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STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE CHEROKEE GROUP (MIDDLE PENNSYLVANIAN), CENTRAL CHEROKEE BASIN, SOUTