., Brac. and Bry.
813-15 Sh., m. gy. and gy.-blk., fis.
815-17 Ls., as 2nd abv.
Vilas Sh. Fm.
817-20 Sh., m. gy., cly. to sl. slty., hd., calc., fis.

LOG 10 (See Plate 4, Well 8)

MCLAUGHLIN SONS COMPANY

NO. 1 KELLY

Near cen. SW cor. sec. 24, T. 8 S., R. 15 E.

Jackson County, Kansas

Altitude: 1090 feet

Footage described: 600- to 936-foot depth

Kanwaka Sh. Fm.

- 600-12 Sh. and sltst., intbd.; sh., olv. gy., fis., slty., mica.;
sltst., lt. gn.-gy., qtzs., mica., carb.

Oread Ls. Fm.

- 612-16 Ls., m. lt. gy. to gn.-gy., f. xl., arg., sl. slty., pt.
pyr., Brac. and Fus.
616-18 Sh., m. lt. gy., fis., slty., calc., Crin.
618-42 Ls., v. lt. gy. to lt. gn.-gy., f. xl., mod. arg., pt. sft.
Ost., Fus., Brac. and Crin., spr. ang. frag. of gn.-gy.
cht.
625-35 Abnt. ang. frag. of dk. gn.-gy. fos. cht.
642-47 Sh., m. dk. gy. to gy.-blk., fis., cly. to sl. slty.
(Heebner Sh. Mbr.)
647-50 Ls., m. dk. gy., mot. gy.-blk., f. xl., hd., sl. arg.,
Brac.
650-55 Mdst., lt. olv. gy., cly., calc.
655-63 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
arg., pt. sl. pyr., abnt. fos. / Brac., Bry., Crin. and
Fus.

Lawrence Fm.

- 663-66 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr., qtzs., mica., dol.
cmt. abnt. frag. of gn. min.
666-74 Sh., m. lt. gy. to lt. gn.-gy., fis., cly. to slty., sl.
mica.
674-95 Mdst., sltst., and ls., intbd.; mdst., olv. gy., cly., mica.,
calc.; sltst., lt. gn.-gy., calc., mica.; ls., olv. gy.
to brn.-gy., f. xl., sl. arg., fos. (Amazonia Ls. Mbr.)
695-720 Sh., olv. gy., fis., calc., hd., cly. to sl. slty., mica.
705-10 Intbd. gn.-gy., sltst., mica., carb.
710-15 Sh. and sltst. to v. f. gr. ss., intbd.
715-20 Sh. and sltst., to v. f. gr. ss., intbd.

- 720-27 Ss., lt. gn.-gy., v. f. gr., qtzs., qtz. gr. sbang. to sbrd. and elong. to eqnt., mica., carb., mod. fri., pt. calc., pt. dol. cmt.
- 727-28 Coal, shy.
- 728-50 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., qtz. gr sbang. to sbrd. and elong. to eqnt., fri., mica., large books of mica.
- 750-74 Sh. and sltst., intbd.; sh., olv. gy., slty., mica.; and sltst., lt. gn.-gy., mica., sil. cmt., carb.
- 774-80 Sltst., lt. gn.-gy., qtzs., mica., pt. carb., calc., pt. pyr.
- 780-84 Sh., olv. gy. to lt. gn.-gy., fis., hd., cly. frag. of brn.-gy. cl.-fest.
- 784-91 Sh., m. dk. gy., fis., hd., cly. irreg. ferrug.-stn., "trails" on bdg. surfaces of several sh. frag., ang. frag. of brn.-gy., cl.-fest.
- 791-95 Ls., m. gy. to lt. brn.-gy., pt. arg. to v. arg., abnt. Crin., Gast. and Brac. (Haskell Ls. Mbr.)
- Stranger Fm.
- 795-803 Sh., m. gy. to dk. gn.-gy., fis., cly., sl. mica., cav. of 1st abv.
- 803-04 Coal, shy.
- 804-07 Sh., as 2nd abv.
- 807-11 Ls. and sltst. to v. f. gr. ss., intbd.; ls., m. gy. to brn.-gy., f. xl., mod. arg., slty., Crin. and Brac.; sltst., lt. gn.-gy., carb., mica., calc. (Westphalia Ls. Mbr., 807-809)
- 811-20 Sltst. and sh., intbd.; sltst., carb., mica., pt. calc.; sh., m. gy., slty. to cly., mica., fis.
- 820-26 No samples.
- 826-90 Sh., olv. gy., fis., hd., cly., sl. mica.
- 835-45 Intbd., brn.-red sh., cav. of lt. gn.-gy. sltst., as 3rd abv.
- 855-60 Intbd. sltst., lt. gn.-gy., carb., mica., calc.
- 870-75 Intbd. gy.-brn. cl.-fest.
- 875-80 Same
- 880-85 Same
- 890-93 Sh., olv. gy. to dk. gy.
- Stanton Ls. Fm.
- 893-97 Ls., lt. gn.-gy. to brn.-gy., f. xl., mod. arg. to arg., Fus., Crin. and Brac.
- 897-901 Sltst., to v. f. gr. ss., lt. gn.-gy., qtzs., mica., calc.
- 900-01 Sh., m. dk. gy., fis., hd., cly., sl. carb., mica.
- 901-26 Ls., v. lt. gy. to lt. gn.-gy., f. xl., sl. arg., Crin. and Brac.
- 926-30 Sh., m. gy. to gy.-blk., fis. to plty.
- 930-34 Ls., m. gy., f. xl., abnt. xl. calc., mod. arg., Brac., Bry. and Crin.

Vilas Sh. Fm.

934-36 Sh., m. gy., fis., cly. to sl. slty., sl. mica., mod. carb.,
calc.

LOG 11 (See Plate 4, Well 9)

GOENS AND OTHERS

NO. 1 WABAUNSEE

NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 3, T. 8 S., R. 14 E.

Jackson County, Kansas

Altitude: 1250 feet

Footage described: 954- to 1355-foot depth

Note: Several descriptions represent a single sample

Kanwaka Sh. Fm.

954-57 Ls., lt. gn.-gy., lt. brn.-gy., arg. to sl. slty.,
Brac., Crin., Bry. and Fus., spr. frag. of carb. sh.
(prob. cav.) (Clay Creek Ls. Mbr.)

957-80 Sh. and sltst., intbd.; sh., lt. gn.-gy., cly., sl. carb.;
sltst., lt. gn.-gy.; sh. contains spr. Plcy.

Oread Ls. Fm.

980-1022 Ls., lt. gn.-gy. and lt. olv. gy., f. xl., pt. sl. arg.,
pt. pyr., Brac., Crin., Bry.; spr. frag. dk. gn.-gy.,
v. hd., fos. ls., and sbrd. frag. of gy.-blk. fis. sh.,
spr. frag. of olv. gy. fos. cht.; spl. prob. contains
Leavenworth Ls. to Plattsmouth Ls. interval (Heebner Sh.
Mbr., about 1016-1020.)

1022-35 Mdst., lt. gn.-gy., calc., pt. pyr., spr. cav. of 1st abv.

1035-60 Ls., lt. gn.-gy. and yel.-gy., f. xl., pt. sl. arg., Brac.,
Crin. and Fus.

Lawrence Fm.

1060-1100 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., fri., qtz. gr.
sbang. to sbrd. and elong. to eqnt., pt. calc., th.
intbd. of gn.-gy., slty., mica., sh. or mdst., spr. frag.
of fos. (prob. cav.)

1100-10 Ls., gn.-gy., pt. stn. red.-brn., arg. to slty., pt. fos.;
base purely a guess because of inadequate smpl. design-
nation (Amazonia Ls. Mbr.)

1110-70 Intbd. ss., sltst., and slty. sh.; lt. gn.-gy. and v. lt.
gy., mica.; ss., v. f. gr. and pt. calc.

1155-61 Ls. is recorded on the drillers log for this well
but could not be sure from smpl. examination (Haskell Ls.
Mbr.; Stranger Fm. top at about 1161-foot depth.)

1170-82 Ls., v. lt. gy. to lt. gn.-gy., f. xl. to m. xl., pt. sl.
arg., pt. pyr., Crin., Brac., Bry., and Ost. (Iatan Ls.
Mbr.)

1182-85 Sh., m. lt. gy., cly., pt. sl. slty., mica.

1185-1260 Intbd. sh., sltst., and v. f. gr. ss.; lt. gn.-gy., mica.;
sltst. and ss., pt. calc., driller records only sh. and
ls. in this interval

Stanton Ls. Fm.

- 1260-85 Ls., v. lt. gy. to lt. gn.-gy., v. f. xl. / some c. xl. calc., pt. sl. arg., Brac., Fus. and Crin. / th. olv. gy., cly., sl. mica. sh. brk.
- 1285-90 Sh., m. dk. gy. and gy.-blk., fis., cly., sl. mica.
- 1290-95 Ls., m. dk. gy., pt. mot. gy.-blk., pt. pyr., Crin., Brac., and Ost.
- 1295-1300 No samples (? Vilas Sh. Fm.)
- 1300-20 Ls., gn.-gy. and dk. gn.-gy., arg., pt. fos. / Crin., Bry., and Brac.
- 1320-55 Intbd. sh. and ls.; sh., olv. gy., calc., fos.; ls., gn.-gy. to brn.-gy., fos. and chty., poor smpl.

LOG 12 (See Plate 5, Well 4, lower part)

J. J. LYNN

NO. 1 ANNA C. WARNER

SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 5, T. 13 S., R. 17 E.

Shawnee County, Kansas

Altitude: 1119 feet

Footage described: 600- to 700-foot depth

Stranger Fm.

- 600-03 Ss., v. f. gr. to sltst., m. lt. gy., calc., sl. mica.

Stanton Ls. Fm.

- 603-07 Ls., m. gy., slty., Crin., Brac., Fus.
- 607-09 Ls., v. pale orng., v. f. xl., fos.
- 609-18 Sltst. and slty. sh. intbd.; sltst., m. lt. gy. to m. gy., mica., calc., pt. carb.; sh., m. gy., calc., mica.
- 618-20 Sh., olv. gy.
- 620-30 Ls., lt. olv. gy. to v. pale orng. to lt. gy., v. f. xl., pt. dol., Crin., Fus.
- 630-34 Ls., m. lt. gy., v. f. xl., sl. arg., pt. dol., Crin., ?Brac.
- 634-40 Sh., dk. gy. and blk.
- 640-48 Ls., brn.-gy., v. f. xl., arg.
- 648-63 Sh., m. gy., calc., mica., carb., pt. slty. (Vilas Sh. Fm.)
- 663-65 Ls., m. lt. gy. to m. gy., v. f. xl., arg.
- 665-70 Ls., m. gy. to pale yel.-brn., v. f. xl., sl. arg., fos. / Ost.
- 670-83 Ls., lt. gy., to v. pale orng. to pale yel.-brn., v. f. xl., pt. dol., Fus.
- 683-85 Sh., gy.
- 685-90 Ls., m. lt. gy. to m. gy., v. f. xl., sl. arg., chty.
- 690-700 Sltst. and sh. intbd., m. lt. gy. to m. gy., calc.

LOG 13 (See Plate 5, Well 12; used also as Plate 9, Well 18)

EMPIRE OIL AND REFINING COMPANY

NO. 1 SCHWALM

SE cor. sec. 19, T. 12 S., R. 11 E.

Wabaunsee County, Kansas

Altitude: 1355 feet

Footage described: 1200- to 1630-foot depth

?Kanwaka Sh. Fm.

1200-15 Sh., olv. gy. to gn.-gy., cly. to sl. slty., sl. mica.

Oread Ls. Fm.

1215-36 Ls., gn.-gy., f. xl., pt. sft. and sl. arg., Crin., Brac.

1223-30 M. gy., cly., calc. sh. brks.

1236-40 Sh., dk. gn.-gy., cly., sl. mica., pt. sl. calc.

1240-48 Sh., gn.-blk., fis., cly., mica. (Heebner Sh. Mbr., 1236-1248)

1248-50 Ls., gn.-gy., pt. mot. gy.-blk., f. xl., hd., fos.

1250-53 Mdst., gn.-gy., calc., Gast.

1253-56 Ls., lt. brn.-gy., f. xl., pt. sft. and mod. arg., Brac.,
Crin.

1256-58 Mdst., as 2nd abv.

1258-60 Ls., gn.-gy., pt. v. arg., pt. lmy. sh., Brac., Crin.

Douglas Grp.

1260-1375 Sh., gn.-gy. to dk. gn.-gy., cly., mica., sl. carb., pt.
mod. slty., pt. fos.

1283-91 V. f. xl., dk. gn.-gy., th. fos. ls.

1291-98 Intbd. lt. gn.-gy., calc. sltst. to v. f. gr. ss.,
slty. fos. ls. (Amazonia Ls. Mbr., 1288-1298)

1310-17 Intbd. brn.-gy. sltst.

1317-36 Intbd. lt. gn.-gy., v. f. gr., mica., carb., dol.
cmt., pt. fri., sbang. to sbrd., eqnt.

1336-50 Pt. fos. / intbd. lt. gn.-gy., calc., sltst.

1375-85 No samples.

1385-90 Intbd. gn.-gy., cly., sh., and lt. gn.-gy., ss., v. f. to
m. gr., qtzs., mica., pt. calc., pt. fos., / spr. scat.
frag. of lt. gn.-gy., arg., fos., ls. (prob. cav.)

1390-1497 Ss., v. f. to f. gr., qtzs., mica., pt. carb., pt. fri.,
sbang. to sbrd. and elong. to eqnt., pt. carb., sil. cmt.,
pt. stn. yel.-brn.-gy. / m. gy. cly., sh. pts.

1410-30 Pt. fos. / Ost. and Brac.

1423-40 Th. coal str.

1494-97 Scat. Crin. frag.

1497-98 Sh., m. gy., cly. to slty., mica.

Stanton Ls. Fm.

1498-1500 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
arg., fos., / Fus., Crin., and Brac., pt. arg. to slty.,
pt. ool., scat. sh. frag. (prob. cav.)

1500-06 Ss., v. f. gr., qtzs., calc., mica., Crin., Brac.; slty. to
sdy. gn.-gy. ls. frag.

1506-07 Mdst., gn.-gy., cly., calc., pyr.

1507-32 Ls., v. lt. gy. to lt. gn.-gy., and lt. brn.-gy., f. xl.,
Crin., Brac.

- 1532-37 No samples.
 1537-46 Ls., as 2nd abv. / m. dk. gy. sh. pts.
 1546-48 Sh., gy.-blk., fis., cly., mica.
 1548-50 Ls., gn.-gy., f. xl., pt. mod. arg., Crin.
 1550-62 Mdst., gn.-gy., mica., calc. (Vilas Sh. Fm.)
 1562-90 Ls., as 6th abv.
 1565-83 M. gy., fis., cly., calc., fos., sh. brks.
 1583-90 Gn.-gy., sbang. fos. cht. frag.
 1590-1615 Ls., gn.-gy., f. xl., pt. mod. arg., Brac., Crin., ramose
 Bry., / m. gy. calc. fos. sh. brks.
 1606-15 Ls., m. gy. to gn.-gy., fos. cht. frag.
 1615-30 Sh., gn.-gy., cly. to slty., mica., pt. calc., pt. fos.

LOG 14 (See Plate 6, Well 3)

CARL J. CRAMM ET AL.

NO. 1 ALLEN

SE $\frac{1}{2}$ NE $\frac{1}{2}$ SE $\frac{1}{2}$ sec. 13, T. 21 S., R. 15 E.

Coffey County, Kansas

Altitude: 1108 feet

Footage described: 60- to 690-foot depth

Oread Ls. Fm.

- 60-75 Ls., lt. gy. to lt. gn.-gy., f. xl., pt. sft. and pt. arg.,
 Crin., Brac.
 75-85 Ls., v. lt. gy. to lt. brn.-gy., xl., pt. sl. arg., Crin.,
 Brac., Fus.

Lawrence Fm.

- 85-207 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., carb., dol. cmt.,
 qtz. gr. sbang. to sbrd. and eqnt. / scat. ls. frag.
 (prob. cav.).
 207-26 Sh., olv. gy., fis., cly. to sl. slty., sl. mica., carb. / fos.
 ls. strs.
 226-34 Sltst. to v. f. gr. ss., lt. grn.-gy.; and slty. ls. intbd.
 234-57 Mdst. to calc. sh., choc. brn., ferug., Crin., Brac. incl.
Rhipidomella carbonaria, ang. frag. fos. cl.-fest.
 257-60 Ls., m. gy., v. arg., coquin.
 260-72 Ls., lt. brn.-gy., f. xl., Crin., Brac. (Haskell Ls. Mbr.,
 257-272)

Stranger Fm.

- 272-300 Ss., gn.-gy., v. f. gr. to sltst., mica., calc., mod. carb.
 290-300 Fos. / Brac.
 300-06 Ls., gn.-gy. stn. red.-brn., slty., abnt., fos. / Fus., Crin.,
 Brac. (Westphalia Ls. Mbr.)
 306-20 Ss., v. f. gr. to sltst., as 2nd abv.
 310-315 Cav. of 1st abv.
 315-320 Intbd. slty. sh.
 320-350 Mispl. smpl. of ls. / abnt. Fus., as 2nd abv., prob. sh.
 350-95 Sh., brn.-gy. to olv. gy., slty. to cly., mica., mod. carb.;
 and sltst. lt. grn.-gy., qtzs., mica., carb. intbd. / spr.
 frag. ls. and spr. Fus. (prob. cav.).

- 395-425 Sh., olv. gy., fis., cly. to slty., mica.
 405-25 Scat. ls. frag. (prob. cav.).
 415-25 Spr. ang. frag. red.-brn., cl.-fest.
- Stanton Ls. Fm.
- 425-33 Ls., m. lt. gy. to lt. gn.-gy., pt. ool., Crin., Brac., Fus.
 433-35 Slst. to v. f. gr. ss., gn.-gy., qtzs., mica.
 435-40 Ls., as 2nd abv.
 440-65 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
 arg., Brac., Bry., Fus., Crin.
 465-72 Ls., m. gy., f. xl.
 472-515 Ls., m. dk. gy., f. xl., fos.; and sh. m. dk. gy., fis.,
 cly., pt. fos. intbd. / spr. frag. lt. gy. ls.
 515-44 Ls., lt. gn.-gy. to m. gy. to m. dk. gy., f. xl., pt. mod.
 arg., fos.
 544-45 Sh., m. gy., fis., slty., mod. mica.
 545-47 Ls., as 2nd abv.
 547-60 Sh., dk. gy., fis., cly., sl. mica., abnt. fos.
 560-80 Ls., as 4th abv.
 580-605 Ls., as 5th abv. / dk. gn.-gy., fos. cht. frag. and a th. sh.,
 m. gy., fis., cly. to slty., mod. mica. intbd.
 605-57 Ls., wh. to v. lt. gy., f. xl. / abnt. c. xl. calc., Crin.,
 Brac. / spr. th. m. gy. sh. pts.
 657-70 Ls., olv. gy. to dk. gy., pt. sft., v. f. xl., Crin., Brac.
 665-70 Spr. ang. frag. red.-brn., cl.-fest.
 670-75 Sh., gn.-gy. to m. gy., fis., cly. to slty., sl. mica.; and
 ls., as 1st abv. intbd.
 675-90 Sh., as 1st abv.

LOG 15 (See Plate 7, Well 6)

REID AND OTHERS

NO. 2 AXTON

Near cen. S. line NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 27 S., R. 11 E.

Greenwood County, Kansas

Footage described: 340- to 950-foot depth

Kanwaka Sh. Fm.

- 340-42 Sh., dk. gn.-gy., fis., cly. to slty., mica.

Oread Ls. Fm.

- 342-50 Ls., m. gy. to brn.-gy., f. xl., pt. mod., arg., Fus., Crin.,
 Brac. incl. Crurithyris planoconvexa, Bry.
 350-62 Sh., dk. gn.-gy., fis., mod. calc., cly., abnt. fos., Brac.
 incl. Crurithyris planoconvexa and Crin., spr. ls. frag.
 (prob. cav.)
 362-72 Ls., m. lt. gy. to lt. gn.-gy., lt. gn.-gy. pt. mot. gy.-
 blk., sft. and mod. to v. arg., f. xl., Crin., Brac., Bry.
 372-76 Sh., dk. gn.-gy. and gy.-blk., fis., cly. / calc. str.
 (Heebner Sh. Mbr.)
 376-78 Ls., brn.-gy., v. f. xl., hd., Crin., sl. arg.
 378-90 Mdst., gn.-gy. and gy.-red intbd., gn.-gy., hd. calc.,
 pt. mot. gn.-gy and gy.-red, cav. of 1st and 2nd abv.

- 390-417 Same as 1st abv., pt. calc.
 400-05 Th. intbd., gy.-red arg., fos. ls.
- 417-19 Ls., lt. brn.-gy., v. f. xl., dol., fos.
 419-22 Mdst., as 2nd abv., non-calc.
 422-32 Ls., lt. gn.-gy. to lt. yel.-by., f. xl., pt. sft. and
 mod. arg., Crin., Brac.
- Lawrence Fm.
- 432-37 Sh., m. gy., fis., slty. to cly., mica., carb.
 437-43 Mdst., gn.-gy. and gy.-red intbd., as 3rd abv.
 443-50 Sltst., m. gy. to gn.-gy., qtzs., mica., calc.
 450-73 Mdst., as 8th abv.
 473-529 Sltst., lt. gn.-gy., qtzs., mica., pt. mod. carb., sil.;
 and sh., m. gy. to dk. gn.-gy., fis., cly. to slty.,
 mica., as 1st abv., intbd.; ss. and ls. intbd.; ss.
 v. f. to f. gr., ls., gy.-red to brn.-gy., fos.
 529-635 Sh., dk. olv. gy. to dk. gn.-gy., fis., hd., cly. to slty.,
 mica., pt. mod. carb.
 570-90 Intbd. sltst.
 590-600 Calc., sltst.
 600-30 Intbd. sltst.
- 635-41 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod.
 arg., Crin., Brac. (Haskell Ls. Mbr.)
- Stranger Fm.
- 641-50 Sh., m. gy., and brn.-gy., fis., cly. to sl. slty., mica.,
 pt. sl. carb.
 650-60 Mdst., gn.-gy. and gy.-red, cly., pt. calc.; and sh., m. gy.,
 as 1st abv., intbd.
 660-64 Ls., yel.-gy. to lt. brn.-gy., f. xl., Crin. (Westphalia Ls.
 Mbr.)
 664-743 Sh., gn.-gy., fis., cly. to sl. slty., mica., ang. frag.,
 brn.-gy., cl.-fest., pt. mod. fos., / Plcy., Gast., Crin.
 710-43 W/o ang. frag. of cl.-fest.
- Stanton Ls. Fm. top
- 743-886 Ls., v. lt. gy. to lt. brn.-gy., f. xl., pt. ool., pt. pyr.,
 pt. sft. and sl. arg., / Crin., Brac. and Ost., cav. of
 1st abv. in upper 10'
 760-70 Olv. gy. fis., cly., calc., fos., sh. pts.
 770-80 Pt. mod. dol.
 780-800 Abnt. c. xl., calc.
 800-10 Olv. gy., fis., cly., sh. brk.
 810-55 Abnt. c. xl., calc.
 820-30 Olv. gy., fis., cly., sh. brk.
 830-40 Fos., gy.-blk., lmy., sh. to arg., ls. pts.
 870-86 Abnt. c. xl., calc.
- 886-96 Sh., m. gy., fis., cly., sl. mica., Gast.
 896-900 Ls., gn.-gy., f. xl., / c. xl., calc., pt. pyr., fos.
 900-10 Ls., as 1st abv.; and sltst., m. gy. to gn.-gy., qtzs.,
 910-50 Sh., m. gy., fis., cly., mica., calc., pt. carb., pt. fos.

LOG 16 (See Plate 7, Well 15)

REX & MORRIS AND OTHERS

NO. 1 WRIGHT

Near Cen. N $\frac{1}{2}$ Lot 16, sec. 30, T. 28 S., R. 8 E.

Butler County, Kansas

Footage described: 1295- to 1900-foot depth

Kanwaka Sh. Fm.

- 1295-1308 Sh., m. gy., fis., cly. to slty., mica., pt. mod. carb.;
and sltst., gn.-gy. and brn.-gy., qtzs., mica., sil.
cmt., intbd.; spr. scat. frag. of brn.-gy. ls., and spr.
Fus. (prob. cav.)

Oread Ls. Fm.

- 1308-45 Ls., lt. gn.-gy. to brn.-gy. to m. dk. gy., f. xl., / c.
xl., calc., pt. sft. and mod. arg., Crin., Brac. incl.
Crurithyris planoconvexa
1315-25 Olv. gy. fis., cly., mica., sh. brk., fos. / Plcy.
1325-35 Olv. gy., fis., cly., mica., sh. brk., fos. / Crin.
1335-45 Sh. brk., olv. gy., fis., cly., mica., Crin.
1345-53 Sh., dk. gn.-gy. and gy.-blk., fis., cly., sl. mica., slty.
(Heebner Sh. Mbr.)
1353-55 Ls., brn.-gy., f. xl., pt. fos., sl. arg.
1355-86 Sh., dk. olv. gy., fis., cly., mica.; and sltst. to v. f.
gr. ss., lt. gn.-gy., qtzs., mica., fri., sbang. to sbrd.
and elong. to eqnt., intbd.; spr. cav. of 1st and 2nd abv.
1386-1400 Ls., v. lt. gy. to yel.-gy. to lt. brn.-gy., pt. sft. and
mod. arg., fos. / Crin. and Brac.
1390-95 Olv. gy., cly., fis., mica., sh. brk.
1400-07 No samples.
1407-09 Ls., as 2nd abv.

Lawrence Fm.

- 1409-11 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., dol. cmt.
1411-18 Sh., olv. gy., fis., cly., sl. mica., carb.
1418-20 Sltst., gn.-gy., qtzs., calc., pt. carb.
1420-22 Sh., as 2nd abv.
1422-23 Coal, shy.
1423-25 Sh., as 4th abv.
1425-28 Ls., lt. brn.-gy. to olv. gy., f. xl., pt. arg., c. xl.,
calc., Crin. (Amazonia Ls. Mbr.)
1428-39 Sh., olv. gy., fis., cly., sl. mica.
1439-41 Mdst., gy.-red, cly. to slty.
1441-60 Mdst., gn.-gy., cly. to sl. slty., sl. mica. / a th. intbd.
ls., as 2nd abv.
1460-92 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., carb., spr. cav.
of 1st abv.
1470-92 Olv. gy., fis., cly. to slty., carb., sh. brks.
1492-93 Coal, shy.

- 1495-1505 Ss., yel.-gy. to lt. gn.-gy., qtzs., mica., v. f. gr.
 1505-10 Sh., m. gy. to olv. gy., cly., fis., carb. / pnt. fos.
 1510-17 No samples.
 1517-50 Sh., m. gy. and brn.-gy., plty., cly. to slty., mica.
 1530-50 Intbd. gn.-gy. to lt. brn.-gy., calc., sltst.
 1550-1658 Sh., olv. gy., fis., cly., sl. mica., slty.
 1580-90 Intbd. lt. brn.-gy. sltst. to v. f. gr. ss.
 1590-1600 Intbd. lt. gn.-gy., calc. sltst.
 1658-60 Ls., lt. brn.-gy., v. f. xl., pt. fos. (Haskell Ls. Mbr.)
 Stranger Fm.
 1660-65 Sh., as 2nd abv.
 1665-73 Ls., m. lt. gy., f. xl., Crin., Brac. ?Fus. (Westphalia Ls. Mbr.)
 1673-76 Ss., lt. gn.-gy., v. f. gr., carb.
 1676-95 Ls., yel.-gy. to lt. gn.-gy., mot. m. gy., v. f. xl., Crin., Brac. / intbd. lt. gn.-gy. sh., and lt. gn.-gy., v. f. gr., carb. ss. (prob. contains Iatan Ls. Mbr.)
 1695-1704 Sh., and ss., as 1st abv., intbd., spr. ls. (prob. cav.)
 Stanton Ls. Fm. top
 1704-33 Ls., v. lt. gy. to lt. gn.-gy. to m. gy., f. xl., / c. xl., calc., pt. mod. arg., Crin., Brac., Bry., and Fus.
 1710-33 Olv. gy., fis., cly. to slty., fos. sh. pts.
 1733-48 Ls., v. lt. gy. to yel.-gy. to lt. gn.-gy., f. xl., / c. xl. calc., pt. sft. and sl. arg., Crin. and Brac.
 1748-50 Sh., dk. gn.-gy., fis. plty., sl. mica.
 1750-85 Ls., as 2nd abv. / v. lt. gy., ang. frag., fos., cht. / sh. brks., sh., as 1st abv.
 1785-1873 Ls., as 1st abv., / sh. pts.
 1825-35 Olv. gy., fis., cly., fis., sh. brk.
 1835-45 Olv. gy., fis., cly., sh. pts.
 1835-73 Abnt. c. xl., calc.
 1873-75 Ls., m. gy., v. arg. to lmy. sh., Crin.
 1875-85 Ls., m. gy., v. arg., fos.; and sh., m. gy., calc., fos., intbd.
 1885-1905 Sh. to sltst., m. gy., calc., pt. fos. / Crin. and Bry.

LOG 17 (See Plate 7, Well 17)

SIMPSON OIL COMPANY ET AL.

NO. 1 EVANS

Near cen. So. line SW $\frac{1}{4}$ sec. 21, T. 28 S., R. 7 E.

Butler County, Kansas

Altitude: 1457 feet

Footage described: 1345- to 1935-foot depth

Kanwaka Sh. Fm.

- 1345-61 Sh., m. gy. to lt. gy., fis., cly. to sl. slty., sl. mica.
 1361-65 Ls., m. gy., pt. sft. and v. arg., pt. slty., Crin., Brac. (Clay Creek Ls. Mbr.)
 1365-78 Sh., as 2nd abv., / Crin., Brac.

Oread Ls. Fm.

- 1378-83 Ls., yel.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod. arg., Crin., Brac., Bry.
 1383-87 Sh., olv. gy., fis., cly., mica.
 1387-95 Ls., as 2nd abv.
 1395-98 Sh., gy.-blk., fis., cly. (Heebner Sh. Mbr.)
 1398-1400 Ls., brn.-gy., v. f. xl., hd., Gast., Crin.
 1400-05 Sh., m. gy. to gn.-gy., fis., cly. to slty., mica., pt. fos. / Brac.
 1405-20 Mdst., gn.-gy. and gy.-red, cly., sl. mica.; sltst., lt. brn.-gy., calc.; and ls., lt. brn.-gy., f. xl., Brac., intbd.
 1420-34 Mdst., gn.-gy. and gy.-red, calc., as 1st abv., / spr. ls. frag. (prob. cav.)
 1434-42 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod. arg., Crin., Brac.
 1442-44 Mdst., as 2nd abv.
 1444-55 Ls., as 2nd abv.

Lawrence Fm.

- 1455-62 Ss., gn.-gy., qtzs., v. f. gr., mica., calc.
 1462-70 Sh., m. gy. to gn.-gy., fis., cly. to slty., mica., pt. carb.
 1470-73 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., dol. cmt.
 1473-75 Mdst., lt. gn.-gy., v. arg. to lmy. sh., Brac.
 1475-87 Ls., brn.-gy., v. f. xl., hd., fos. (Amazonia Ls. Mbr.)
 1487-1521 Sh. and mdst. intbd., olv. gy., fis., cly., v. calc.
 1495-1500 Intbd. gy.-red sh. and mdst.
 1500-10 Intbd. lt. gn.-gy., carb. sltst.
 1510-20 A th. coal str. / spr. frag. of ls. (prob. cav.)
 1521-30 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr., qtzs., mica.
 1530-35 Sh. to mdst., olv. gy., cly., carb.
 1535-65 Sh., as 1st abv., ss., as 2nd abv. and ls., as 4th abv., and a th. coal str.
 1565-80 No samples
 1580-1635 Ss., brn.-gy., v. f. gr., qtzs., mica., carb., dol. cmt. and a th. brn.-gy., fis., cly. to slty., mica., carb. sh. intbd.
 1635-46 No samples.
 1646-59 Ls., lt. brn.-gy., hd., v. f. xl., Crin., Brac., Foram. (Haskell Ls. Mbr.)

Stranger Fm.

- 1659-62 Sh., m. gy., fis., cly., mod. carb.
 1662-90 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl. / c. xl. calc., pt. ool., pt. sft. and mod. arg., Crin., Brac., Bry. / spr. sh. frag. (prob. cav.) (?Iatan-Westphalia Mbr.)
 1690-1728 Sh., olv. gy., fis., cly. to sl. slty., mica., carb.
 1700-20 Scat. frag. of brn.-gy. cl.-fest.

Stanton Ls. Fm. top

- 1728-30 Ls., lt. gn.-gy., f. xl., pt. sft. and mod. arg., fos.
 1730-40 No samples.

- 1740-1905 Ls., v. lt. gy. to lt. gn.-gy., to lt. brn.-gy., f. xl. /
abnt. c. xl. calc., pt. pyr., Fus., Crin., Brac. / olv.
gy., fis., cly. sh. brks. or pts.
1800-10 Gy.-blk., cly., fos. sh. pt.
1830-45 M. gy., fos., cly., fis., sh. brk.
1875-1905 Ls., m. gy.
1885-95 M. gy., fis., cly., mica. sh. brk., ls. / Bry.
1895-1905 Sltst. and sh. brks.
1905-35 Sh., gn.-gy., fis., cly., mica.; and sltst., gn.-gy. to m.
gy. intbd., / spr. ls. frag. (prob. cav.)

LOG 18 (See Plate 7, Well 19)

A. M. LANDON ET AL

NO. 1 MCKAIG

Near NE cor. SE $\frac{1}{4}$ sec. 13, T. 28 S., R. 6 E.

Butler County, Kansas

Footage described: 1460- to 1950-foot depth

Oread Ls. Fm.

- 1460-67 Ss., lt. gn.-gy., qtzs., mica., calc. cmt.
1467-72 Sh., olv. gy., fis., cly. to slty., mica.
1472-84 Ls., lt. gn.-gy., f. xl., pt. sft. and mod. arg., / Crin.
and Brac.

Lawrence Fm.

- 1484-90 Sh. to mdst., olv. gy., as 2nd abv.
1490-1507 Sh., brn.-gy., fis. to plty., cly. to slty., mica., pt.
carb., Gast. / a th. intbd. sltst.
1507-16 Ls., lt. gn.-gy. to brn.-gy., f. xl., abnt. c. xl., calc.,
/ Brac., Ost. and Crin. (Amazonia Ls. Mbr.)
1516-27 Sh., olv. gy. to brn.-gy., fis., hd., cly. to slty., mica.,
mod. carb.
1527-31 Ls., brn.-gy., f. xl., arg., / Crin. and Brac.
1531-48 Sh., olv. gy. to brn.-gy., as 2nd abv.
1548-56 Ss., brn.-gy., v. f. gr., qtzs., mica., carb.
1556-70 Sh., olv. gy. and gy.-brn., fis., cly. to slty., mica.,
pt. mod. carb.
1560-70 Intbd. brn.-gy. and gn.-gy., v. f. gr., qtzs.,
mica., carb. ss.
1570-74 Ss., lt. brn.-gy. to brn.-gy., v. f. gr., qtzs., mica.,
carb.
1574-75 Coal
1575-77 Sh., as 2nd abv.
1577-80 Ss., as 2nd abv.
1580-1650 Ss. and sh., intbd., as 1st and 2nd abv.
1650-93 Sh., dk. gn.-gy., fis., cly., mica.; and sltst. intbd., as
1st abv. but sltst. rather than ss.
1693-1700 Ls., gn.-gy. and m. lt. gy., f. xl., pt. sft. and mod. arg.,
Crin. and Brac. (Haskell Ls. Mbr.)

Stranger Fm.

- 1700-02 Sh., m. gy. to olv. gy., fis., cly., mica.
 1702-08 Ls., as 2nd abv. (Westphalia Ls. Mbr.)
 1708-12 Sh., as 2nd abv.
 1712-27 Ls., as 4th abv. (Iatan Ls. Mbr.)
 1727-66 Sh., olv. gy. to dk. gn.-gy., fis., cly. to sl. slty.,
 mica.
 1730-40 Spr. ls. frag. (prob. cav.)
 1750-66 Ang. frag. of red.-brn. cl.-fest.

Stanton Ls. Fm. top

- 1766-1820 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
 arg., / Fus., Crin., Brac., and Bry.
 1770-80 Sh. brk., dk. gn.-gy., fis., cly.
 1780-90 Sh. brk., dk. gn.-gy., fis., cly.
 1790-1820 Sh. brk., dk. gn.-gy., fis., cly., ls., m. gy.,
 fos. / Crin. and Brac.
 1820-72 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., / abnt. c. xl.,
 calc., por., v. ltl. resd., / Crin. and Brac., / gn.-gy.
 to dk. gn.-gy., fis., cly., mica. sh. pts.
 1872-75 Sh., dk. gn.-gy., fis., cly., mica., abnt. fos., / Crin.,
 Brac. and Echin.
 1875-80 Ls., m. gy. to m. dk. gy., f. xl., hd., Crin.
 1880-90 Ls., as 3rd abv., c. xl., calc., spr. sh. frag. (prob. cav.)
 1890-1920 Ls., v. lt. gy. to lt. gn.-gy., f. xl., / abnt. c. xl.
 calc., v. ltl. resd., / Crin.; spr. scat. frag. of sh.
 (prob. cav.)
 1910-20 A th. gn.-gy., fis., cly., mica. sh. brk.
 1920-50 Sh., m. gy. to m. dk. gy., calc.; and sltst., gn.-gy.,
 intbd., slty., arg. ls., abnt. fos. / Crin., Brac., and
 Bry.

LOG 19 (See Plate 7, Well 23)

NATIONAL REFINING CO.

NO. 1 SMITH

NE $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 28 S., R. 5 E.

Butler County, Kansas

Altitude: 1290 feet

Footage described: 1475- to 2050-foot depth

Kanwaka Sh. Fm.

- 1475-81 Sh., dk. gn.-gy., fis., cly. to slty., mica., pt. mod. calc.

Oread Ls. Fm.

- 1481-85 Ls., gn.-gy., f. xl., pt. arg., Crin. and Bry.

- 1485-87 Sh., as 2nd abv.

- 1487-1525 Ls., lt. gn.-gy. to yel.-gy. to lt. brn.-gy., f. xl., / c.
 xl., calc., pt. sft. and mod. arg., Crin. and Brac.

- 1495-1525 Dk. gn.-gy., sh. brks., as 4th abv.

- 1525-31 Sh., gn.-gy. and gy.-blk., fis., cly., gy.-blk., pt. / calc.
 strs., pt. fos. / Brac.

- 1531-33 Ls., gn.-gy. to brn.-gy., v. f. xl., hd., fos.
 1533-49 Sh., dk. gn.-gy., fis., cly., mica., pt. fos. / Brac., Crin.;
 and mdst., gn.-gy., cly., calc., pt. pyr., spr. cav. of
 1st and 2nd abv., intbd.
 1549-58 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., Crin.
 1558-64 Mdst., gn.-gy. and m. dk. gy., cly., calc., pt. fos.
 1564-67 Ls., as 2nd abv.
- Lawrence Fm.
 1567-97 Sh., as 4th abv.; mdst., olv. gy., cly., calc.; and sltst.,
 lt. brn.-gy., qtzs., mica., dol. cmt., pt. sl. carb.,
 intbd.; spr. scat. ls. frag. (prob. cav.)
 1592-94 Ls., gn.-gy. to brn.-gy., v. f. xl., fos. (Amazonia
 Ls. Mbr.)
 1597-1603 Ss., lt. gn.-gy. to lt. brn.-gy., v. f. gr., qtzs., mica.,
 carb., calc.
 1603-60 Sh., dk. gn.-gy. to m. dk. gy., fis., cly. to sl. slty.,
 mica., v. carb., pt. v. calc.
 1610-20 Intbd. lt. gn.-gy., carb. sltst.
 1620-28 Intbd., gn.-gy. sltst. to v. f. gr. ss. and gn.-gy.,
 calc., mdst., pt. fos., Plcy.
 1628-50 Mdst. and sh., pt. fos. / intbd. lt. gn.-gy., v. f.
 gr. ss.
 1640-60 / a th. gn.-gy., fos., ls., / a th. coal.; intbd.
 lt. gn.-gy., v. f. gr. ss.
 1660-85 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., spr. cav. of 1st
 abv.
 1670-78 Intbd. gn.-gy. sh., and a th. coal
 1678-85 Intbd. brn.-gy., slty., mica., carb. sh.
 1685-1730 Sh. and sltst. to v. f. gr. ss., intbd.; sh., gn.-gy., fis.,
 cly. to slty., mica., carb.; sltst. to ss., lt. gn.-gy.,
 mica., pt. carb., dol. cmt.
 1730-60 Sh., gn.-gy. to olv. gy., as 1st abv.
 1735-45 A th. intbd. lt. gn.-gy., calc. sltst.
 1760-64 Sh., dk. olv. gy. and gy.-blk., fis., cly., sl. mica., gy.-
 blk., pt. / calc. strs.
 1764-68 Ls., lt. brn.-gy., f. xl., pt. sft. and mod. arg., Crin. and
 Brac. (Haskell Ls. Mbr.)
- Stranger Fm.
 1768-70 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., calc., pt. fos. /
 Crin.
 1770-77 Sh. m. gy. to dk. gn.-gy., as 3rd abv.
 1777-89 Ls., lt. gn.-gy. to m. gy., v. f. xl., / c. xl., calc.,
 hd., fos. / Crin. (Westphalia Ls. Mbr.)
 1789-92 Sh., dk. gn.-gy., fis., cly.
 1792-94 Ls., as 2nd abv. (Iatan Ls. Mbr.)
 1794-97 Sltst., v. f. gr. ss., mica., calc.
 1797-1827 Sh., dk. gn.-gy., fis., cly., mica.
 1805-15 Ang. frag. of brn.-gy. fe-st.
- Stanton Ls. Fm. top
 1827-50 Ls., v. lt. gy. to lt. gn.-gy. to lt. brn.-gy., f. xl. /
 abnt. c. xl. calc., ool. in upper 7 ft., pt. sft. and
 sl. arg., Crin. and Brac.

- 1833-40 Sh. brk., dk. gn.-gy., fis., cly. mica.
 1840-50 Spr. sh. frag. (prob. cav.)
 1850-60 Ls., v. lt. gy. to gn.-gy. to m. gy., v. f. xl. / c. xl.
 calc., pt. pyr., Crin.
 1860-1965 Ls., as 2nd abv.
 1908-15 A th. dk. gn.-gy. to gy.-blk., fis., cly., sh. pt.
 1925-37 Same
 1937-45 Same
 1937-65 Ls., gn.-gy. to brn.-gy.
 1965-70 Ls., m. gy. and brn.-gy., v. f. xl., abnt. Fus.
 1970-78 Ls. and sh. intbd., m. gy. to gn.-gy.; ls., pt. arg., fos.;
 sh., fos. / Brac.
 1978-95 Ls., as 1st abv. / a few scat. sh. frag. (prob. cav.)
 1995-2000 No samples.
 2000-09 Ls., as 3rd abv.
 2009-16 Sh., dk. gn.-gy. to gy.-blk., fis. to plty., cly. to sl.
 slty., calc., Crin. and Echin.
 2016-25 Ls., m. gy. to gn.-gy., f. xl. / c. xl. calc., pt. pyr.,
 Brac. and Crin.
 2025-42 Ls., v. lt. gy. to lt. gn.-gy., f. xl. / abnt. c. xl. calc.,
 Crin.
 2042-50 Sh., gn.-gy., plty., cly. to sl. mica., pt. fos. / Crin.

LOG 20 (See Plate 8, Well 2)

ISERN DRILLING COMPANY

NO. 1 PROPP

Near NE cor. NE $\frac{1}{4}$ sec. 14, T. 34 S., R. 11 E.

Chautauqua County, Kansas

Footage described: 20- to 540-foot depth

Stranger-Lawrence Fm.

- 20-50 Ss., lt. brn., v. f. gr., qtzs., gr. sbang. to sbrd., eqnt.,
 sil. cmt.
 50-60 Sltst., lt. gn., sl. calc., mica., spr. scat. coal frag.
 60-140 Ss., yel.-brn. to yel.-gy. to lt. olv.-gy. in low. pt.,
 v. f. to f. gr., qtzs., gr. sbang. to sbrd., eqnt.,
 pt. fri., pt. calc. cmt., pt. dol. cmt., pt. mica.
 110-15 Scat. gr. stn. pt. blk. / carb. str.
 115-20 Scat. par. of a dk. min., v. fri.
 130-35 Scat. frag. of dk. gy. carb., calc. sh.
 140-55 Sh., dk. gn.-gy., slty., mica., sft., spr. fos. / Crin., and
 Brac.
 155-60 Sltst., gn.-gy., calc., mica., spr. fos.
 160-210 Sh., gn.-gy. to m. gy., cly. to sl. slty., spr. fos., mica.,
 pt. calc.
 170-75 Spr. Crin.
 175-80 Crin. and Gast.
 185-90 Spr. frag. of coal
 190-95 Crin.
 195-205 Scat. frag. of ls.
 205-10 Crin.

- 210-75 Ss., gn.-gy., v. f. gr. to sltst., qtzs., gr. sbang. to sbrd., eqnt., pt. calc., pt. dol. cmt., mica. pt. fri. / m. lt. gy. to m. gy. slty. sh. str.
- 230-35 F. to m. gr.
- 245-60 F. to m. gr.
- 235-40 Scat. pyr. xls.
- 260-70 Scat. pyr. xls.
- 275-81 No samples.
- 281-330 Sh., dk. gn.-gy. to m. gy. in low. pt., slty. to sl. slty. in low. pt., mica., pt. sl. calc.
- 330-37 Ss., lt. brn., v. f. gr., qtzs., gr. sbang. to sbrd., elong. to eqnt., mica., sil. cmt.
- 337-400 Sh., gn.-gy., cly. to slty., pt. calc.
- 340-45 Scat. frag. lt. olv. gy. sltst. and ls.
- 345-50 Lt. olv. gy. sltst.
- 395-400 Gast.
- 400-35 Sh., m. gy., pt. slty., mica., pt. calc.
- 435-45 Ls., shy., Crin., and sh. intbd.
- 445-50 Sh., m. gy., mica.; and sltst., gn.-gy., arg., calc., intbd.
- 450-60 Sh., as 3rd abv.
- 460-77 Sltst. to slty. ls., gn.-gy., Crin. and Brac.
- 477-506 Sh., m. gy. to m. dk. gy., sl. slty., fis., pt. fos. / Crin. and Bry.
- Stanton Ls. Fm.
- 506-17 Ls., lt. brn.-gy., m. xl., shy., ool. elp. to sph. / qtz. nuclei., Crin., Bry., Echin. spines
- 517-20 Sh., m. gy., calc., mica., fos.
- 520-40 Ss., lt. olv.-gy. to gn.-gy., ool., calc., gr. sbang. to sbrd. and elong. to eqnt.

LOG 21 (See Plate 8, Well 6)

J. R. FESTER ET AL.

NO. 1 TRAVIS BROTHERS

NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 2, T. 35 S., R. 9 E.

Chautauqua County, Kansas

Footage described: 448- to 955-foot depth

Lawrence Fm.

- 448-50 Sh., m. lt. gy. to m. gy., mica., slty.
- 450-63 Ss., lt. gy. to v. lt. gy., v. f. gr. to sltst., qtzs., gr. eqnt. to elong. and sbang. to sbrd.
- 463-67 Sh., as 2nd abv.
- 467-76 Ss., gn.-gy. and brn.-gy., v. f. to f. gr., dol. cmt.
- 476-78 Sh., as 4th abv.
- 478-80 Ss., as 2nd abv.
- 480-87 Sh., as 6th abv. / scat. frag. of gy.-red mdst.
- 487-500 Ls., m. lt. gy. to lt. brn.-gy., f. xl., abnt. Fus. / intb. m. lt. gy., calc. sl. slty., sh.
- 500-10 Sh., m. gy., calc., fos., / intbd. calc., mica., sltst.

- 510-83 Sh., m. gy. to m. dk. gy., slty., mica., carb.
550-77 Intbd. calc. sltst.
- 583-87 Ss., brn.-gy., v. f. gr., qtzs., mica.
- 587-603 Sh., m. lt. gy. to m. gy., slty., mica., / intbd. sltst., pt.
carb. and scat. ls. frag. (prob. cav.) in lwr. pt.
- 603-10 Ss., lt. brn.-gy., v. f. gr., mica.
- 610-14 Sh., m. gy., slty., calc.
- 614-16 Ls., lt. gy. to lt. brn.-gy., f. xl., fos.
- 616-20 Ss., as 3rd abv.
- 620-24 Ls., as 2nd abv. (Haskell Ls. Mbr., 614-624)
- Stranger Fm.
- 624-28 Sh., as 4th abv.
- 628-36 Ss., lt. brn. gy., v. f. gr. to sltst., mica.
- 636-40 Sh., m. lt. gy., calc., fos.
- 640-57 Ss. and sh. intbd., as 1st and 2nd abv.
- 657-746 Sh., m. gy., slty., mica., / sltst. str.
705-10 Intbd. brn. gy. sltst.
- 746-50 Ss., gn.-gy., v. f. gr., qtzs., gr. sbang. to sbrd., mica.
- 750-70 Sh., m. lt. gy., fis., mica., pt. fos.
- 770-80 Sh., dk. gn.-gy., fos.
- 780-86 Ss., lt. gn.-gy., v. f. gr. to sltst., as 3rd abv.
- 786-800 Sh., m. gy. to dk. gn.-gy., calc., sl. slty.
- 800-03 Ss., v. f. gr. to sltst., as 2nd abv.
- 803-14 Sh., m. gy., as 2nd abv.
- 814-19 Ss., as 4th abv.
- 819-26 Sh., as 4th abv.
- 826-29 Ss., as 6th abv.
- 829-43 Sh., m. gy., cly., mica., fos.
- 843-52 Sh., brn.-gy., slty., mica., / v. f. gr. ss. or sltst. str.
- 852-90 Ss., lt. gn.-gy., qtzs., mica., calc. and sh., gn.-gy., mica.,
fis. intbd.
- Stanton Ls. Fm. top
- 890-94 Ls., lt. gy. to lt. brn.-gy. to brn.-gy., f. to m. xl., pt.
/ brn.-gy. elip. and sph. ool., Brac., Crin., and Bry.
- 894-955 Ss., v. lt. gy., f. to m. gr., gr. ang. to sbrd., elong.
to eqnt., fri., pt. calc., mica.; and sh. m. gy., cly.,
fis. intbd.
- 925-30 Qtz. gr. stn. / bl. spec.
- 947-50 Fos. / Bry.

LOG 22 (See Plate 8, Well 12)

J. R. LOWELL AND F. G. HOLL

NO. 1 OLSEN

NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 13, T. 35 S., R. 7 E.

Cowley County, Kansas

Altitude: 1256 feet

Footage described: 1045- to 1810-foot depth

Kanwaka Sh. Fm.

- 1045-57 Sh. to mdst., m. gy. to gy.-red, slty., mica., / gy., fos.,
sh. str. and spr. ss. and ls. frag. (prob. cav.)

Oread Ls. Fm.

- 1057-67 Ls., lt. gn.-gy. to m. dk. gy. to brn.-gy., f. xl., mod.
arg., Fus., Crin., Brac., Bry., and Echin. spines.
- 1067-70 Sh., dk. gn.-gy., fis., cly. to sl. slty.
- 1070-75 Ls., as 2nd abv.
- 1075-83 Sh., m. dk. gy., slty., mica.
- 1083-95 Ls., m. dk. gy. to brn.-gy., f. xl., Crin., Brac., Fus.,
Echin. spines, Bry.
- 1095-1100 Sh., dk. gy., slty., mica.
- 1100-07 Sh. to mdst., m. dk. gy. to dk. gy.-red, cly. to slty.,
mica.
- 1107-12 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., gr. sbang. to
sbrd., elong. to eqnt., calc. cmt.
- 1112-37 Sh. to mdst., as 2nd abv. / intbd. gn.-gy. sltst.
- 1137-40 Ls., lt. brn.-gy. to brn.-gy., fos., pt. arg.
- 1140-42 Sh., as 5th abv.; and ss., gn.-gy., v. f. gr., mica., intbd.
- 1142-44 Ls., as 2nd abv.
- 1144-49 Sh. to mdst., m. gy. to gy.-red, pt. fos. / Brac. and Bry.
- 1149-56 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., arg., Crin.,
Bry., Brac., incl. Crurithyris planconvexa.

Lawrence Fm.

- 1156-80 Sh. to mdst., dk. gn.-gy. to gy.-red, slty., mica.
- 1180-88 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., Crin., Brac.
(Amazonia Ls. Mbr.)
- 1188-1210 Sh. to mdst., as 2nd abv., mdst., calc. / Brac.
- 1210-15 Ss., lt. gn.-gy., v. f. gr. to sltst., qtzs., mica., pt.
calc., pt. / dol. cmt.
- 1215-33 Sh. to mdst., m. gy. to gy.-red, mdst. pt. fos. / Ost.
1221-27 Spr. ls. frag. (prob. cav.)
- 1233-43 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr., qtzs., mica.,
pt. pyr., dol. cmt.
- 1243-48 Sh. to mdst., m. gy. to gy.-red, slty., mica.
- 1248-52 Ls., lt. brn.-gy., f. xl., fos.
- 1252-70 Ss., v. lt. gy. to lt. gn.-gy., pt. carb., pt. pyr., dol.
cmt., / th. m. gy. sh. brks.
- 1270-80 Ss., as 2nd abv.
- 1280-1301 Sh. to mdst., dk. gn.-gy. to gy.-red; and sltst., lt. brn.-
gy., intbd.

- 1301-09 Ss., lt. gn.-gy., v. f. gr., qtzs., pt. carb., mica.
 1309-72 Sh., m. lt. gy. to m. gy., slty., mica., fis., pt. carb.
 1340-68 Fos. / Brac., Bry., Crin., Gast., Plcy. and Ost.
 1372-77 Ls., lt. brn.-gy. to brn.-gy., f. xl., mod. arg., Fus.,
 Brac., Crin., Bry. (Haskell Ls. Mbr.)
- Stranger Fm.
 1377-81 Sh. to mdst., m. gy. to gy.-red, mica., slty.
 1381-83 Sltst., v. lt. gy. to lt. gn.-gy.
 1383-1420 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr. to m. gr., gr.
 ang. to sbrd., elong. to eqnt., pt. fri.
 1386-1405 M. gy., slty., mica. sh. brks.
 1405-15 M. gy. sh. brk., spr. ls. frag. (prob. cav.)
 1415-20 M. gy. sh. brk.
 1420-21 Sh., dk. gn.-gy., slty., mica.
 1421-26 Ls., brn.-gy., f. xl., mod. arg., sl. slty., abnt. Fus.,
 Bry., Crin., and Brac.
 1426-28 Sh., m. dk. gy. to dk. gn.-gy.
 1428-38 Ss., lt. gn.-gy., v. f. gr., qtzs., gr. ang. to sbrd.
 and eqnt. to elong., mica., fri., calc. cmt., gr. stn.
 blk., spr. ls. frag. (prob. cav.)
 1438-44 Sh., as 2nd abv.
 1444-50 Ss., as 2nd abv., pt. carb.
 1450-1643 Sh., m. gy. to dk. gn.-gy., slty., mica.
 1470-76 Gy.-red mdst.
 1476-82 Intbd. gn.-gy. and red-brn. sltst.
 1482-89 Intbd. brn.-gy., carb. sltst. and m. gy. sh.
 1489-1500 Intbd. carb. sltst. and slty. sh.
 1500-12 Intbd. slty. sh. and lt. gn.-gy. calc., sltst.
 1512-60 As 1st abv., pt. carb.
 1560-70 Pt. pyr.
 1570-85 Lt. gn.-gy., sltst. to v. f. gr., mica., ss.
 1585-1605 Lt. gn.-gy., calc. sltst.
 1615-43 Lt. gn.-gy., v. f. gr. ss. intbd.
 1643-45 No samples.
 1645-60 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr. to f. gr., mica.;
 and sh., gn.-gy., sl. slty., mica., intbd.
 1655-60 Sh. to sltst., pt. carb.
 1660-70 Sh., dk. gn.-gy., fos. / Ammodiscus and Ammovertella.
 1670-79 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., pt. carb.,
 pt. calc., pt. dol. cmt.
 1679-90 Sh., m. dk. gy. to dk. gn.-gy., slty., mica., carb.; and
 sltst., lt. gn.-gy., carb., calc., intbd.
 1690-93 Ss., lt. gn.-gy., v. f. gr.
 1693-1700 Sh. and sltst. intbd., as 2nd abv.
 1700-04 Ss., lt. gn.-gy., f. gr., qtzs., mica.
 1704-12 Sh. and sltst., as 4th abv.
- Stanton Ls. Fm. top
 1712-16 Ls., brn.-gy., f. to m. xl., mod. arg., Crin.
 1716-54 Ss., v. lt. gy. to lt. gn.-gy., v. f. to m. gr., mica., pt.
 carb., pt. calc., pt. dol. cmt., pt. fri., gr. ang. to sbrd.
 and elong. to eqnt. / m. gy., slty., mica. sh. brks.

- 1754-73 Sh., m. gy.; and sltst., lt. gn.-gy., calc., intbd.
 1773-77 Ss., as 2nd abv.
 1777-1810 Sh. and sltst. intbd., as 2nd abv.

LOG 23 (See Pl. 8, Well 15)

AMERADA (L. H. WENTZ AND OTHERS)

NO. 1 DANIEL RUSH

NW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 36, T. 34 S., R. 6 E.

Cowley County, Kansas

Altitude: 1356 feet

Footage described: 1300- to 2040-foot depth

Kanwaka Sh. Fm.

- 1300-30 Ss., v. lt. gy. to lt. gn.-gy., f. to m. gr., qtzs., gr. ang.
 to sbrd. and elong. to eqnt., fri., a few scat. pyr. frag.
 1320-25 Qtz. frag. stn. brn., / a th. dk. gn.-gy., slty.
 sh. brk.
 1330-34 Sh. and mdst., intbd.; sh., dk. gn.-gy.; mdst., mod. red.-
 brn., slty., mica.
 1334-42 Slstst., lt. brn.-gy. to brn.-gy., qtzs., mica., mod. calc.
 1342-45 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., gr. ang. to sbrd.
 and elong. to eqnt., fri.
 1345-47 Sh. to mdst., m. gy. to gy.-red, slty., mica.
 1347-52 Ls., lt. brn.-gy., f. xl., sdy., Crin. (?Clay Creek Ls. Mbr.)
 1352-60 Sh. and mdst., intbd.; sh., gn.-gy., calc.; mdst., gy.-red,
 calc.
 1360-67 Slstst., lt. brn.-gy., mica., calc.
 1367-77 Sh. and sltst. and gy.-red mdst., intbd.; as 1st and 2nd abv.
 1377-82 Sh., dk. gn.-gy., slty., mica., hd.

Oread Ls. Fm.

- 1382-93 Ls., m. gy. to brn.-gy., f. xl., abnt. fos. / Fus., Brac.,
 Bry., Crin. and Echin. spines
 1393-96 Sh. to mdst., dk. gn.-gy. to gy.-red, slty., mica., fos.
 1396-98 Ls., as 2nd abv.
 1398-1403 Sh., dk. gy. to gy.-blk., pt. slty., pt. mica., fis. (Heeb-
 ner Sh. Mbr.)
 1403-07 Ls., lt. gn.-gy. to m. dk. gy., f. xl., Fus., Brac., Crin.;
 gn.-gy. ls. is mod. arg. and sft.
 1407-11 Sh., m. dk. gy., slty., mica., fos.
 1411-18 Slstst., gn.-gy., mica., pt. calc.
 1418-20 Sh., m. gy., slty., Crin.
 1420-22 Ls., m. gy., f. xl., mod. arg., Crin.
 1422-28 Sh., m. gy.; and mdst., gy.-red, intbd.
 1428-30 Slstst. to f. gr. ss., gn.-gy.
 1430-37 Sh. and mdst. intbd.; as 2nd abv., a few scat. ls. frag.
 (prob. cav.)
 1437-40 Ss., gn.-gy., v. f. to f. gr., qtzs., mica., ang. to sbrd.
 1440-45 Sh., gn.-gy. to m. gy., mod. calc., fos.; and mdst., gy.-
 red, Gast. and Ost., intbd.

- 1445-70 Ss., gn.-gy., v. f. gr., mica., pt. mod. calc., ang. to sbrd. and elong. to eqnt., scat. qtz. frag. stn. yel.-brn., m. gy. slty. sh. brks.
- 1470-79 Sh. and mdst., intbd.; as 2nd abv., pt. fos. / Crin. and Brac. incl. Crurithyris planoconvexa, gy.-red mdst. / Ost., pt. calc.
- 1479-95 Ls., m. lt. gy. to lt. brn.-gy., f. xl., Crin., Echin., Fus., sl. arg.
- 1480-85 Fos., m. gy. sh. brk.
- 1485-90 M. gy. fos. sh. brk., pyr. observed in a few scat. ls. frag.
- Lawrence Fm.
- 1495-1517 Sh. and mdst., intbd.; sh., m. gy., mdst., gy.-red, mod. calc., Ost., / intbd. gn.-gy. sltst.
- 1517-21 Ss., lt. gn.-gy., v. f. gr., pt. calc., pt. dol. cmt., pt. stn. red.-brn.
- 1521-28 Sh. and mdst., intbd.; as 2nd abv., pt. fos. / Crin. and Bry.
- 1528-31 Ls., lt. gn.-gy., f. xl., Brac. and Bry., arg., sft. and pt. sdy.
- 1531-47 Sh. mdst. and sltst. intbd.; sh. and mdst., as 4th abv.; sltst., lt. gn.-gy., mica.
- 1547-50 Ls., as 2nd abv., slty.
- 1550-64 Ss., sh., and mdst. intbd., as 5th and 6th abv.
- 1564-1660 Sh., m. dk. gy. to dk. gn.-gy., cly. to sl. slty., mica., hd., gy.-red mdst., intbd.
- 1580-85 Gy.-red mdst. / Ost.
- 1650-56 Fos. / Crin.
- 1656-60 Fos. / Crin. and a th. arg. intbd. ls. / Brac. and Crin.
- 1660-75 Sh. and ls., intbd.; sh., dk. gn.-gy., cly. to sl. mica.; ls., gn.-gy. to brn.-gy., f. xl., mod. arg., Crin. and Brac.
- 1675-93 Sh., mdst., and sltst., intbd.; sh., m. gy.; mdst., gy.-red; sltst., gn.-gy., pt. calc. to v. f. gr. ss.
- 1693-97 Ls., lt. gn.-gy. to brn.-gy., f. xl., Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1697-1704 Ss., v. lt. gy. to lt. gn.-gy., f. to m. gr., qtzs., mica., fri., sbang. to sbrd. and elong. to eqnt.
- 1704-06 Sh., m. gy. to dk. gn.-gy., slty., mica.
- 1706-09 Ss., as 2nd abv.
- 1709-13 Ls., lt. gn.-gy. to brn.-red, f. xl., Crin. (Westphalia Ls. Mbr.)
- 1713-15 Sh., m. gy. and mdst., gy.-red., intbd., cly. to slty., mica.
- 1715-27 Ss., v. lt. gy. to lt. gn.-gy., f. to m. gr., fri., sbang. to sbrd. gr.
- 1727-33 Sh. and mdst., intbd.; as 2nd abv.
- 1733-48 Ss., gn.-gy., f. to m. gr., qtzs., abnt. c. xl. calc. as a calc. cmt., a number of qtz. grains stn. red.-brn.

- 1748-51 Sh., dk. gn.-gy., cly. to slty., mica.
 1751-58 Sltst., lt. gn.-gy., mica., sil. cmt.
 1758-65 Sh., as 2nd abv.
 1765-75 Sltst., as 2nd abv.
 1775-82 Ss., lt. gy. to lt. gn.-gy., v. f. to f. gr., qtzs., mica.,
 ang. to sbrd. gr.
 1782-86 Sh., m. dk. gy., slty., mica.
 1786-93 Ss., as 2nd abv..
 1793-96 Sh., as 2nd abv.
 1796-1800 Ss., as 4th abv.
 1800-08 Sh. and sltst., intbd., m. gy. to lt. brn.-gy. mica.
 1808-17 No samples.
 1817-40 Sh., mdst. and sltst., intbd.; sh., m. gy.; mdst., gy.-red,
 and sltst., lt. gy. to lt. gn.-gy.
 1817-22 A th. m. gy. to lt. brn.-gy. fos. ls. bd.
 1840-55 No samples.
 1855-1902 Sh., mdst., and sltst., intbd.; as 2nd abv.
 1888-95 Pt. carb.
 1902-08 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., carb.
 1908-10 Sh., m. gy., slty., mica.
 1910-14 Ss., as 2nd abv.
 1914-54 Sh., m. gy., hd., sl. mica. and gn.-gy. sltst., intbd.
 1954-63 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., dol. cmt.
 1963-72 Sh. and sltst., intbd.; as 2nd abv.
 1972-79 Ss., as 2nd abv.
 1979-2002 Sh., mdst., and sltst., intbd.; sh., dk. gy., cly. to sl.
 slty., mica., fis., Ost. and arenac. Foram. incl.
Ammodiscus and Ammovertella; mdst., gy.-red; sltst.,
 lt. gn.-gy.
- Stanton Ls. Fm. top
 2002-06 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., sdy., arg., Brac.
 and Crin.
 2006-08 Sh., as 2nd abv.
 2008-10 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., pt. carb.,
 pt. calc., pt. dol. cmt., sbang. to sbrd., eqnt. gr.
 2010-13 Sh., m. dk. gy., slty., mica., fis.
 2013-15 Ls., lt. brn., c. xl., sdy., Crin.
 2015-17 Sh., as 2nd abv.
 2017-27 Ss., as 3rd abv., and sltst., lt. gn.-gy., intbd.
 2027-37 Sltst. to v. f. gr. ss., lt. gn.-gy. qtzs., mica., pt.
 carb., pt. calc., pt. dol. cmt., pt. pyr.
 2037-40 Sh., m. gy., slty., mica., pt. carb.

LOG 24 (See Plate 8, Well 17)

W. N. MCKNAB

NO. 1 HENRY WALDSCHMIDT

Near SW cor. NW sec. 18, T. 34 S., R. 6 E.

Altitude: 1198 feet

Footage described: 1400- to 2040-foot depth

?Kanwaka Sh. Fm.

1397-1425 Sh., mdst., and ss., intbd.; sh., m. dk. gy.; mdst., gy.-red, ss., gn.-gy., sh., hd., slty., mica., ss., v. f. gr., qtzs., a few scat. frag. of brn.-gy. ls. (prob. cav.)

1425-30 Sh., gy.-blk. to blk., fis., sl. slty.

Oread Ls. Fm.

1430-34 Ls., brn.-gy. to gn.-gy., f. xl., Crin., Brac., Bry., Echin., Fus.

1434-48 Sh., dk. gy. to gy.-blk., sl. slty., mica., Brac., Crin., pt. pyr. (Heebner Sh. Mbr.)

1448-52 Ls., lt. brn. to brn.-gy. to brn.-blk., f. xl., Fus., Crin., Brac., pt. pyr.

1452-55 Sh., gn.-gy., slty., mica., hd.

1455-62 Ss., gn.-gy., v. f. gr. to sltst., dol. cmt., pt. calc.

1462-65 Sh., as 2nd abv. / scat. frag. of ls. (prob. cav.)

1465-68 Ss., as 2nd abv.

1468-70 Sh., as 2nd abv.

1470-80 Sh. and mdst., intbd.; sh., m. gy.; mdst., gy.-red, calc.

1480-82 Ls., dk. yel.-orng., arg.

1482-90 Sh., m. gy., hd., slty., mica.; and mdst., gy.-red, intbd.

1490-1500 Sh., gn.-gy., hd., slty., mica., carb.; and ss., lt. gn.-gy., v. f. gr., intbd.

1500-22 Ls., v. lt. gy. to lt. gn.-gy., f. xl., Crin., Brac., Bry., Gast., Fus., pt. arg. / a m. gy. sh. brk. in lwr. pt.

Lawrence Fm.

1522-30 Sh., m. gy., slty., mica., carb., mdst., gy.-red, intbd.

1530-40 Ls., m. gy., f. xl., Crin., Brac., arg.

1540-47 Sh. and mdst., intbd., as 2nd abv.

1547-51 Ls., as 2nd abv. (Amazonia Ls. Mbr., 1530-1547)

1551-84 Sh. and mdst., sh., dk. gn.-gy.; and mdst., gy.-red, cly. to sl. slty., pt. fos. / Gast., scat. ls. frag. (prob. cav.), ss., v. f. gr., qtzs., lt. gn.-gy. intbd. at 1564-66, 1576-78, and 1580-81

1584-87 Ss., gn.-gy., f. to m. gr., qtzs., pt. calc., pt. dol. cmt.

1587-94 No samples.

1594-1605 Sh. and ss., intbd.; sh., gn.-gy., cly., xl., mica.; and ss., lt. gn.-gy., mica., calc. cmt.

1605-65 Sh., mdst., and ss., intbd.; sh., m. lt. gy. to dk. gn.-gy.; mdst., gy.-red, hd., cly. to slty., mica., pt. carb., pt. pyr., intbd. gn.-gy., v. f. gr. sd. in the sltst. in lwr. pt.

1665-67 No samples.

1667-70 Ss., as 1st abv.

1670-85 Sh., m. gy., hd., slty., mica.

1685-89 No samples.

- 1689-1743 Sh., sltst., and mdst., intbd.; sh., m. dk. gn. to gn.-gy. to dk. gn.-gy.; and sltst., m. dk. gy. to gn.-gy., mica., pt. carb.
- 1698-1702 Gy.-red mdst.
- 1702-09 Gy.-red mdst., pt. pyr.
- 1715-20 Sltst., calc.
- 1720-36 Gy.-red mdst., a few scat. frag. of fos., v. lt. gy. ls. and brn. cht.
- 1736-43 Crin.
- 1743-44 Sh., gy.-blk., fis., sl. calc.
- 1744-50 Ls., lt. brn.-gy., f. xl., sft., mod. arg., fos. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1750-59 Sh., gy.-blk. to dk. gn.-gy., hd., slty., mica., pt. pyr., pt. carb., gy.-red mdst. strs.
- 1759-63 Ss., gn.-gy., qtzs., f. gr.
- 1763-65 Sh., gn.-gy., cly., mica.
- 1765-67 Ls., as 3rd abv. / Crin. (Westphalia Ls. Mbr.)
- 1767-94 Sh. and ss., intbd.; sh., m. dk. gy., slty., mica., pt. carb.; and ss., gn.-gy., pyr., pt. carb.
- 1794-95 Coal, shy.
- 1795-1810 Sh. and ss., intbd.; as 2nd abv.
- 1810-14 Ls., olv. gy. and lt. brn., f. xl., fos.
- 1814-28 Sh. and ss. to sltst., intbd., sh., dk. gn.-gy., pt. carb.; ss., gn.-gy. to lt. brn., v. f. gr. to sltst., qtzs., mica.
- 1828-33 Ls., as 2nd abv., Crin.
- 1833-48 Sh. and ss., intbd., as 2nd abv.
- 1848-58 Ss., gn.-gy., v. f. to f. gr., qtzs., mica., pt. dol. cmt., pt. calc.
- 1858-60 Sh., dk. gy., hd., slty., mica.
- 1860-64 Ss., as 2nd abv.
- 1864-77 Sh., m. gy., hd., slty., mica.
- 1877-80 Ss., as 4th abv.
- 1880-1920 Sh. and mdst., intbd., sh., m. gy.; and mdst., gy.-red, slty., mica., pt. pyr. / Crin., Brac. incl. Crurithyris planoconvexa, Plcy., Gast., Ost. incl. Bairdia
- 1920-37 Sh. and mdst., intbd.; sh., m. gy.; and mdst., gy.-red, slty., mica., hd., gn.-gy. sltst., intbd.
- 1920-25 A few scat. fos. (prob. cav.)
- 1937-40 No samples.
- 1940-47 Sh. and sltst., intbd.; sh., m. gy.; and sltst., lt. gn.-gy.
- 1947-50 Ss., olv. gy., v. f. gr., qtzs.,
- 1950-2016 Sh., mdst., and ss., intbd.; sh., m. gy.; mdst., gy.-red; and ss., v. lt. gy. to lt. gn.-gy., f. to m. gr., qtzs., mica., gr. ang. to sbrd. and elong. to eqnt.
- 1965-70 Dk. gn.-gy., slty., mica. sh.
- 1970-73 Gy.-red mdst.
- 1973-78 Ss., pt. carb.
- 1978-2016 Ss., gn.-gy., mdst., gy.-red, intbd.

Stanton Ls. Fm.

- 2016-20 Ls., gn.-gy. / brn.-gy. ool., f. xl. / some c. sl. calc.,
Crin., slty., mod. arg., ool. elip. to sph.
- 2020-40 Ss. and sh., intbd.; ss., gn.-gy., v. f. to f. gr., qtzs.,
dol. cmt., pt. calc., pt. carb.; and sh., dk. gn.-gy.,
slty., mica.
- 2035-40 Sh., pt. carb.

LOG 25 (See Plate 8, Well 18)

EARL F. WAKEFIELD

NO. 1 KNAPP

Near SW cor. NW $\frac{1}{4}$ sec. 2, T. 34 S., R. 5 E.

Cowley County, Kansas

Altitude: 1227 feet

Footage described: 1505- to 2165-foot depth

Kanwaka Sh. Fm.

- 1505-20 Sh. to shy. ls., m. gy., sl. slty., calc., hd.
- 1520-25 Ls., v. lt. gy. to lt. brn.-gy., f. xl., Fus. and Crin.
(?Clay Creek Ls. Mbr.)
- 1525-44 Prob. m. gy. sh. throughout, not much smpl. in upper pt.

Oread Ls. Fm.

- 1544-61 Sh., m. gy., hd., slty., mica., calc.
- 1544-50 Ls., lt. gy. to gn.-gy. to lt. brn.-gy., f. xl.,
Brac., Bry., Crin. and Fus.
- 1550-61 Ls., m. lt. gy. to m. dk. gy., f. xl., Brac. and
Crin., sl. arg.
- 1561-76 Sh., m. gy. to m. dk. gy., cly., calc., fos. (Heebner Sh.
Mbr.)
- 1576-79 Ls., dk. gy., f. xl., Crin. and Bry.
- 1579-1607 Sh., m. gy., cly. to sl. slty., calc., / red. sh., v. f. gr.
ss., and v. th. ls. intbd.
- 1607-13 Ss., gy.-orng. pk to lt. brn., f. gr. qtzs., sbang. to sbrd.,
mica., dol. cmt.
- 1613-19 Sh., m. lt. gy. and pale red.-brn., sl. mica.
- 1619-22 Ls., lt. brn.-gy., sd.-size carb. particles, Crin. and Bry.
- 1622-46 Sh., as 2nd abv. / v. f. gr. ss. intbd.
- 1646-54 Ls., lt. gy. to lt. brn.-gy., f. xl., Crin. and Bry.

Lawrence Fm.

- 1654-1727 Sh., m. lt. gy., hd., sl. slty., mica. / pale red.-brn. sh.
and ls. intbd., pt. calc.
- 1727-34 Ss., gy. to lt. gn.-gy., v. f. to f. gr., qtzs., mica.
- 1734-1861 Sh., m. gy., hd., slty., mica.
- 1750-60 Intbd. red. sh.
- 1760-70 Intbd. calc. sltst. bd.
- 1770-85 Intbd. gy.-red mdst., carb.
- 1800-15 Intbd. gy. mdst. and calc. sltst.
- 1815-45 Intbd. olv. gy. sh.
- 1845-61 M. gy. sh.
- 1861-64 Ls., lt. gy. to gn.-gy., Brac. and Crin., sdy. (Haskell Ls.
Mbr.)

Stranger Fm.

- 1864-80 Sh., dk. gn.-gy., hd., mica., calc., slty., pyr., pt. carb.
 1880-1920 Ss., lt. gn.-gy., v. f. gr., mica., carb. strcs., dol. cmt.
 1920-24 Sh., gn.-gy., fis., cly., sl. slty.
 1924-36 Ss., f. to c. gr., ang. to sbrd., elong. to eqnt. gr.
 1936-38 Coal, shy.
 1938-45 Sh., dk. gn.-gy., slty., mica., plant fos.
 1945-55 Ss., as 3rd abv.
 1955-57 Coal, shy.
 1957-70 Sh. or mdst., gn.-gy., cly.
 1970-72 Ls., gn.-gy. to lt. brn.-gy., sdy., Crin.
 1972-2007 Ss., gn.-gy., v. f. gr. to sltst., calc. / dk. gn.-gy. sh.
 brks.
 2007-20 Sh., m. lt. gy. to dk. gn.-gy., cly., mica., carb., fos. /
 plant remains
 2020-30 Ss., gn.-gy., f. gr., carb., dol. cmt.
 2030-56 Sh., gn.-gy., carb., cly., fos. / plant remains
 2056-65 Ss., lt. gn.-gy. to f. gr., qtzs., carb.
 2065-66 Coal, shy.
 2066-70 Sh., as 3rd abv.
 2070-97 Ss., as 3rd abv., mica.
 2097-2103 Sh., m. gy., slty., mica., carb.
 2103-20 Ss., as 2nd abv.
 2120-33 Sh., m. lt. gy., sl. slty., mica.

Stanton Ls. Fm.

- 2133-37 Ls., brn.-gy., f. to m. xl., Crin., sdy.
 2137-39 Sh., m. dk. gy., sl. slty. to cly., pt. calc.
 2139-50 Ss., v. lt. gy. to lt. gn.-gy., f. to m. gr., qtzs., sbang.
 to sbrd. and elong. to eqnt., dol. cmt.
 2150-53 Sh., as 2nd abv.
 2153-62 Ss., as 2nd abv.
 2162-65 Sh., dk. gy., slty., mica., hd.

LOG 26 (See Plate 9, Well 5)

LADD AND OTHERS

NO. 1 ACHTEN

Near cen. S $\frac{1}{2}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 12, T. 4 S., R. 14 E.

Nemaha County, Kansas

Altitude: 1165 feet

Footage described: 954- to 1250-foot depth

?Kanwaka Sh. Fm.

- 945-54 Sh., gn.-gy., slty., mica.
 954-1000 No samples.

Oread Ls. Fm.

- 1000-12 Ls., lt. gn.-gy., Crin. and Brac.; and sh., m. gy. to lt.
 gn.-gy., calc., intbd.
 1012-20 Ls., m. gy. to lt. gn.-gy., mod. arg., pt. sft., spr. ang.
 frag. of gn.-gy., fos. cht., Brac. and Crin.

- 1020-23 Sh., m. gy., cly., calc., Crin. and Brac.
 1023-33 Sh., olv. gy., fis., cly. to sl. slty., mica.; and ls.,
 lt. gn.-gy., mod. arg., fos., intbd.
 1033-38 Sh., m. gy. to gy.-blk., fis., mod. calc. (Heebner Sh.
 Mbr.)
 1038-40 Ls., m. gy. mot. gy.-blk., f. xl., hd., Crin., Brac. and
 Gast.
 1040-46 Sh., m. gy., cly., sl. mica.; and sltst., lt. gn.-gy., mica.,
 calc., Brac. and Crin., intbd.
 1046-48 Ls., slty., fos.
 Stranger-Lawrence Fm.
 1048-50 Sltst., as 2nd abv.
 1050-56 No samples.
 1056-60 Sltst., lt. gn.-gy., mica., calc.; and sh., m. gy., cly.
 to slty., mica., intbd.
 1060-66 Mdst., gn.-gy. and gy.-red intbd., pt. stn. brn.-gy., cly.,
 sl. slty., mica.
 1066-80 No samples.
 1080-1100 Sh., m. gy. to olv.-gy., fis., cly. to sl. slty., sl. mica.;
 and sltst., lt. gn.-gy., mica., carb., calc., intbd.
 1100-04 Sh., olv.-gy., fis., cly., sl. mica.
 1104-10 Ls., brn.-gy., calc., sl. carb., abnt. fos. / Crin. and
 Brac.
 1110-20 Sh., as 2nd abv.
 1120-28 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., gr. sbang. to
 sbrd. and eqnt., dol. cmt.
 1128-32 Mdst., olv.-gy. and gy.-red intbd., cly., sl. slty., mica.,
 calc.
 1132-36 Ss., as 2nd abv., carb.
 1136-42 Sh., olv.-gy., mica., sl. slty., sl. calc., carb.
 1142-45 Sh., as 1st abv., and gy.-red mdst. intbd.
 1145-61 Ss., v. lt. gy. to lt. gn.-gy., qtzs., v. f. gr., mica.,
 fr., gr. sbang. to sbrd. and elong. to eqnt.
 1150-55 Gn.-gy. and gy.-red mdst. intbd.
 1161-63 Sh., m. gy., fis., cly., calc., Crin. and Bry.
 1163-65 Ls., lt. gn.-gy. to brn.-gy., f. xl., Crin. and Brac.
 1165-95 No samples.
 1195-1210 Sh., m. gy. to olv.-gy., fis. to cly., sl. slty., mica.
 Stanton Ls. Fm.
 1210-34 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
 arg., pt. pyr., Crin., Brac., Echin. spines, and Fus.
 1234-36 Sh., as 2nd abv.
 1236-38 Ls., as 2nd abv.
 1238-43 Sh., gy.-blk., fis., cly. to sl. slty., sl. mica.
 1243-45 Ls., m. gy. to brn.-gy., f. xl., / abnt. c. xl. calc., mod.
 arg., fos.
 Vilas Sh. Fm. top
 1245-47 Sh., m. gy., fis., cly., sl. mica., slty.
 1247-50 Ls., as 6th abv.

LOG 27 (See Plate 9, Well 15)

RAMSEY PETROLEUM

NO. 1 KAUL

SE cor. NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 2, T. 11 S., R. 11 E.

Wabaunsee County, Kansas

Altitude: 1115 feet

Footage described: 900- to 1250-foot depth

Oread Ls. Fm.

- 900-05 Sh., olv. gy., fis., cly. to sl. slty., mica., mod. calc.
- 905-28 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sl. slty., Bry., Crin., Ost., Brac.
- 910-15 Pt. mot. m. lt. gy. to dk. gy.
- 910-25 Scat. ang. frag., gn.-gy., fos. cht., pt. pyr., pt. mod. arg.
- 925-28 Pt. mod. arg. to slty.
- 928-32 Sh., olv. gy., fis., cly. to slty., mica., calc.
- 932-36 Sh., gy.-blk., fis., cly., mica. (Heebner Sh. Mbr., 928-936)
- 936-38 Ls., gn.-gy., pt. mot. gy.-blk., f. xl., hd. Crin., Brac.
- 938-42 Mdst., gn.-gy., calc.
- 942-65 Ls., v. lt. gy. to brn.-gy., f. xl., sft., sl. arg., abnt. Crin., Brac. from 955-960; pt. slty. / med. dk. gy. calc. sh. brk. from 960-965.

Lawrence Fm.

- 965-70 Sh., m. dk. gy. to brn.-gy., fis., cly. to sl. slty., mica., cav. of 1st abv.
- 970-75 Ss., v. lt. gy., v. f. gr. to sltst., qtzs., mica., mod. calc., spr. ls. frag. (prob. cav.)
- 975-80 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. arg., slty., abnt. Fus., Crin. (Amazonia Ls. Mbr.)
- 980-1000 Ss., v. lt. gy. to lt. gn.-gy., lt. brn.-gy., v. f. gr. sltst., qtzs., mica., pt. calc.
- 1000-10 No samples.
- 1010-30 Ss., as 2nd abv., intbd. brn.-gy., v. f. xl., fos. ls.
- 1030-40 Ss., as 4th abv., pt. sl. calc., spr. ls. frag. (prob. cav.)
- 1040-60 Mdst. and sh., olv. gy. to dk. gn.-gy., shy. ls., pt. fos., pnt. fos.
- 1055-60 Intbd. ss., as 5th abv.
- 1060-70 Sh. and sltst. intbd., gn.-gy., pt. calc.
- 1070-75 Ls., lt. gy. to v. lt. gn.-gy., f. xl., pt. mod. arg. to slty., Crin., Brac. incl. Crurithyris planoconvexa, Rhipidomella carbonaria (?Cass Ls.)
- 1075-80 Intbd. ls. and sh., v. ltl. spl. (Haskell Ls. Mbr.)

Stranger Fm.

- 1080-85 Intbd. sh. and sltst., v. ltl. spl.
- 1085-90 Sh., m. gy. to gn.-gy., fis., slty. to cly., mica.; lt. gn.-gy. sltst., pt. carb.

- 1090-95 Sh., as 1st abv., intbd. ss., lt. gn.-gy., pt. stn. yel.-brn., v. f. gr., qtzs., mica.
- 1095-1154 Ss., v. lt. gy., v. f. gr., qtzs., fri., sbang. to sbrd., mica.
- 1100-05 Pt. stn. yel.-brn.
- 1105-10 Gn.-gy. fis., cly. to sl. slty., mica., sh. brks.
- 1136-50 Ls., lt. brn.-gy., v. f. xl., fos.; and sh., m. gy., fis., cly. to slty., mica., intbd. (Iatan Ls. Mbr., 1136-1146)
- 1154-69 Sh., m. gy. to gn.-gy., fis., cly. to sl. slty., mica., spr. ss. frag. (prob. cav.)
- 1165-69 Intbd. gy.-red mdst.
- Stanton Ls. Fm.
- 1169-71 Ls., lt. gn.-gy., f. xl., Crin.
- 1171-74 Ss., lt. brn., v. f. gr., qtzs., mica., pt. calc.
- 1174-85 Sh., as 3rd abv.
- 1185-1203 Ls., v. lt. gy. to lt. gn.-gy., v. f. xl., Crin., Brac. / m. gy. fis., cly., calc. sh. brks.
- 1203-07 Sh., gn.-gy. and gy.-blk., fis., cly., mica., pt. calc.
- 1207-10 Ls., m. gy. to gn.-gy., f. xl., pt. sft. and mod. arg., Crin., Brac.
- Vilas Sh. Fm. top
- 1210-24 Sh., as 7th abv.
- 1224-40 Ls., gn.-gy., mot. gy.-blk. and brn.-gy., f. xl., pt. sft. and mod., Crin., Brac. / sh. brks., see 4th abv.
- 1240-45 Ls., gn.-gy., slty., and calc. sltst., intbd.
- 1245-50 Ls., as 2nd abv.

LOG 28 (See Plate 9, Well 18)

Also shown as Plate 5, Well 12 and described as Log 13.

LOG 29 (See Plate 9, Well 35)

R. J. WIXSON AND OTHERS

NO. 1 DOWNING

NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 10, T. 18 S., R. 10 E.

Lyon County, Kansas

Altitude: 1150 feet

Footage described: 850- to 1254-foot depth

Kanwaka Sh. Fm.

850-65 Sltst., gn.-gy., mica., carb., dol. cmt., scat. ls. (prob. cav.)

858-65 Intbd., v. f. gr. ss.

Oread Ls. Fm.

865-90 Ls., lt. gn.-gy., pt. mot. gy.-blk., f. xl., pt. sft. and mod. arg., Brac., Bry., Fus., Crin.

880-90 Calc. sh. pts.

890-95 Sh., gn.-gy., and gy.-blk., fis., cly. to sl. slty., sl. mica. (Heebner Sh. Mbr.)

- 895-97 Ls., gn.-gy., mot. gy.-blk., hd. v. f. xl., Fus., Brac.,
Bry.
- 897-903 Sh., gn.-gy., fis., cly. to slty., mica., calc.
- 903-20 Ls., v. lt. gy., f. xl., Crin., Brac.
- 910-20 Intbd. gn.-gy. sh.
- Lawrence Fm.
- 920-30 Sltst., to v. f. gr. ss., gn.-gy., qtzs., mica., carb., dol.
cmt., pt. fos. / Brac., Plcy., Gast.
- 930-43 Mdst., gn.-gy., cly., sl. mica., calc.
- 943-60 Ls., lt. gn.-gy., to lt. brn.-gy., arg. to slty., Crin.,
Brac.; sltst., as 2nd abv.; and sh., gn.-gy., fis.,
cly. to slty., mica. intbd. (Amazonia Ls. Mbr., 943-956)
- 960-64 Sh., m. gy., fis., cly. to sl. slty., mica., carb. / a th.
coal str.
- 964-1008 Sltst. to v. f. gr. ss., lt. gn.-gy., qtzs., dol. cmt.,
carb.; and sh., gn.-gy., fis., slty., mica., carb. intbd.
- 996-999 No samples.
- 1008-18 Sh., gn.-gy. to olv. gy., fis., mica., carb.; and sltst.,
gn.-gy., mica., carb., intbd.
- 1018-52 Sh., as 1st abv.
- 1052-56 Ls., gn.-gy. to lt. brn.-gy., v. f. xl., hd., Fus., Crin.,
Brac. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1056-60 Mdst., gn.-gy., cly., sl. mica., calc., pt. fos. / Crin.
- 1060-70 Ss., v. f. gr. to sltst., lt. gn.-gy. to gn.-gy., dol. cmt.,
carb.
- 1070-72 Sltst. to v. f. gr. ss., lt. gn.-gy., qtzs., mica., dol.
cmt.
- 1072-80 Sh., olv. gy., fis., cly. to sl. slty., mica., pt. carb.
- 1080-84 Ls., lt. gn.-gy., sft. and arg., Crin., Brac. (Westphalia
Ls. Mbr.)
- 1084-94 Sh., as 2nd abv.
- 1094-1100 Sltst., lt. gy., qtzs., mica., carb., sil. cmt.
- 1100-46 Sh., gy., fis., cly. to slty., mica., pt. carb.; and ss.,
lt. gy. to gn.-gy., to brn.-gy., v. f. gr., qtzs., mica.,
carb., intbd.
- 1146-91 Sh., gn.-gy. to olv. gy., cly. to sl. slty., sl. mica.,
pt. sl. carb.; and sltst., lt. gn.-gy., qtzs., mica.,
carb., intbd.
- 1158-70 No samples.
- Stanton Ls. Fm.
- 1191-92 Ls., lt. brn.-gy., f. xl., slty. to sdy., Crin., Brac.
- 1192-1200 Ss., lt. gn.-gy., pt. mot. lt. brn.-gy., v. f. gr., qtzs.,
mica., pt. dol. cmt., pt. pyr., abnt. gn. min., gr.
sbang. to sbrd. and elong. to eqnt.
- 1200-01 Sh., olv. gy., fis., cly., mica.
- 1201-25 Ls., v. lt. gy. to lt. olv. gy., f. xl., pt. sft. and sl.
arg., Brac., Crin., Foram.

- 1225-30 Sh., olv. gy. and gy.-blk., fis., cly., gy.-blk. pt. / calc. str.
- 1230-42 Ls., lt. gn.-gy., f. xl., pt. sft. and mod. arg., Brac., Crin., Fus., spr. cav. of 1st abv.
- Vilas Sh. Fm. top
- 1242-48 Sh., m. gy. to gn.-gy. to olv. gy., cly. to sl. slty., sl. mica., sl. carb., spr. cav. of 1st and 2nd abv.
- 1248-54 Ls., lt. gn.-gy., pt. mot. gy.-blk., pt. sft. and arg., Crin., Brac.

LOG 30 (See Plate 9, Well 39)

BIRD, HANLEY AND SHEEDY

NO. 1 WELCH

Near NE cor. SE $\frac{1}{4}$ sec. 30, T. 20 S., R. 10 E.

Lyon County, Kansas

Altitude: 1419 feet

Footage described: 1085- to 1503-foot depth

Kanwaka Sh. Fm.

- 1085-88 Ls., lt. gy. to lt. gn.-gy. to gn.-gy., slty., Fus., Crin. and Brac. (?Clay Creek Ls. Mbr.)
- 1088-97 Sh. and sltst., intbd.; sltst., lt. gy. to lt. gn.-gy. to gn.-gy.; sh., m. gy., fis., slty., mica.

Oread Ls. Fm.

- 1097-1116 Ls., as 2nd abv.
- 1100-16 Ls., v. lt. gy. to lt. gn.-gy.
- 1116-18 Sh., gn.-gy., fis., cly., mica.
- 1118-22 Ls., as 2nd abv.
- 1122-31 Sh., dk. gy. to gy.-blk., fis., cly. to sl. slty., sl. mica. (Heebner Sh. Mbr.)
- 1131-33 Ls., lt. gn.-gy. to gn.-gy., pt. mot. gy.-blk., f. xl., Crin. and Brac.
- 1133-47 Mdst., gn.-gy., cly., sl. slty., mica., calc., spr. cav. of 1st and 2nd abv.
- 1147-50 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., sft., arg., fos.
- 1150-53 Sh., m. gy. to gn.-gy., fis., cly. to slty., mod. mica., calc.
- 1153-64 Ls., v. lt. gy. to lt. gn.-gy., f. xl., mod. hd., Crin., Brac., Fus. and Echin. spines

Lawrence Fm.

- 1164-66 Mdst., as 4th abv.
- 1166-70 Ss., lt. gn.-gy., v. f. gr. qtzs., mica., sil. cmt.
- 1170-72 Mdst., as 2nd abv.
- 1172-79 Ls., gn.-gy. to brn.-gy., f. xl., hd., / c. xl. calc., fos., pt. pyr.; abnt. fos. / Brac., Crin., Plcy., arg. to slty.
- 1179-81 Ss., lt. gn.-gy., v. f. gr. to sltst., mica., calc., pt. fos. / productid spines, pt. mod. carb., abnt. gn. min.
- 1181-84 Sh., m. gy., fis., cly. to slty., mod. mica., mod. calc.
- 1184-86 Ls., as 3rd abv. (Amazonia Ls. Mbr., 1172-1186)

- 1186-89 Ss., as 2nd abv.
 1189-95 Sh., gn.-gy. to olv. gy., fis., cly., sl. mica.
 1195-1200 Sh., as 1st abv. / intbd. th. coal str.
 1200-12 Sltst. and slty. sh., intbd.; sltst., lt. gn.-gy., mica., carb., qtzs., dol. cmt.; sh., m. gy. to gn.-gy., cly. to slty., mica., fis.; spr. frag. of coal (prob. cav.)
 1212-20 Ss., gn.-gy., v. f. gr. qtzs., mica., carb., dol. cmt.
 1220-44 Sltst. and slty. sh., intbd.; sltst., lt. gn.-gy., qtzs., mica., carb.; sh., m. gy., fis., cly. to slty., mica.
 1237-44 Sh., olv. gy.
 1244-1323 Sh., olv. gy., cly. to sl. slty., pt. sl. carb., sl. mica.
 1323-26 Ls., gn.-gy., f. xl., hd., sl. arg., Brac. and Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
 1326-37 Sh. and sltst., intbd.; sltst., v. lt. gy. to lt. gn.-gy., qtzs., mica., sl. carb.; sh., m. gy. to gn.-gy., slty., mica.
 1337-48 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., carb. / a th. coal str.
 1348-70 Sltst., ss., and slty. sh., intbd.; as 1st and 2nd abv.
 1370-77 Sh., olv. gy., fis., cly. to slty., mica., hd., pt. mod. carb.
 1377-82 No samples.
 1382-1440 Sh., as 2nd abv.
- Stanton Ls. Fm.
 1440-44 Ls., lt. brn.-gy., pt. mot. gy.-blk., pt. mod. arg. to slty., f. xl., hd., Brac. incl. Rhipidomella carbonaria and productid spines, Bry., Crin. and Ost.
 1444-46 Sh., olv. gy., fis., cly., mica., calc.
 1446-83 Ls., wh. to v. lt. gy., v. f. xl. abnt. c. xl. calc., Crin., Brac. and Bry.
 1457-70 M. gy. sh. pts.
 1483-86 Sh., gy.-blk., fis., cly., calc. str.
 1486-97 Ls., gn.-gy., as 2nd abv. Spr. cav. of 1st abv.
- Vilas Sh. Fm.
 1497-1503 Sh., olv. gy., fis., cly. to sl. slty., sl. mica.
- LOG 31 (See Plate 9, Well 47)
 PHILLIPS PETROLEUM COMPANY
 NO. 1 ZIMMERMAN
 SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 20, T. 23 S., R. 9 E.
 Greenwood County, Kansas
 Footage described: 1250- to 1755-foot depth
- Oread Ls. Fm.
 1254-75 Ls., v. lt. gy. to gn.-gy., f. xl., pt. sft. and mod. arg., Crin. / spr. sh. frag. (prob. cav.)
 1275-79 Mdst., gn.-gy., cly., calc.
 1279-85 Sh., gy.-blk., fis., cly., mica. (Heebner Sh. Mbr., 1275-1285)
 1285-87 Ls., gn.-gy., hd., v. f. gr., fos.

- 1287-95 Mdst., as 3rd abv., pt. fos. / Brac., cav. of 1st and 2nd abv.
- 1295-1306 Ls., v. lt. gy., f. xl., Crin. and Brac. / th. olv. gy., calc. sh. brk.
- Lawrence Fm.
- 1306-19 Mdst., m. gy., cly., sl. mica.
- 1319-38 Sh., gn.-gy., fis., cly., calc.; and sltst., intbd. lt. gn.-gy., mica., carb., calc. / th. gn.-gy. to dk. gn.-gy., v. f. xl., fos. ls. in the 1325-1335 int.
- 1338-43 Ls., gn.-gy. and brn.-gy., f. xl., Crin. (Amazonia Ls. Mbr.)
- 1343-61 Sh., gn.-gy., fis. to plty., slty., cly., mica., pt. mod. calc. / carb. sh. and a th. shy. coal in the 1348-1354 int. and intbd. lt. gn.-gy. sltst. in the 1354-1361 int.
- 1361-69 Sltst. to v. f. gr. ss., qtzs., mica., pt. carb.
- 1369-76 Ss., lt. gn.-gy., v. f. gr. / intbd. gn.-gy., slty., mica. sh. pt.
- 1376-82 Ss. and sltst. intbd., as 1st and 2nd abv.
- 1382-1405 Intbd. olv. gy., cly., mica. sh. and olv. gy. and brn.-gy., cly. to mod. slty., mica., carb. sh.
- 1398-1405 Intbd. lt. gn.-gy. calc. sltst.
- 1405-07 No samples.
- 1407-83 Sh. to mdst., brn.-gy., cly., mica., pt. carb.
- 1421-30 Sh., brn.-gy. to dk. gn.-gy.
- 1438-45 Sh., brn.-gy. to dk. olv. gy.
- 1483-92 Sh., dk. gn.-gy., fis., cly., sl. mica., sl. slty.
- 1492-93 Sh., gy.-blk., fis., cly., sl. mica.
- 1493-96 Ls., lt. brn.-gy. and lt. gn.-gy., f. xl., pt. sl. slty., pt. sl. arg., fos. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1496-1500 Sltst. to v. f. gr. ss., lt. gn.-gy. to lt. brn.-gy., mica., calc.
- 1500-05 Sh., gn.-gy. to dk. gn.-gy., as 4th abv.
- 1505-17 Ss., gn.-gy. and brn.-gy., f. to m. gr., qtzs., mica., sil. cmt., / a m. gy., slty. sh. str. in the 1511-17 int.
- 1517-66 Ss., v. f. gr. to m. gr., as 1st abv., / carb. sh. brks. and spr. ls. frag. (prob. cav.) in the 1524-60 int.
- 1566-68 Sh., gn.-gy., cly. to slty., mica.; and ls., gn.-gy., v. f. xl., fos., intbd.
- 1568-83 Sh. to mdst., gn.-gy., cly., calc.
- 1580-83 Intbd. ls., as 2nd abv.
- 1583-87 Ss., as 3rd abv.
- 1587-91 Sh., dk. gn.-gy., fis., cly., mica.; and mdst., as 2nd abv.
- 1591-92 Ss., as 5th abv.
- 1592-95 Sh., lt. gn.-gy., cly. to slty., mica.
- 1595-99 Sh. and mdst. intbd., as 3rd abv.
- Stanton Ls. Fm. top
- 1599-1605 Ls., lt. gn.-gy. and lt. brn.-gy., f. xl. / c. xl. calc., pt. sft., ool., fos.
- 1605-07 Ls., gn.-gy., v. f. xl., fos.
- 1607-09 Sh., dk. gn.-gy., lmy.

- 1609-58 Ls., v. lt. gy. to gn.-gy., f. xl., pt. sft. and sl. arg., fos.
 1614-22 Lt. gn.-gy. to lt. brn.-gy., Crin.
 1622-28 V. lt. gy. to lt. gn.-gy., hd., Crin.
 1628-35 Scat. ang. frag. dk. gn.-gy., fos. cht.
 1638-42 Dk. gn.-gy., fis., cly., mica., sh. brk.
 1642-50 Scat. ang. frag. dk. gn.-gy., fos. ch. / spr.
 sh. frag. (prob. cav.)
 1650-58 Dk. gn.-gy., fis., cly., mica., sh. brk.
 1658-61 Sh., m. to dk. gy., fis., cly. to sl. slty., sl. mica.
 1661-70 Ls., as 2nd abv.
 1670-73 Sh., dk. gn.-gy., fis., cly., mica.
 1673-1705 Ls., wh. to lt. gn.-gy. to lt. brn.-gy., f. xl. / abnt.
 c. xl. calc., fos.
 1679-91 Crin., Fus., and Brac.
 1691-1705 Scat. ang. frag. lt. gn.-gy. fos. cht. and a
 dk. gn.-gy., fis., cly. sh. brk.
 1705-20 Sltst., lt. gn.-gy., mica., carb., calc.
 1712-20 A th. slty. ls.
 1720-37 Ls., gn.-gy. and lt. brn.-gy., f. xl., fos.; and sh.,
 gn.-gy., fis., cly., calc. intbd.
 1737-55 Sh., gn.-gy., plty., cly., sl. mica., calc.

LOG 32 (See Plate 9, Well 50)

PHILLIPS PETROLEUM COMPANY

NO. 7A AAGARD

Gen. SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 14, T. 24 S., R. 9 E.

Greenwood County, Kansas

Footage described: 780- to 1355-foot depth

?Kanwaka Sh. Fm.

- 780-85 Sh., m. dk. gy., fis., cly. to slty., mica., pt. calc.,
 spr. ls. frag. (prob. cav.)

Oread Ls. Fm.

- 785-87 Ls., dk. gy. and dk. gn.-gy., mot. gy.-blk., f. xl., arg.,
 fos.
 787-822 Ls., lt. gn.-gy., f. xl., pt. sft. and pt. arg., pt. pyr.,
 Crin. and Brac.
 790-95 Intbd. gy.-blk. ls., and gy.-blk. fos., sh. pts.
 795-800 Intbd. m. dk. gy. to dk. gn.-gy., ls. / sh. pts.
 806-15 A few scat. frag. of ang. gn.-gy. fos. cht.
 815-20 Dk. gn.-gy., fis., cly. to mica., sh. brk.
 822-24 Sh., gy.-blk., fis., sl. slty., sl. mica. (Heebner Sh. Mbr.)
 824-26 Ls., gn.-gy., v. f. xl., hd., fos.
 826-28 Mdst., gn.-gy., cly., sl. mica., calc.
 828-46 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
 arg., Crin., Brac.
 833-40 Cav. of 1st and 2nd abv.
 840-45 Cav. of 1st and 2nd abv., / a th. gn.-gy. fis., cly.,
 sl. mica., fos. sh. brk.

Lawrence Fm.

- 846-48 Sltst., lt. gn.-gy., qtzs., mica., sil. cmt., pt. fos.
 848-50 Sh., dk. gn-gy., slty. to cly., mica., pt. carb.
 850-85 Sh., m. gy. to m. dk. gy., cly. to sl. slty., mica.
 850-55 A th. coal; a few scat. ls. frag. (prob. cav.)
 855-85 Sh., carb. / intbd. gn.-gy. and brn.-gy., f. xl.,
 ls., / Crin. and lt. gn.-gy., qtzs., mica.,
 calc., sltst., pt. pyr. (Amazonia Ls. Mbr., 868-870)
 875-80 A th. coal
 880-85 Coal frag. (prob. cav.)
 885-950 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr., qtzs., mica.,
 fri., sbang. to sbrd. and elong. to eqnt.; cav. of 1st
 abv.
 915-50 M. gy. and gn.-gy., fis., cly. and sl. slty., mica.,
 sh. pts. or brks.
 930-50 Sh. pts. carb.
 950-58 Sh., dk. gn.-gy.
 958-74 No samples.
 974-76 Sh., as 2nd abv.
 976-82 Ss., gn.-gy., v. f. gr., qtzs., mica., carb. cmt.
 982-1032 Sh., dk. gn.-gy., slty., mica., carb.
 990-95 Intbd. sltst.
 1005-10 Intbd. sltst.
 1010-32 Sh., olv. gy.
 1015-30 Intbd. sltst.
 1032-34 Sh., dk. gn.-gy., fis., cly., mica.
 1034-36 Ls., lt. brn.-gy., f. xl., pt. sft. and mod. arg., fos. /
 Crin. (Haskell Ls. Mbr.)

Stranger Fm.

- 1036-40 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., pt. / dol.
 cmt., spr. sh. frag. (prob. cav.)
 1040-65 Ss., v. lt. gy. to lt. gn.-gy., f. to m. gr.
 1057-65 Intbd. gn.-gy., slty. sh. and sltst.
 1065-75 Spr. sh. frag. (prob. cav.)
 1075-95 Ss., lt. gn.-gy. to stn. lt. brn.-gy., v. f. to m. gr.
 1095-1150 Ss., f. to v. f. gr., fri., sbang. to sbrd., eqnt.
 1125-30 Grs. stn. red.-brn.
 1137-45 Intbd. gn.-gy. sh. brks.
 1145-50 Ss., as 2nd abv.
 1150-51 Sh., m. gy. to dk. gn.-gy., slty., mica.
 1151-56 Ls., brn.-gy., f. xl., pt. mod. slty., Crin.
 1156-70 Ss., as 3rd abv.; a few scat. cav. of 1st abv.
 1170-77 Sh., m. dk. gy. to gn.-gy., fis., cly. to slty., mica.
 Stanton Ls. Fm. top
 1177-82 Ls., m. dk. gy., some frag. stn. yel.-brn. and v. f. xl.,
 pt. slty., pt. ool., fos.
 1182-95 Sltst. to ss., gn.-gy., qtzs., mica., calc.,
 1185-95 Intbd. slty. ls., as 2nd abv.

- 1195-1313 Ls., v. lt. gy. to lt. gn.-gy., many frag. stn. yel.-brn.,
f. xl., / some c. xl., calc., Crin. and Brac.
1200-21 Scat. ang. frag., v. lt. gy. and lt. gn.-gy., fos.
cht.
1210-22 Carb., calc. sh. pts.
1237-54 Carb. calc. sh. pts.
1254-75 Abnt. c. xl. calc.
1275-80 Carb. sh. pts.
1280-85 Carb. sh. pts., fos. / Brac., Bry. and Ost.
1290-95 Th. gy.-blk., fis., sh. brk.
1295-1313 Carb. sh. pts., fos. / Brac., Bry., and Crin.;
ls., c. xl. calc., pt. pyr.
1313-17 Sh., m. gy., fis., cly. to slty., mica., calc.
1317-23 Ls., as 2nd abv., Crin.
1323-37 Sh., as 2nd abv., pt. pyr., a few scat. ls. frag. (prob. cav.)
1337-40 Ls., as 2nd abv.
1340-55 Sh., m. gy. to dk. gn.-gy., fis., slty., mica., calc.

LOG 33 (See Plate 9, Well 64)

ROTH AND FAUROT COMPANY

NO. 1 WILLIAM H. HARRIS

NE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 14, T. 27 S., R. 7 E.

Butler County, Kansas

Footage described: 1295- to 1715-foot depth

Kanwaka Sh. Fm.

- 1295-1308 Sh. to mdst., gn.-gy. to dk. gn.-gy., cly., sl. slty., mica.
1308-10 Ls., gn.-gy. to brn.-gy., f. xl., pt. mod. arg., Crin.
(?Clay Creek Ls. Mbr.)
1310-50 Sh., dk. gn.-gy., fis. to cly., hd., sl. mica., cly. to
slty.
1350-64 No samples.
1364-80 Sh., as 2nd abv.

Oread Ls. Fm.

- 1380-90 Ls., gn.-gy. to brn.-gy., f. xl., pt. sft. and mod. arg.,
Crin.
1390-93 Sh., dk. gn.-gy. and gy.-blk., fis., cly., sl. slty., mica.
(Heebner Sh. Mbr.)
1393-95 Ls., gn.-gy., v. f. xl., hd., fos.
1395-1408 Sh. and ss., intbd., sh., dk. gn.-gy., fis., cly.; ss., lt.
gn.-gy. to lt. brn.-gy., v. f. gr. to f. gr., qtzs.,
mica., dol. cmt., spr. cav. of 1st and 2nd abv.
1408-20 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and arg.,
fos.; / a gn.-gy., fis., cly., mica. sh. brk.

Lawrence Fm. (top within 1420-1430 depth interval)

- 1420-30 No samples.
1430-48 Sh. to mdst., gn.-gy., cly., mica., calc.
1448-54 Sltst. to v. f. gr. ss., lt. gn.-gy., qtzs., mica., pt. mod.
carb., pt. dol. cmt.

- 1454-66 Mdst., gn.-gy., cly., sl. mica., calc.
 1460-72 Ss., lt. gn.-gy. to lt. brn.-gy., v. f. gr., qtzs., mica.
 1472-78 Sh. and ls., intbd.; sh., dk. gn.-gy., fis., cly. to slty.,
 pt. mod. calc.; ls., brn.-gy., c. xl., abnt. Crin. and
 Brac. (Amazonia Ls. Mbr., 1474-1476)
 1478-82 Ss., as 2nd abv.
 1482-88 Sh., dk. gn.-gy. to gy-blk., fis., cly., coaly
 1488-95 Sltst. to v. f. gr. ss., as 6th abv.
 1495-1507 Ss., lt. gn.-gy., some qtz. gr. stn. red-brn., qtzs., mica.,
 carb., fri., v. f. gr., qtz. gr. sbang. to sbrd. and
 eqnt.
 1507-15 Sh., dk. gn.-gy., fis., cly., mica. / a lt. gn.-gy. arg.,
 fos. ls. intbd.
 1515-16 Coal, shy.
 1516-20 Sh., as 2nd abv.
 1520-60 Ss., as 2nd abv., spr. frag. of ls., coaly sh. (prob. cav.)
 1560-80 Sh. to mdst., gn.-gy., cly., sl. slty., sl. mica.
 1570-80 Intbd. lt. gn.-gy., sltst.
 1580-1603 No samples.
 1603-16 Sh. to mdst., as 2nd abv.
 1616-22 Ls., lt. gn.-gy., m. xl., pt. slty., pt. arg., ool., Crin.
 (Haskell Ls. Mbr.)
- Stranger Fm.
 1622-27 Sh., dk. gn.-gy., fis., cly., carb.
 1627-30 Ls., v. lt. gy. to lt. gn.-gy., pt. sft., mod. arg., Crin.,
 Bry., and Brac.
 1630-50 Ss., v. lt. gy., v. f. gr., qtzs., mica., fri., qtz. gr.
 sbang. to sbrd. and elong. to eqnt.
 1650-75 Ss. and sh., intbd., as 1st and 3rd abv.
 1675-1715 Sh., dk. gn.-gy., fis. to plty., cly. to sl. slty., sl. mica.,
 pt. mod. carb.
- Stanton Ls. Fm.
 1715-1900 Spl. intervals too lg. to log accurately; prob. mostly ls.

LOG 34 (See Plate 9, Well 68)

Also shown as Plate 7, Well 17 and described as Log 17.

LOG 35 (See Plate 9, Well 74)

BARNSDALL OIL COMPANY

NO. 1 J. A. SNODGRASS

Near NW cor. SE $\frac{1}{4}$ sec. 36, T. 30 S., R. 6 E.

Cowley County, Kansas

Altitude: 1409 feet

Footage described: 1400- to 1990-foot depth

Kanwaka Sh. Fm.

1400-06 Sh., dk. gn.-gy., cly. to sl. slty., sl. mica., calc.

Oread Ls. Fm.

1406-12 Ls., lt. gn.-gy., f. xl., hd., v. ltl. residue, Crin. and
 Brac.

- 1412-28 Sh., as 2nd abv., pt. fos. / Crin., Brac. incl. Crurithyris planoconvexa
- 1428-32 Ls., red.-brn., v. f. xl., hd., fos.
- 1432-52 Ls., lt. brn.-gy. to gn.-gy. to dk. gn.-gy., f. xl., pt. mod. arg. to slty., abnt. fos. / Crin., Bry., Fus., and Brac. incl. abnt. Crurithyris planoconvexa, / m. dk. gy. to dk. gn.-gy. (pt. gy.-blk.) fis., cly., fos., sh. pts. or brks.
- 1452-75 Mdst., gn.-gy. and gy.-red, intbd., cly. to sl. slty., sl. mica., pt. calc., spr. cav. of 1st abv.
- 1475-77 Sh., dk. gn.-gy. and gy.-blk., fis., cly., pt. calc., fos. (Heebner Sh. Mbr., 1455-1477)
- 1477-79 Ls., gn.-gy., v. f. xl., v. hd., v. ltl. residue, Fus., Crin., Brac.
- 1479-88 Mdst., as 3rd abv.
- 1488-90 Ls., lt. gn.-gy., fos.
- 1490-1510 Sh., ss., and mdst., intbd.; sh., gn.-gy., fis., cly. to slty., mica.; ss., v. f. to f. gr., qtzs., mica., qtz. gr. sbrd. to sbang. and elong. to eqnt.; mdst., gy.-red, calc.
- 1510-14 Ls., lt. gn.-gy., f. xl., fos.
- Lawrence Fm.
- 1514-25 Sh., m. gy., fis., cly., mica., calc.
- 1520-25 Ss., lt. gn.-gy., intbd.
- 1525-61 Sh. and ss. intbd., as 1st abv.
- 1561-71 Ls., v. lt. gy. to lt. gn.-gy., f. xl., hd., Crin. (Amazonia Ls. Mbr.)
- 1571-80 Sh., gn.-gy., fis., cly. to slty., mica.
- 1580-90 Sh. and ss. intbd.; sh., gn.-gy. to m. gy., fis., cly. to slty., mica.; ss., v. f. to m. gr., qtzs., mica., pt. carb., qtz. gr. sbrd. to sbang. and elong. to eqnt.
- 1590-1690 Sh. and ss. intbd., as 1st abv.; sh. pt. carb. / plant fos.
- 1600-10 A th. coal, shy.
- 1643-50 A th. coal, shy.
- 1690-1730 Sh., gn.-gy. and brn.-gy., fis., cly., mica., pt. calc., pt. fos. / Crin.
- 1730-37 Sh., dk. gn.-gy., fis., cly. to sl. slty., sl. mica.
- 1737-40 Sh., gy.-blk., fis. / calc. strs.
- 1740-42 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1742-85 Sh. and ss., intbd., as 3rd abv., sh. pt. carb.
- 1785-1805 Sh., gn.-gy. to dk. gn.-gy., fis., cly., mica., pt. carb. / plant fos.
- 1800-05 Intbd. ss., v. f. to f. gr., qtzs., mica.
- 1805-20 Sh., as 2nd abv.
- 1820-22 Ls., brn.-gy., v. f. xl., hd., fos.
- 1822-42 Sh. and ss., intbd., as 2nd and 3rd abv.

Stanton Ls. Fm. top

- 1842-49 Ls., brn.-gy. to gn.-gy., f. xl., mod. hd., pt. mod. arg. to slty., abnt. Crin.
- 1849-58 Sh., m. dk. gy. to dk. gn.-gy., fis., cly. to sl. slty., mica., pt. carb., pt. fos.
- 1858-64 Sh. and ss., intbd.; sh. contains plant fos.
- 1864-75 Ls., v. lt. gy. to m. dk. gy. and lt. to dk. gn.-gy., v. f. xl. and hd., Crin., Brac., / a th. intbd. sh. brk. as 2nd abv.
- 1875-1902 Ls., v. lt. gy. to lt. gn.-gy., f. xl., por., Crin., Fus., / fos. sh. brks.
- 1892-1902 Olv. gy. to dk. gn.-gy. sh. brk.
- 1902-07 Ls., v. lt. gy. to gn.-gy., v. f. xl., hd., Crin.
- 1907-38 Sh., gn.-gy. and dk. gn.-gy., fis., cly., mica., sl. slty., Crin. and plant fos.
- 1915-25 Lmy. sh. to shy. ls., Crin. and plant fos.
- 1938-42 Ls., gn.-gy., f. xl., arg., abnt. fos. / Crin., Brac., and Bry.
- 1942-67 Sh., as 2nd abv., dk. gn.-gy. to gy.-blk., pt. pyr.
- 1967-78 Ls., as 2nd abv.
- 1978-90 Sh., as 2nd abv.

LOG 36 (See Plate 9, Well 79)

PRAIRIE OIL AND GAS COMPANY

NO. 1 EWERS

NW $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 31, T. 31 S., R. 6 E.

Cowley County, Kansas

Footage described: 1600- to 2200-foot depth

Oread Ls. Fm.

- 1600-06 Ls., dk. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod. arg., / Crin. and Brac.
- 1606-10 Sh., dk. gn.-gy. and gy.-blk., fis. to plty., cly., mica., pt. fos., / Crin. and Brac. (Heebner Sh. Mbr.)
- 1610-12 Ls., brn.-gy., v. f. xl., v. hd., fos.
- 1612-15 Mdst., gn.-gy., cly., mica.
- 1615-38 Mdst., gy.-red and gn.-gy. intbd., cly., hd. / irreg. shaped calc. pel.
- 1625-35 Scat. cav. of 1st and 2nd abv.
- 1638-53 Sh., gn.-gy., fis., cly., calc., / Crin. and Brac. incl. Crurithyris planoconvexa, / a th. intbd. gy.-red to lt. brn.-gy., fos., ls.
- 1645-53 Intbd. mdst., as 2nd abv.
- 1653-57 Ls., lt. brn.-gy. to lt. gn.-gy., f. xl., pt. sft. and arg. to slty., Crin.
- 1657-62 Mdst., as 3rd abv.
- 1662-67 Ls., as 2nd abv.

Lawrence Fm.

- 1667-1705 Mdst., gn.-gy., cly., mica., pt. calc.
- 1705-10 No samples.

- 1710-30 Mdst. to sh., as 2nd abv. / intbd. gy.-red mdst. and lt. gn.-gy., carb., calc. sltst. to v. f. gr. ss.
- 1730-34 Sh., gn.-gy. to dk. gn.-gy., fis., cly., pt. calc.
- 1734-46 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., Brac., Crin. (Amazonia Ls. Mbr.)
- 1746-51 Sh., as 2nd abv.
- 1751-65 Ss., lt. gn.-gy. to stn. yel.-brn., qtzs., mica., dol. cmt.
1760-65 Ss., carb., gn.-gy., slty., mica., sh. brk.
- 1765-68 Sh., gn.-gy. to brn.-gy., cly. to slty., mica., spr. ls. frag. (prob. cav.)
- 1768-90 Sh. and ss., intbd.
- 1790-1868 Sh., as 6th abv.
1812-18 Carb. pts.
1850-68 Sh., dk. gn.-gy., pt. calc.
- 1868-71 Ls., gn.-gy. to brn.-gy., f. xl., pt. sl. arg., Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1871-92 Sh., gn.-gy., plty., cly., sl. mica.
- 1892-1907 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., mod. carb., sil. cmt.
- 1907-10 Sh., dk. gn.-gy., plty., cly., sl. mica.
- 1892-1907 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., mod. carb., sil. cmt.
- 1907-10 Sh., dk. gn.-gy., plty., cly. to slty., mica.
- 1910-35 Sh. and v. f. gr. ss. to sltst., intbd., as 1st and 2nd abv.
- 1935-74 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr. to f. gr., qtzs., mica., sil. cmt.
1950-70 V. f. qtz. gr., fri., sbang. to sbrd. and elong. to eqnt. / a th. m. dk. gy., slty. sh. pt.
- 1974-82 Sh., m. dk. gy., fis., cly., mica., carb.
- 1982-2052 Sh., gn.-gy. to dk. gn.-gy., fis., plty. to slty., pt. calc.
2040-50 Fos. / Crin., Gast., pt. pyr., a few scat. ang. frag. of red.-brn. cl.-fest.
- Stanton Ls. Fm. top
- 2052-65 Ls., gn.-gy. to lt. brn.-gy., f. xl., pt. mod. arg. to slty. / Brac. incl. Crurithyris planoconvexa, Crin.
- 2065-72 Sh., as 2nd abv.; pt. fos. / Crin.
- 2072-87 Ls., as 2nd abv., / abnt. c. xl., calc.
- 2087-91 Sh., as 4th abv.; fos. / Crin.
- 2091-2140 Ls., as 4th abv., some m. dk. gy. ls.
- 2140-60 Sh., gn.-gy. to dk. gn.-gy., plty., cly. to sl. mica., mid. calc.
- 2160-80 Sh., dk. gn.-gy. to gy.-blk., fis. to plty., cly. to slty., mica., pt. mod. calc., fos. / Brac. and Crin.
2170-80 Plcy.
- 2180-2200 As 1st abv. / ang. frag. of red.-brn. cl.-fest.

LOG 37 (See Plate 9, Well 83)

TEXAS COMPANY

NO. 1 N. CRANSTON

Near SE cor. SW $\frac{1}{4}$ sec. 19, T. 32 S., R. 6 E.

Cowley County, Kansas

Altitude: 1241 feet

Footage described: 1490- to 2150-foot depth

Oread Ls. Fm.

- 1490-97 Ls., lt. brn.-gy. to dk. gn.-gy., f. xl. / abnt. c. xl. calc., arg. to slty., abnt. fos. / Crin., Bry., Brac. incl. Crurithyris planoconvexa and Hustedia
- 1497-1531 Sh., dk. gn.-gy. to gy.-blk., fis., cly. to slty., calc., Crin. and Brac. (Heebner Sh. Mbr.)
- 1531-33 Ls., gn.-gy. to dk. gn.-gy. and brn.-gy., pt. mod. arg., f. xl., hd., Crin., Brac. and Fus.
- 1533-40 Mdst., gn.-gy. and gy.-red, cly., calc.
- 1540-50 Misplaced spl. of anhy.
- 1550-64 Mdst., as 2nd abv., spr. cav. of 3rd and 4th abv.
- 1564-70 Ls., lt. gn.-gy., v. f. xl., Crin.
- 1570-73 Sh., gn.-gy., slty. to cly., mica.
- 1573-83 Ls., as 2nd abv., gn.-gy. and gy.-red, mdst. frag. (prob. cav.)

Lawrence Fm.

- 1583-1646 Mdst., as 6th abv.
- 1590-1600 Intbd. olv. gy., cly., carb., sh. and lt. gn.-gy., v. f. gr., qtzs., ss.
- 1600-10 Intbd. coaly sh.
- 1620-46 Intbd. gn.-gy., cly., mica., pt. carb., sh.
- 1646-49 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod. arg., Crin., Bry. and Brac.
- 1649-51 Sltst. to v. f. gr., ss., lt. gn.-gy., mica., sil. cmt.
- 1651-54 Ls., as 2nd abv. (Amazonia Ls. Mbr., 1646-1654)
- 1654-70 Mdst. and sh. intbd.; as 4th abv.
- 1670-1710 Sh., m. gy. to gn.-gy., fis. to cly., mica., carb.
- 1670-80 Intbd. gn.-gy. to gy.-red mdst.
- 1680-90 Mdst. frag. (prob. cav.)
- 1690-1700 Intbd. lt. gn.-gy. sltst.
- 1710-50 Sh. and sltst. and v. f. gr., ss., intbd.; sh. as 1st abv., sltst., pt. calc.
- 1750-60 Sh. and sltst., intbd.
- 1760-70 Sh., as 1st abv.
- 1770-90 Sh., olv. gy. to gn.-gy., fis., cly. to slty., mica., carb.
- 1790-94 Sh., dk. gn.-gy. to gy.-blk., cly., sl. mica.
- 1794-1801 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod. arg., pt. slty., Crin. (Haskell Ls. Mbr.)

Stranger Fm.

- 1801-04 Sltst., gn.-gy., qtzs., mica., calc., pyr.
- 1804-09 Sh., as 3rd abv.

- 1809-12 Ls., gn.-gy. to lt. brn.-gy., v. f. xl., hd., pt. pyr., fos.
(Westphalia Ls. Mbr.)
- 1812-34 Sh. and sltst., intbd.; as 2nd and 3rd abv.
- 1834-43 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., carb., dol. cmt.
- 1843-50 Sh. and sltst., intbd.; as 2nd abv.
- 1850-78 Sh., dk. gn.-gy., fis., cly., carb., a few scat. ss. frag.
(prob. cav.)
- 1860-70 Th. coal
- 1878-82 Ss., as 3rd abv., v. f. to m. gr.
- 1882-90 Sh., as 2nd abv.
- 1890-92 Ss., as 2nd abv.
- 1892-1920 Sh. and ss., intbd.; as 2nd abv. / ang. frag. of red.-brn.
cl.-fest.
- 1920-60 Sh., m. dk. gy. to gn.-gy., fis., cly. to slty., mica.
- 1960-90 Sh., as 1st abv., sl. slty., pt. fos. / a few scat. frag.
of brn.-gy., cl.-fest.
- 1980-90 Pt. fos. / Crin.
- 1990-95 Sh., dk. gn.-gy. to gy.-blk., fis., cly. to sl. slty., sl.
mica.
- Stanton Ls. Fm. top
- 1995-2005 Ls., lt. gn.-gy. to dk. gn.-gy., f. xl., pt. mod. arg. to
slty., Crin.
- 2005-13 Sh., as 2nd abv.
- 2013-26 Ls., as 2nd abv., Crin. and Brac.
- 2026-32 Sh., as 4th abv.
- 2032-46 Ls., as 4th abv.
- 2046-2150 Sh., as 6th abv., Crin. and Brac., pt. pyr., a few scat. ls.
frag. (prob. cav.)
- 2090-2100 Th. brn.-gy., fos. ls. strs.
- 2100-10 Fos. / Gast.

LOG 38 (See Plate 9, Well 88)

Also shown as Plate 8, Well 18 and described as Log 25.

LOG 39 (See Plate 9, Well 90)

Also shown as Plate 8, Well 17 and described as Log 24.

LOG 40 (See Plate 9, Well 92)

SHERIDAN AND BARWICK

NO. 1 WARREN

Near cen. $W\frac{1}{2}$ $NW\frac{1}{4}$ $NW\frac{1}{4}$ sec. 18, T. 35 S., R. 6 E.

Cowley County, Kansas

Footage described: 1445- to 2190-foot depth

Oread Ls. Fm.

1445-1513 Sh., gn.-gy., slty., mica.; mdst., gy.-red; and ss., gn.-gy.,
v. f. to f. gr., qtzs., mica., gr. ang. to sbrd. and
eqnt., intbd. (Heebner Sh. Mbr. base at 1513-foot depth.

1513-20 Ls., lt. brn. to lt. brn.-gy., f. xl., abnt. fos. / Brac.,
Crin., Bry. and Fus.

- 1520-76 Sh., m. dk. gy., slty., mica., Crin.; mdst., gy.-red, calc; and ss., gn.-gy., v. f. gr., intbd.
1535-40 Spr. ls. frag. (prob. cav.)
- 1576-86 Ls., brn.-gy., f. xl., pt. arg., Crin., Brac., Bry. and Fus.
1580-85 Ls., gn.-gy., sft. and mod. arg.
- 1586-92 Mdst., m. gy. and gy.-red intbd., cly. to sl. slty.
- 1592-1604 Ls., v. lt. gy. to lt. gn.-gy., as 2nd abv.
- Lawrence Fm.
- 1604-54 Sh. to mdst., calc., fos. / Fus., as 2nd abv.; and ss., gn.-gy., v. f. gr., qtzs., intbd., / spr. ls. frag. (prob. cav.)
- 1654-63 Ls., v. lt. gy. to lt. gn.-gy., f. xl., Crin., Fus., and Brac. (Amazonia Ls. Mbr.)
- 1663-1720 Sh., m. gy., slty., mica., pt. fos. / Fus. and Brac.; mdst., gy.-red; and ls., th., mod. arg., intbd.
1665-75 Intbd. ss., gn.-gy., qtzs., v. f. gr., mica.
1675-85 Intbd. ls. / Fus. and Brac.
1695-1705 Intbd. ls., lt. gn.-gy. to brn.-gy.
- 1720-30 Ss., lt. gn.-gy., f. to m. gr., qtzs., gr. ang. to sbrd. and eqnt., pt. dol. cmt., pt. calc., pt. carb., mica.
- 1730-36 Mdst., dk. gn.-gy. and gy.-red intbd., slty., ferug. stn.
- 1736-44 Ss., as 2nd abv.
- 1744-47 Sh., m. dk. gy. to dk. gn.-gy., fis., slty., mica.
- 1747-50 Ss., as 4th abv.
- 1750-1820 Sh., gn.-gy., slty. to cly., mica.; mdst., gy.-red, calc.; and ss., lt. gn.-gy., qtzs., v. f. to f. gr., intbd.
1768-75 Gy.-red mdst. str.
1795-1805 Fos. / Crin. and Ost.
1805-15 Fos. / Crin.
- 1820-32 Ls., lt. gn.-gy. to brn.-gy., f. xl., mod. arg., Brac., Crin. and Fus. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1832-41 Sh., dk. gy., slty., mica., pt. calc.; mdst., gy.-red, calc., sl. slty.; and sltst., dk. gn.-gy., mica., pt. carb., intbd.
- 1841-45 Ls., lt. gn.-gy. to brn.-gy., f. xl., mod. arg., Crin.
- 1845-51 Sh. to mdst. and sltst. intbd., pt. pyr. / a th. gy.-brn. ls. (Westphalia Ls. Mbr., 1841-1851.)
- 1851-57 Ss., gn.-gy., f. to c. gr., qtzs., mica., gr. ang. to sbrd. and elong. to eqnt.
- 1857-1946 Sh., dk. gy., slty., mica., pt. carb.; and ss., as 2nd abv., intbd.
1880-1945 Mst. ss., qtzs., pt. / ferug. stn.
- 1946-2140 Sh., m. gy. to m. dk. gy. to dk. gn.-gy., cly. to slty., mica.; mdst., gy.-red, calc., sl. mica.; and sltst., to v. f. gr. ss., gn.-gy., gr. and stn. red-brn., pt. calc., pt. dol. cmt., intbd.
2075-2085 Abrt. col. cge. in ss. and sltst. to v. lt. gy. and lt. gn.-gy.

- 2140-54 Sh., m. dk. gy. to dk. gn.-gy.; and mdst., gy.-red, mica.,
intbd.
- Stanton Ls. Fm.
- 2154-60 Ls., lt. gy. to gn.-gy. to lt. brn.-gy., pt. / gn.-gy. to
lt. brn.-gy. ool., f. xl., Brac. and Crin., pt. ooc. /
v. f. to m. qtz. gr., ang. to sbrd. and elong to eqnt.
- 2160-67 Sh., m. dk. gy., slty., mica.
- 2167-86 Ss., lt. gy. to lt. gn.-gy., qtzs., v. f. to f. gr., mica.,
gr. sbang. to sbrd. and elong. to eqnt., pt. calc., pt.
dol. cmt.
- 2175-85 Pt. carb.
- 2186-90 Sh., m. gy., slty., mica.; and sltst., gn.-gy., calc.,
intbd.

LOG 41 (See Figure 30)

B. B. BLAIR

NO. 1 COX

SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 10, T. 4 S., R. 7 E.

Marshall County, Kansas

Altitude: 1295 feet

Footage described: 920- to 1140-foot depth

Lecompton Ls. Fm.

- 920-28 Ls., lt. gn.-gy., f. xl., pt. mod. arg., pt. pyr., Crin.,
Fus. and Brac. / a m. lt. gy., calc. sh. brk. or pt.
- 928-33 Ls., as 1st abv., / abnt. Fus.
- 933-37 Sh., gy.-blk., fis., cly., sl. mica. / m. dk. gy. strs.
- 937-40 Ls., gn.-gy., pt. mot. dk. gy., arg., Crin., Brac., abnt.
Fus.
- 940-85 Ls., v. lt. gy. to lt. gn.-gy., to lt. brn.-gy., f. xl.,
pt. mod. arg., Brac., Crin. / th. m. gy. sh. brks. or
pts. (Kanwaka Sh. Fm. top at about 954-foot depth and Oread
Ls. Fm. top at about 967-foot depth)
- 974-80 Abnt. ang. frag. dk. gn.-gy., fos. cht.
- 985-1010 Ls., v. lt. gy., f. xl. / c. xl. calc., pt. sl. arg.,
Crin., Fus., Brac. / dk. gy. and gy.-blk., carb. pts.
Spr. cht. frag. (prob. cav.)
- 1010-12 Sh., gy.-blk., fis., cly., sl. mica. (Heebner Sh. Mbr.)
- 1012-14 Ls., m. gy. and gn.-gy., v. f. xl., v. hd., Crin. and Fus.
- 1014-18 Mdst., lt. olv. gy. to gn.-gy., calc., pyr. / spr. frag. of
gy.-red mdst.
- 1018-26 Ls., v. lt. gy. and lt. gn.-gy., f. xl. / c. xl. calc.,
pt. sl. arg., Crin. and Brac.

Lawrence Fm.

- 1026-31 Mdst., gn.-gy. and gy.-red, as 2nd abv.
- 1031-35 Ls., lt. gn.-gy. and lt. brn.-gy., f. to m. xl. / c. xl.
calc., Crin., Brac., Fus. and Bry.
- 1035-39 Ls., as 1st abv., mst. v. f. xl., Crin.
- 1039-41 Mdst., gn.-gy., and gy.-red, as 3rd abv.
- 1041-45 As 2nd abv. / Crin., Brac., Bry. (Amazonia Ls. Mbr., 1031-1045)

- 1045-49 Sh., m. gy. to m. dk. gy., cly. to mod. slty., pt. pyr., mica., spr. carb. mat.
- 1049-66 Ls., lt. gn.-gy. and gn.-gy., f. xl. / c. xl. calc., pt. mod. arg., Crin., Fus., Brac., Bry. / gn.-gy. and gy.-red mdst. brks. or pts. (Cass Ls. Mbr.)
- 1066-68 Sh., gn.-gy., pt. sl. mica. and gy.-blk., fos., cly. (Little Pawnee Sh. Mbr.)
- 1068-70 Ls., gn.-gy., pt. mot. m. dk. gy., f. xl., hd., Brac. and Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1070-80 Mdst., gn.-gy. and gy.-red, pt. fos. / Brac., cav. of 1st abv.
- 1080-86 Ls., gn.-gy., v. f. xl., pt. ool. and ooc., fos., cav. of 1st abv.
- 1086-90 Mdst., gn.-gy. and gy.-red, as 2nd abv.
- 1090-97 Ls., gn.-gy., f. xl., Crin., Brac., Bry. and abnt. Fus., spr. sh. and mdst. frag. (prob. cav.) (Iatan Ls. Mbr., 1080-1097)
- 1097-1105 Sh., m. gy., cly. to slty., mica., Brac. incl. Crurithyris planoconvexa
- Stanton Ls. Fm.
- 1105-14 Ls., lt. gn.-gy., ool. and ooc., Brac., Crin. / m. gy., calc., fos. sh. pts.
- 1114-35 Ls., v. lt. gy. to lt. gn.-gy., f. xl., Crin., Brac. and Bry. / m. gy., calc., sh. brks. or pts.
1126-30 Fus.
- 1135-38 Sh., m. dk. gy. and gy.-blk., cly., sl. mica., sl. slty., m. dk. gy. pt. fos. / Crurithyris planoconvexa and other Brac.
- 1138-40 Ls., gn.-gy., f. xl., pt. arg., Crin. and Bry.

LOG 42

ELLIS BROTHERS ET AL.

NO. 1 ARMSTRONG

Near cen. Wst. $\frac{1}{2}$ NE $\frac{1}{4}$ sec. 10, T. 6 N., R. 15 E.

Nemaha County, Nebraska

Altitude: 900 feet

Footage described: 505- to 700-foot depth

Oread Ls. Fm.

- 505-33 Ls., v. lt. gy. to lt. gn.-gy., f. xl., sl. arg., fos. cht., pt. pyr., Brac. incl. Crurithyris planoconvexa and Rhipidomella carbonaria, Fus. and Crin. / carb. sh. pts.
- 520-25 Gn.-gy. sh. pts.
- 533-35 Sh., dk. gn.-gy. and gy.-blk., fis., dk. gn.-gy. pt. calc., sl. mica., sl. slty., spr. cav. of 1st abv. (Heebner Sh. Mbr.)

- 535-37 Ls., lt. gn.-gy. to gn.-gy. mot. gy.-blk., v. f. xl.,
Crin., Brac., and Fus. / spr. cav. of 1st and 2nd abv.
- 537-41 Mdst., gn.-gy., cly., calc., pt. pyr.
- 541-45 Ls., yel.-gy. and lt. brn.-gy., f. to m. xl., sl. to mod.
arg., abnt. fos. / Fus., Crin., Brac. and Bry.
- Lawrence Fm.
- 545-55 Mdst., gy.-red and gn.-gy., intbd., calc., cly. to sl.
slty., spr. frag. of slty. lt. gn.-gy., fos. ls.
- 555-60 No samples.
- 560-62 Mdst., as 2nd abv.
- 562-66 Ls., v. lt. gy. and lt. gn.-gy., slty., pt. shy., pt.
pyr., Crin. and Brac., / gy.-red stn. ls. frag. (Amazonia
Ls. Mbr.)
- 566-70 Mdst., gy.-red, calc., cly. to sl. slty.
- 570-75 Mdst., as 5th abv.
- 575-85 Mdst., mot. gy.-red and gn.-gy. to lt. olv. gy., cly. to
sl. slty., sl. mica., calc. / spr. ls. frag. (prob. cav.)
- 585-640 Sh., m. lt. gy. and gn.-gy., cly. to slty., sl. mica.;
and sltst., gn.-gy., sl. mica., carb., pt. mod. calc.,
spr. cav. of 1st abv., intbd.
- 600-05 Mdst., gn.-gy., and a shy. coal str.
- 605-10 Spr. scat. coal frag. (prob. cav.)
- 610-15 Intbd. sltst., gn.-gy. calc.
- 630-35 Intbd. ls., brn.-gy., th., fos., arg. (?Cass Ls.
Mbr.)
- 635-40 Intbd. ls., gn.-gy., shy., m. xl., Brac., incl.
Crurithyris planoconvexa, and Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
- 640-45 Mdst., gy.-red and gn.-gy., calc., cly. to sl. slty.; and
sltst., gn.-gy., mica., carb., calc. / spr. ls. frag.
(prob. cav. of 1st abv.), intbd.
- 645-51 Mdst., as 1st abv.
- 651-59 Ls., gn.-gy., v. f. xl., spr. fos. / Brac. and Fus. (Iatan
Ls. Mbr.)
- 659-61 Sh., gn.-gy., cly. to sl. slty., sl. mica.
- Stanton Ls. Fm.
- 661-74 Ls., lt. gn.-gy. to lt. olv. gy. to lt. brn.-gy., f. xl.,
pt. shy., abnt. fos. / Fus.; Brac., incl. Rhipidomella
carbonaria and Crurithyris planoconvexa; Bry., incl.
fenestrate and ramose; and Echin. spines
- 670-74 Spr. frag. ooc. ls. and gy.-red stn. ls.
- 674-78 Mdst., gy.-red and gn.-gy., cly. to sl. slty., calc.
- 678-95 Ls., v. lt. gy., f. xl., ooc., Crin. and Brac. / ang.,
fos. cht. frag. and gy.-red stn. ls. frag. Spr. frag.
of mdst. (prob. cav.)
- 695-98 Sh., gn.-gy. and lt. olv. gy., fis., cly. to sl. slty.,
calc., Brac., Crin., and Echin. spines / spr. frag. blk.
fis. sh., spr. cav. of 1st and 2nd abv.
- 698-700 Ls., m. lt. gy., arg., Crin.

LOG 43

EARL F. WAKEFIELD AND OTHERS

NO. 1 NATIONAL LIFE INSURANCE CO.

Near cen. NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 6 S., R. 20 E.

Atchison County, Kansas

Altitude: 1093 feet

Footage described: 275- to 600-foot depth

Kanwaka Sh. Fm.

- 275-93 Sh. and sltst., intbd.; sh., m. gy., slty., mica.; sltst.,
gn.-gy., mica., calc.

Oread Ls. Fm.

- 293-306 Ls., lt. gn.-gy. to gn.-gy., f. xl., sft., mod. arg.,
Crin., Fus., Brac., spr. ang. frag. of gn.-gy. fos. cht.
- 306-14 Ls., as 1st abv. and sh., olv. gy., slty., mica., intbd.
- 314-16 Ls., as 2nd abv.
- 316-19 Sh., gy.-blk., fis., calc. strs. (Heebner Sh. Mbr.)
- 319-21 Ls., gn.-gy., mot. gy.-blk., hd., f. xl., fos.
- 321-38 Mdst., olv. gy., cly. to sl. slty., calc.
- 338-49 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod.
arg., Crin. and Fus.

Lawrence Fm.

- 349-60 Sh. to mdst., gn.-gy. to lt. brn.-gy., calc., cly. to sl.
slty., sl. mica., cav. of 1st abv.
- 360-71 Sh. to sltst., gn.-gy., mica., fis. to blk., mod. calc.
- 371-72 Coal, shy.
- 372-74 Sh., as 2nd abv.
- 374-80 Sltst., to v. f. gr. ss., m. lt. gy. to lt. gn.-gy., qtzs.,
mica., carb., dol. cmt.
- 380-90 Ss. to sltst., intbd.; ss., gn.-gy., qtzs., v. f. gr., carb.,
mica., calc.; sltst., lt. gn.-gy. to olv. gy., qtzs.,
mica., carb.
- 390-413 Sh. and sltst., intbd.; sh., olv. gy., fis., slty., mica.,
pt. calc.; sltst., lt. gn.-gy., mica., calc.
- 413-15 Ls., brn.-gy., arg., sdy., fos.
- 415-56 Sh. and sltst., intbd.; as 2nd abv.
410-30 Spr. ls. frag. (prob. cav.)
- 456-58 Ls., m. gy. to brn.-gy., v. arg., abnt. fos. / Crin., Brac.
(Haskell Ls. Mbr.)

Stranger Fm.

- 458-63 Sh., m. gy., calc., abnt. fos. / Brac., Plcy., and Gast.
- 463-65 Ls., as 2nd abv.
- 465-73 Sh., as 2nd abv.
- 473-76 Ss. to sltst., lt. gn.-gy., v. f. gr., qtzs., mica., dol.
cmt., abnt. frag. of a gn. min., spr. frag. of ls. (prob.
cav.)
- 476-80 Sh., as 4th abv., no fos.
- 480-95 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., carb., dol.
cmt.

- 495-98 Mdst., gn.-gy. and gy.-red, intbd., cly., calc.
 498-500 Ls., gy.-brn., f. xl., Crin. and Brac. (Westphalia Ls. Mbr.)
 500-06 Ss., lt. gn.-gy., qtzs., mica., carb., sil. cmt.
 506-14 Sh. and mdst., intbd.; sh., olv. gy., fis., cly., sl. mica.;
 mdst., gy.-red, cly., calc.
 514-24 Sh., olv. gy., cly., sl. mica., arenac. forams.
 524-34 Sh., as 1st abv., no forams.
 534-40 Ls., lt. brn.-gy., f. xl., pt. mod. arg., Crin.
 540-42 Sh., m. gy., fis., cly., pt. calc.
 542-46 Ls., lt. gn.-gy., f. xl., pt. sft. and mod. arg., Crin. and
 Brac. (Iatan Ls. Mbr., 534-546)
 546-55 Sh., olv. gy. to m. gy., fis., cly. to sl. slty., sl. mica.,
 pt. fos. / Crin.
- Stanton Ls. Fm.
 555-61 Ls., gn.-gy. to dk. gn.-gy., f. xl., abnt. c. xl. calc., pt.
 sft. and arg., Crin., Fus., and Brac.
 561-65 Ss., v. f. gr. to sltst., lt. gn.-gy., calc., fos.
 565-67 Ls., as 2nd abv.
 567-70 Ss. and sltst., as 2nd abv.
 570-85 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod.
 arg., Brac., Bry. and Crin.
 585-90 Sh., olv. gy. to gy.-blk., fis., cly., sl. mica., blk. fis.
 pt. / calc. strs.
 590-92 Ls., lt. gn.-gy. to brn.-gy., f. xl. / c. xl. calc., Crin.
 and Brac.
- Vilas Sh. Fm.
 592-600 Sh., m. gy., fis., slty., mica., pt. calc.

LOG 44

CONTINENTAL OIL CO. AND OTHERS

NO. 1 BERRIDGE

Near NW cor. SW $\frac{1}{4}$ sec. 8, T. 9 S., R. 17 E.

Jefferson County, Kansas

Altitude: 1126 feet

Footage described: 525- to 870-foot depth

Oread Ls. Fm.

- 525-28 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., mod. sft., arg.,
 Crin. and Brac.
 528-30 Sltst., lt. gn.-gy., qtzs., mica., pt. carb., pt. calc.
 530-40 Ls., as 2nd abv., Fus. and Bry., pt. pyr.
 540-43 Sh. to sltst., m. gy. to gn.-gy., calc.
 543-55 Ls., lt. gn.-gy., f. xl., mod. arg., Fus., Brac., Bry.,
 Crin., ang. frag. of gn.-gy. to dk. gn.-gy., fos. cht.
 555-58 Sh., gn.-gy. to gy.-blk., cly., blk. fis., pt. / calc. strs.
 (Heebner Sh. Mbr.)
 558-60 Ls., gn.-gy. to m. dk. gy., mot. gy.-blk., f. xl., hd., pt.
 pyr., Brac.
 560-64 Sh., olv. gy. to m. dk. gy., cly. to slty., sl. mica., sl.
 carb.

- 564-80 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft., mod. arg., Crin., Brac., Fus., and Bry.
- Lawrence Fm.
- 580-90 Ss., lt. gn.-gy., v. f. gr., qtzs., dol. cmt., abnt. c. mica flakes, pt. mod. carb., pt. pyr., spr. cav. of lst abv.
- 590-600 Sh. to mdst., olv. gy., cly. to slty., calc.
- 600-07 Ls., brn.-gy., f. xl., fos. (Amazonia Ls. Mbr.)
- 607-11 Sh., lt. gn.-gy., fis., slty., mica., pt. calc., pt. carb.
- 611-12 Coal, shy.
- 612-15 Sh., as 2nd abv.
- 615-38 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., carb., pt. dol. cmt., pt. calc., spr. cav. of lst abv.
- 638-50 Sh. and sltst., intbd.; sh., m. gy., fis., cly., sl. mica.; sltst., lt. gn.-gy. to lt. brn.-gy., mica., mod. carb., pt. dol. cmt., pt. calc.
- 650-58 Sh. to mdst., gn.-gy., slty., mica., calc.
- 658-60 Ls., brn.-gy., mod. arg., fos.
- 660-90 Sltst., lt. gn.-gy., qtzs., mica., mod. carb.; intbd. sh., olv. gy., slty., mica., carb.
- 680-90 Intbd. ss., gn.-gy., mica., carb., qtzs., pt. mod. calc.
- 690-705 Sh., olv. gy., fis., cly., sl. slty., sl. mica.
- 705-07 Ls., gn.-gy. to brn.-gy., arg., Crin. and Brac. (Haskell Ls. Mbr.)
- Stranger Fm.
- 707-10 Sh., as 2nd abv.
- 710-20 Mdst., gn.-gy., calc., Brac., cav. of lst abv.
- 720-22 Ls., brn.-gy., f. xl., mod. arg., fos. (Westphalia Ls. Mbr.)
- 722-29 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., dol. cmt., sl. carb.
- 729-55 Sh. and sltst., intbd.; sh., olv. gy., fis., cly. to slty., mod. mica., pt. carb.; sltst., lt. gn.-gy., mica., pt. mod. calc.
- 755-56 Coal, shy.
- 756-803 Sh. and sltst., intbd., as 2nd abv.
- 803-30 Sh., m. gy. to olv. gy., fis., cly. to slty., mica.
- Stanton Ls. Fm.
- 830-33 Ls., lt. gn.-gy. to brn.-gy., f. xl., arg., Crin.
- 833-45 Ls., sh., and sltst., intbd.; ls., as lst abv.; sh., m. gy., fis., calc., cly. to slty., mica.; sltst., lt. gn.-gy., calc.
- 845-47 Sh., m. gy., fis., cly. to slty.
- 847-58 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. sft. and mod. arg., Brac. and Crin.
- 858-66 Sh., m. gy. to olv. gy. to gy.-blk., fis., calc., sl. slty., sl. mica.
- 866-70 Ls., m. gy., f. xl., mod. arg., fos.

LOG 45

QUENEMO CITY WATER WELL

sec. 12, T. 17 S., R. 17 E.

Franklin County, Kansas

Footage described: 0- to 200-foot depth

- 0-41 Surficial material
 41-56 Brn. to brn.-gy., cht. gvl.
- Lawrence Fm.
 56-143 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., v. fri.,
 qtz. gr. ang. to sbrd. and elong. to eqnt., dol. cmt.,
 sl. carb., spr. frag. of cht. gvl. (prob. cav.), scat.
 qtz. gr. stn. / ferrug. material
 59-89 Spr. cht. gvl. cav.
 89-94 F. to m. gr. ss.
 94-143 Ss., v. lt. gy. to lt. gn.-gy.
- 143-50 Sh., m. gy., cly. to sl. slty., fis., sl. mica., / a th. lt.
 brn.-gy., arg., fos. ls.
- 150-55 Ls., v. lt. gy. to lt. gn.-gy. to lt. brn.-gy., f. xl., sl.
 arg., Crin., Brac. and Echin. spines (Haskell Ls. Mbr.)
- Stranger Fm.
 155-76 Ss., lt. gn.-gy., v. f. gr., qtzs., mica., pt. fos. / Crin.,
 dol. cmt., qtz. gr. sbang. to sbrd. and eqnt., / cav. of
 1st and 2nd abv.
- 176-200 Sh., sltst., and ss., intbd.; sh., m. gy., fis., cly. to sl.
 slty., sl. mica., carb.; ss., v. f. to f. gr., qtzs.,
 mica., gr. sbang. to sbrd. and elong. to eqnt.; sltst.,
 lt. gn.-gy., qtzs., mica., dol. cmt., abnt. aggs. of a
 pwdy. wh. sft. min., pt. carb., pt. pyr.

LOG 46

B. O. HOLLETT COMPANY

NO. 1 L. C. BUTLER

SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T. 20 S., R. 15 E.

Coffey County, Kansas

Footage described: 335- to 610-foot depth

Douglas Grp.

- 335-75 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., dol. cmt.,
 a few scat. frag. of ls. (prob. cav.), one smpl.
- 375-95 Ss., as 1st abv., / abnt. Fus., Brac., Crin., spr. Bry.,
 fos. loose in ss. and not in calc. matrix, a few scat.
 frag. of m. gy. and lt. brn.-gy. ls., pt. ?cong.
- 395-460 Sh. and sltst., intbd.; sh., olv. gy., fis., cly. to slty.,
 mica.; sltst., lt. brn.-gy., qtzs., mica., carb., sil.
 cmt.
- 460-95 Sh., olv. gy. to m. gy., fis., cly. to sl. slty., mica.
- 495-518 Sh., olv. gy., fis., cly., mica.

Stanton Ls. Fm.

- 518-29 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. mod. sft. and mod. arg., Brac., Crin., a few scat. sh. cav.
 529-32 Ss., lt. gn.-gy., v. f. to f. gr. qtzs., mica., dol. cmt.
 532-59 Ls., v. lt. gy. to lt. gn.-gy., f. xl., hd., pt. sl. arg., Crin. and Brac.
 559-66 Sh., gy.-blk., fis., cly., mica.
 566-72 Ls., gn.-gy., v. f. xl., fos.

Vilas Sh. Fm. top

- 572-75 Sh., gn.-gy., cly., mica., Bry.
 575-600 Ls., as 4th abv.
 600-07 No samples.
 607-10 Ls., as 2nd abv.

LOG 47

CECIL T. WELCH AND OTHERS

NO. 1 KERNS

NW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 26 S., R. 13 E.

Woodson County, Kansas

Altitude: 974 feet

Footage described: 0- to 500-foot depth

0-11 Surficial material

Lawrence Fm.

- 11-25 Ss., v. f. to f. gr., qtzs., mica., qtz. gr. sbang. to sbrd. and eqnt., sil. cmt., some gr. stn. brn.-red, spr. cav. of surficial material
 25-42 Ss., as 1st abv., v. lt. gy. to lt. gn.-gy., carb., calc.
 42-50 Sh. and sltst., intbd., gn.-gy.; sh., gn.-gy., fis., cly. to slty., mica., carb.; sltst., lt. gn.-gy., fis., cly. to slty., mica., carb.; sltst., lt. gn.-gy., mica.
 50-63 Sh., as 1st abv.
 63-95 Sh. and ss., intbd., as 2nd and 3rd abv.; ss., carb.
 95-132 Sh. and sltst., intbd.; sh., m. gy. to gn.-gy., fis., cly. to slty., mica.; sltst., lt. gn.-gy., qtzs., mica., pt. carb.
 132-37 Ls., dk. gn.-gy., f. xl., pt. sl. arg., Crin.
 137-40 Ls., gn.-gy., arg., Crin. (Haskell Ls. Mbr., 132-140)

Stranger Fm.

- 140-44 Sh., gn.-gy., fis., cly., calc., Crin.
 144-49 Ls., v. lt. gy. to lt. gn.-gy., f. xl. / c. xl. calc., pt. slty., Crin., abnt. Fus. (Westphalia Ls. Mbr.)
 149-60 Ss., v. lt. gy. to lt. gn.-gy., qtzs., mica., v. f. gr., pt. mod. calc., spr. cav. of 1st abv.
 160-70 Ss. to sltst., as 1st abv.
 170-322 Sh., gn.-gy., fis., cly. to sl. slty., mica., pt. mod. carb.
 240-60 Sh., m. gy. to olv. gy.
 260-322 Sh., olv. gy.

Stanton Ls. Fm. top

- 322-32 Ls., v. lt. gy. to lt. gn.-gy., ool. / qtz. gr. nuclei,
abnt. c. xl. calc., Crin., Brac. incl. Rhipidomella
carbonaria
- 332-36 Sh., gn.-gy., fis., cly., mica.
- 336-59 Ls., v. lt. gy. to lt. gn.-gy., Crin., Brac., abnt. c. xl.
calc.
- 340-50 Hd. / abnt. c. xl. calc. / dk. gn.-gy., fis., cly.,
mica., calc., sh. pts.
- 350-60 Less c. xl. calc.
- 359-61 Sh., dk. gn.-gy., fis., cly., mica., calc., Crin.
- 361-80 Ls., as 2nd abv., abnt. c. xl. calc., Crin., Brac. incl.
Punctospirifer kentuckyensis
- 380-86 Ls., m. dk. gy. to gn.-gy., f. xl., Crin., pt. pyr., pt. a
calcarenite of sd.-size Crin. frag.
- 386-89 Ls., v. lt. gy. to lt. gn.-gy., f. xl., some c. xl. calc.,
pt. sft. and mod. arg., Crin., Brac. and Fus.
- 389-500 Sh., gn.-gy., fis., hd., cly. to slty., mica., mod. calc.,
spr. ls. cav. in upper pt.
- 420-30 Fos. / Crin. and Brac.
- 430-33 / th. m.gy. slty., fos. ls.
- 444-50 Ls., m. gy., arg., Bry., Crin.
- 452-61 Ls., m. gy., arg., Bry., Brac. and Crin.
- 468-78 Spr. ls. frag. (prob. cav.), sh. pt. carb.

LOG 48

CROMWELL AND LEWIS

NO. 1 HALL

Near cen. So. line NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 7, T. 29 S., R. 7 E.

Butler County, Kansas

Altitude: 1438 feet

Footage described: 1400- to 2025-foot depth

Kanwaka Sh. Fm.

- 1400-25 Sh., m. gy. to gn.-gy., fis., cly. to slty., mica., pt.
mod. carb.; and sltst., to v. f. gr. ss., lt. gn.-gy.,
qtzs., mica., pt. mod. carb., pt. calc. / scat. ls.
frag. (prob. cav.)

Oread Ls. Fm.

- 1425-30 Ls., v. lt. gy. to gn.-gy. to dk. gn.-gy., f. xl. / c. xl.
calc., pt. sft. and mod. arg., pt. pyr., Fus., Crin.,
Brac., / intbd. carb. sh. strks.
- 1430-35 No samples.
- 1435-50 Ls., as 2nd abv. / Trilo. pygidia
- 1450-60 Ls., dk. gn.-gy., f. xl., pt. mod. arg. to slty., Crin.,
Brac., / a dk. gy., carb., fis., cly., mica. sh. brk.
- 1460-68 Sh., dk. gn.-gy. to gy.-blk., fis., cly., mica., pt. fos.
/ Crin. (Heebner Sh. Mbr.)
- 1468-70 Ls., gn.-gy., v. f. xl., Crin., Brac.

- 1470-1503 Mdst., gn.-gy., and gy.-red, pt. calc.; and ls., gn.-gy., th. arg., fos., intbd.
1485-1500 Abnt. sm. calc. pel.
- 1503-05 Ls., lt. brn.-gy., f. xl., slty., Crin.
- 1505-18 Ls., lt. gn.-gy., and lt. brn.-gy., f. xl., pt. sft. and sl. arg. to slty., Crin., / a m. gy. to gn.-gy., calc., sh. brk.
- Lawrence Fm.
- 1518-25 Sh., m. gy., fis. to plty., cly. to slty., pt. mod. carb., mica.
- 1525-80 Mdst., gn.-gy., cly., calc.; and sltst., lt. gn.-gy., qtzs., calc. intbd. / gy.-red mdst. strks.
- 1550-65 Arg., brn.-gy. and gn.-gy. ls. strks. and abnt. dk. gn.-gy. ls. pel.
- 1565-70 Ls., lt. gn.-gy., th., arg., Crin., Brac.; and sltst., lt. gn.-gy., calc., carb., intbd.
- 1570-80 Ls., sltst., and mdst. intbd., as 1st and 2nd abv. (Amazonia Ls. Mbr., 1565-1577)
- 1580-90 Sh., m. gy. to gn.-gy., cly., to slty., mica., carb.; and sltst. to v. f. gr. ss. intbd., lt. gn.-gy., mica., carb., pt. mod. calc., / spr. ls. frag. (prob. cav.)
- 1590-1681 Mdst., carb., as 3rd abv. and ss., lt. gn.-gy., v. f. gr., qtzs., mica., gr. sbang. to sbrd. and elong. to eqnt., sil. cmt.
- 1600-20 Intbd. ss., carb.
- 1620-30 Intbd. slty. to sdy., olv. gy. sh.
- 1650-60 Intbd. ls., olv. to brn.-gy., f. xl., fos.
- 1681-1742 Sh., olv. gy., cly. to slty., mica.
- 1690-1700 Intbd. sltst., lt. gn.-gy.
- 1700-25 Pt. fos. / Crin., scat. ls. and ss. frag. (prob. cav.)
- 1742-44 Ls., dk. gn.-gy. and brn.-gy., f. xl., Crin. (Haskell Ls. Mbr.)
- Stranger Fm.
- 1744-55 Ss., lt. gn.-gy., v. f. gr., mica., calc. / a m. gy., cly., fis., carb. sh. brk.
- 1755-57 No samples.
- 1757-67 Ls., lt. gn.-gy. to lt. brn.-gy., f. xl., pt. sft. and mod. arg. to slty., Brac., Crin., / a th. olv. gy., fis., cly., sh. brk. (?Iatan Ls. Mbr.)
- 1767-70 Sh., gn.-gy., mica.
- Stanton Ls. Fm. top
- 1770-85 Ls., m. gy. to gn.-gy., v. f. xl., hd., Crin., Brac.
- 1785-95 Ls., lt. gn.-gy., m. gy., and brn.-gy., Crin., as 1st abv.
- 1795-1805 Ls., as 2nd abv., Fus., Crin., / th. lt. gn.-gy., qtzs. ss. and gn.-gy., fis., cly., mica. sh. brks. intbd.
- 1805-25 Ls., v. lt. gy. and lt. gn.-gy., f. xl., Brac., Crin., / a th. gn.-gy., fis., cly., mica., calc. sh. brk.; and scat. ss. frag. (prob. cav.)

- 1825-33 Ls., as 4th abv. / a dk. gn.-gy., cly., calc. sh. brk.
 1833-40 Ss., lt. gn.-gy., v. f. gr., dol. cmt.
 1840-1905 Ls., lt. gn.-gy., to lt. brn.-gy., f. xl. / abnt. c. xl.
 calc., Brac., Crin., / dk. gn.-gy., carb. sh. pts.
 1848-1875 Por. / intbd. lt. gn.-gy., v. f. gr. ss.
 1855-75 Fos. / Bry., Crin., Brac.
 1875-1905 Scat. ang. frag. of lt. gn.-gy., fos. cht.
 1895-1905 Intbd. ss., lt. gn.-gy., qtzs., v. f. gr.
 1905-20 No samples.
 1920-70 Ls., m. gy. and gn.-gy., v. f. xl., hd., Crin., Brac., Bry.,
 / a dk. gn.-gy., carb., fos. sh. brk.
 1925-40 As 1st abv., no sh. brk.
 1940-70 Dk. gn.-gy., sh. pts.
 1970-80 Ls., v. lt. gy. to lt. gn.-gy., f. xl., Crin., / a dk. gn.-
 gy., fis., cly. to slty., carb. sh. and a th. lt. gn.-
 gy., v. f. gr., qtzs. ss.
 1980-92 Ls., as 1st abv. / dk. gn.-gy. sh. brk.
 1992-2025 Mdst., and sltst. intbd., gn.-gy., calc., mdst. pt. fos. /
 Crin.

LOG 49 (See Figure 31, Cross Section D, Well 1)

C. L. CARLOCK

NO. 1 STARKEY

Near Cen. So. line SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 21, T. 30 S., R. 7 E.

Cowley County, Kansas

Altitude: 1412 feet

Footage described: 1318- to 1950-foot depth

Kanwaka Sh. Fm.

1318-40 Sh., gn.-gy., slty. to cly., mica.

1340-44 Sltst., lt. gn.-gy., qtzs., mica.

Oread Ls. Fm.

1344-49 Ls., gn.-gy. and brn.-gy., f. xl. / c. xl. calc., pt. sft.
 and mod. arg. to slty., Crin., Brac. incl. Crurithyris
 planoconvexa.

1349-55 Sh., dk. gn.-gy. and gy.-blk., fis. to cly. to sl. slty., sl.
 mica., dk. gn.-gy. pt. fos. / Brac. and Crin. (Heebner Sh.
 Mbr.)

1355-57 Ls., dk. gn.-gy. and brn.-gy., v. f. xl., hd., Brac., Crin.

1357-60 Sh., dk. gn.-gy., fis., cly. to slty., calc., pt. fos. / Brac.

1360-70 Mdst., gn.-gy., cly., mod. calc., cav. of 1st and 2nd abv.

1370-77 Sltst., lt. gn.-gy., qtzs., mica., calc.; and Ls., lt. gn.-gy.,
 slty., fos., intbd.

1377-82 Mdst., gn.-gy. and gy.-red intbd., cly. to sl. slty., pt.
 calc., sl. mica. / sp. ls. frag. (prob. cav.)

1382-94 No samples.

1394-1403 Sh. and mdst. intbd., as 2nd abv.

1403-14 Ls., yel.-gy. to lt. brn.-gy., f. xl., pt. mod. arg., Crin.,
 Foram. / a m. dk. gy. sh. brk. and cav. of 1st abv.

Lawrence Fm.

- 1414-25 Sltst., v. lt. gy., qtzs., mica., dol. cmt.; ss., v. f. gr.,
fri.; and Sh., gn.-gy., mica., intbd.
- 1425-27 Ls., gn.-gy., v. f. xl., fos.
- 1427-32 No samples.
- 1432-42 Mdst. as 5th abv., sltst. to v. f. gr. ss., as 3rd abv.; and
a coal str. intbd.
- 1442-52 Sh., gn.-gy. to m. gy., fis., cly., pt. calc.; and ss., v.
lt. gy. to lt. gn.-gy., v. f. gr., qtzs., mica., sil.
cmt., intbd.
- 1452-66 Sh., as 1st abv.; and mdst. gn.-gy., cly., calc., intbd.
- 1466-79 Ls., lt. olv.-gy. to gn.-gy., v. f. xl., pt. mod. arg., Fus.,
Brac., Crin., / a sh. brk. in lwr. pt. (Amazonia Ls. Mbr.)
- 1479-1502 Sh., m. gy. to gn.-gy., fis., cly. to slty., mica.; mdst.,
gy.-red, calc.; and ss., v. lt. gy. to lt. gn.-gy., v. f.
gr., qtzs., mica., carb., intbd.
- 1502-03 No sample.
- 1503-55 As 2nd abv.
1503-12 Mst. ss.
1540-55 Intbd. lt. gn.-gy. sltst.
- 1555-1640 Sh., dk. olv.-gy., fis., cly. to slty., mica., pt. carb.
1565-72 Intbd. gn.-gy., calc. sltst.
- 1640-43 Ls., lt. gn.-gy. to brn.-gy., f. xl., pt. sft. and mod. arg.,
Crin. (Haskell Ls. Mbr.)

Stranger Fm.

- 1643-46 Sltst., gn.-gy. to lt. brn.-gy., qtzs., mica., calc.
- 1646-51 Sh., as 3rd abv.
- 1651-66 Ls., v. lt. gy. to lt. brn.-gy., f. xl., Crin.
1655-60 Dk. gn.-gy., fis., cly., sh. pts. (?Iatan Ls. Mbr.
or ?Iatan-Westphalia Mbr.)
- 1666-72 Sh., dk. gn.-gy., fis., cly., mica.

Lansing Grp.

- 1672-1730 Ls., m. lt. gy. to gn.-gy., f. xl., Crin., Brac., / m. gy.,
cly. to slty., mica. sh. brk. and pts.
1696-1710 Abnt. ang. frag. of cl-fest.
1710-30 Mst. ls. / spr. sh. pts.
- 1730-42 Ls., m. gy. to gn.-gy., f. xl., Crin.
- 1742-50 Ls., v. lt. gy. to lt. gn.-gy., f. xl., pt. mod. arg., Crin.
/ a dk. gn.-gy., fis., cly., mica. sh. pt.
- 1750-1857 Ls., as 2nd abv.
1765-72 Sh. brk., dk. gn.-gy., fis., cly., ls. / Fus.
1772-80 Sh. pts., dk. gn.-gy., fis.
1788-95 Ls. pt. pyr.
1795-1804 Ls., v. lt. gy. to lt. gn.-gy. / abnt. c. xl.
calc., pt. por.
1845-57 Sh. brks., dk. gn.-gy., fis., cly., mica.

Kansas City Grp.

- 1857-1915 Sh., dk. gn.-gy., fis., cly., mica. / spr. scat. ls. frag.
(prob. cav.)
1870-1915 Sh., spr. scat. frag., brn.-gy.

- 1915-26 Ls., m. gy. to m. dk. gy., arg., abnt. fos. / Crin. and
Brac.
1926-50 Sh., m. gy., fis. to cly. to sl. slty., pt. mod. calc. /
th. ls. strks., gy., arg., fos., Crin.

LOG 50

MORRISON DRILLING COMPANY

NO. 1 STURGES

NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 2, T. 33 S., R. 11 E.

Chautauqua County, Kansas

Footage described: 134- to 530-foot depth

Lawrence Fm.

- 134-200 Sh., m. gy. to m. dk. gy., fis., sl. calc., mica., slty.
200-10 Sh., dk. gy., fis. to plty., mica., carb., sl. slty.
210-20 Sh., dk. gn.-gy., fis. to plty., sl. mica., slty., Crin.;
and ls., lt. gy. to m. lt. gy., Crin., intbd. (Haskell Ls.
Mbr., 214-217)

Stranger Fm. (top at about 217-foot depth)

- 220-30 Sh., m. gy., fis. to plty., cly. to sl. slty., / intbd. v.
lt. gy., calc. sltst.
230-70 Slstst. to v. f. gr. ss., v. lt. gy., mica.; and sh., m.
gy., cly. to sl. slty., intbd.
270-310 Ss., wh. to v. lt. gy., qtzs., fri., f. to m. gr., gr. sbang.
to sbrd. and elong. to eqnt. / m. gy., cly., sh. strs., pt.
fos. / Ost.
310-484 Sh., m. gy. to m. dk. gy., fis. to plty., mica., v. sl. calc.,
slty. to cly. in lwr. pt.

Stanton Ls. Fm.

- 484-93 Ls., v. lt. gy. to lt. brn.-gy., m. gr. to c. gr. to f. xl.,
Brac. and Crin.
493-500 Sh., m. gy. to gy., fis., mica., sl. calc.
500-08 Ls., v. lt. gy. to lt. brn.-gy., m. dk. gy. elip. and sph.
ool. or pel., Crin., Brac., Bry.
508-20 Slstst. to slty. ls., lt. gy., calc., fos.
520-30 Sh., m. gy. to m. dk. gy., fis., calc., mica.; and ls. lt.
brn.-gy., slty. fos. / Brac., Bry., and Crin., intbd.

LOG 51

WESTERN KANSAS OIL AND REFINING CORP.

NO. 1 GREGORY

Near SE cor. NW $\frac{1}{4}$ sec. 2, T. 34 S., R. 6 E.

Cowley County, Kansas

Altitude: 1283 feet

Footage described: 1350- to 2035-foot depth

Kanwaka Sh. Fm.

- 1350-80 Sh., m. gy., slty., mica., fis.; and sltst., m. gy., mica.,
pt. dol. cmt.
1380-87 Ss., gn.-gy., v. f. to f. gr., qtzs., mica.
1387-1400 Sh., as 2nd abv.

Oread Ls. Fm.

- 1400-06 Ls., m. gy., f. xl., Crin.
 1406-12 Sh., blk., fis. (Heebner Sh. Mbr.)
 1412-18 Ls., m. dk. gy. to brn.-gy., f. xl., fos.
 1418-40 Sh., m. lt. gy. to gn.-gy., sl. slty., mica.
 1440-44 Ss., lt. olv. gy., v. f. gr., qtzs., mica.
 1444-66 No samples.
 1466-70 Sh., m. gy., calc.
 1470-82 Ls., v. lt. gy. to pnk.-gy., f. xl., Bry., Crin., Fus.,
 Brac. / m. gy. calc. sh. brk.

Lawrence Fm.

- 1482-1512 Sh., gn.-gy. to m. lt. gy., slty., mica. / ls. str. in
 lwr. pt.
 1512-20 Ls., v. lt. gy. to m. gy., f. xl., Crin., Brac., Bry. and
 abnt. Fus. (Amazonia Ls. Mbr.)
 1520-22 Sh., m. gy., slty., mica.
 1522-30 Ss., gn.-gy., v. f. to f. gr., calc. cmt.
 1530-40 Ls., lt. brn.-gy., f. xl., Crin., Brac., Fus., / a m.
 gy. slty., mica. sh. brk.
 1540-57 Sh. and sltst. intbd., m. gy., mica.
 1557-70 Ss., lt. gy. to gn.-gy., v. f. to f. gr., dol. cmt.,
 qtzs., gr. sbang. to sbrd., eqnt., mica. / m. gy. and
 red slty. sh. brks.
 1570-1686 Sh., m. gy. to m. dk. gy., slty., mica.; and ss., lt. gy.
 to gn.-gy., qtzs., v. f. to m. gr., mica., gr. eqnt. to
 elong. and sbang to sbrd., pt. calc., pt. fri., intbd.
 1686-87 Coal bd., shy.
 1687-1700 Sh. and ss. intbd., as 2nd abv.
 1700-25 Sh., m. gy. to m. dk. gy., slty., mica., dk. gy. to blk.
 in lwr. pt.
 1725-29 Ls., lt. brn.-gy., f. xl., Fus., Crin. (Haskell Ls. Mbr.)

Stranger Fm.

- 1729-54 Sh., dk. gy., mica. pt. slty.
 1754-77 Ls., lt. gy., f. xl., Crin., Brac., and abnt. Fus. / dk. gy.
 sh. brks. (?Westphalia Ls. Mbr. or ?Iatan-Westphalia Mbr.)
 1777-79 Sh., dk. gy., pt. calc., slty., mica.
 1779-1808 Ss., gn.-gy., f. gr., qtzs., gr. sbang. to sbrd., eqnt. to
 elong., mica., dol. cmt.
 1808-1933 Sh., m. gy., slty., mica., / v. f. gr. ss., to sltst. str. s.
 1933-79 Ss., gn.-gy., f. to m. gr., qtzs., gr. eqnt. and sbang. to
 sbrd., mica.; and sh., gn.-gy. to m. dk. gy., slty.,
 mica., intbd.

Stanton Ls. Fm.

- 1979-81 Ls., brn.-gy. to gn.-gy., sdy., Crin., Bry.
 1981-97 Ss., gn.-gy., f. gr., qtzs., gr. sbang. to sbrd., elong.
 to eqnt. / a m. gy. sh. brk.
 1997-2002 Sh., gn.-gy., cly. to slty., mica.
 2002-14 Ss., as 2nd abv.
 2014-25 Sh., m. dk. gy., sl. slty., mica., ?fos.
 2025-30 Ls., brn.-gy., sdy., Crin. and Bry.
 2030-35 Sh., as 2nd abv.

LOG 52

BESS AND GRALAPP ET AL.

NO. 1 E. E. HUNT

Near cen. nor. line NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 18, T. 34 S., R. 5 E.

Cowley County, Kansas

Altitude: 1258 feet

Footage described: 1650- to 2245-foot depth

Kanwaka Sh. Fm.

1650-54 No samples.

1654-60 Ss., v. lt. gy. to lt. gn.-gy., v. f. gr. to sltst., calc., mica.

1660-63 Sh., m. gy., slty., mica.

1663-69 Ss., as 2nd abv.

1669-70 Sh., as 2nd abv.

Oread Ls. Fm.

1670-95 Ls., lt. brn. to brn.-gy., f. xl., pt. slty., pt. arg., Brac., Fus., Crin.

1682-90 Ls., wh. to lt. gn.-gy., f. xl. / abnt. c. xl. calc., Fus., Crin.

1695-1708 Sh., m. gy. to m. dk. gy., slty., mica., abnt. fos. / Crin., Gast., Brac. (Crurithyris planoconvexa)

1708-12 Sh., m. dk. gy. to gy.-blk., fis. (Heebner Sh. Mbr., 1695-1712)

1712-18 Ls., brn.-gy. to dk. gy., f. xl., abnt. fos. / Fus., Brac., Crin.

1718-26 Sh., m. gy. to m. dk. gy., cly., pyr., calc., fos.

1726-60 Sh. or mdst., m. gy. and gy.-red, cly., slty., mica.

1740-42 Intbd. ss. str., lt. gn.-gy., v. f. gr.

1742-46 Intbd. ss., lt. gn.-gy.

1760-67 Ss., gn.-gy., v. f. to f. gr., qtzs., mica. to calc.

1767-73 Sh. and mdst., gy. and gy.-red, as 2nd abv.

1773-78 Ss., as 2nd abv.

1778-82 Sh., as 2nd abv.

1782-93 Ls., v. lt. gy. to lt. gn.-gy. to brn.-gy., f. xl., Fus., Brac., Bry., Crin., and Echin.

1793-95 Sh., m. gy., cly., calc.

1795-97 Ls., as 2nd abv.

Lawrence Fm.

1797-1825 Sh., m. gy. and mdst., gy.-red; cly. to slty., mica.

1825-30 Ss., lt. gn.-gy., v. f. gr. to f. gr., qtzs., mica., calc.

1830-54 Sh., m. gy., slty., mica., calc., Echin. plates; intbd. / ss., gn.-gy., f. gr., dol. cmt.

1854-68 Sh. and mdst., as 3rd abv., pt. pyr.

1868-70 No samples.

1870-95 Ss. and sh., as 2nd and 3rd abv.

1895-1903 Ls., gn.-gy. to lt. brn.-gy., f. xl. / abnt. c. xl. calc., Crin., Brac.

1903-45 Sh., m. gy., slty., mica. and ss., gn.-gy., v. f. gr., carb.

1914-19 Intbd. gn.-gy. sltst.

1945-70 Sh., m. gy., slty., mica.

- 1970-80 Sh., dk. gn.-gy.
 1980-90 Sh., dk. gy.
 1990-2000 Sh., dk. gy. and mdst., gy.-red.
 2000-08 Ls., v. lt. gy. to gn.-gy., v. f. xl. / c. xl. calc.,
 pt. arg. and pt. slty., Crin. (Haskell Ls. Mbr.)

Stranger Fm. top

- 2008-20 Sh., m. gy., slty., mica., pyr., carb.
 2020-22 Mdst., gy.-red.
 2022-31 Sh., as 2nd abv.
 2031-41 Ss., v. lt. gy. to lt. olv. gy., v. f. to f. gr., qtzs., gr.
 sbang. to sbrd. and elong. to eqnt., dol. cmt., carb.
 2041-50 Sh. and mdst. intbd., m. gy. and gy.-red, cly.
 2050-65 Ss., lt. gn.-gy., v. f. to f. gr., qtzs., mica., carb., gr.
 sbang. to sbrd., elong. to eqnt.
 2065-67 Sh., m. gy., slty.
 2067-69 Ss., as 2nd abv.
 2069-79 Sh., m. dk. gy. and mdst., gy.-red, intbd.; slty., mica.,
 fos. / plt. fos.
 2079-80 Coal, shy.
 2080-90 Sh., as 2nd abv., and ss., as 5th abv. intbd.
 2090-2130 Ss., gn.-gy., f. to m. gr., pt. fri., qtzs., gr. ang. to sbrd.
 and elong. to eqnt., mica., / intbd. gy.-red and m. gy.
 mdst.
 2130-32 Ls., fos.
 2132-69 Sh., m. gy. and gn.-gy., pyr. and ss., gn.-gy., qtzs. intbd.
 2169-2234 No samples.
 2234-45 Sh. and ss. intbd., as 2nd abv.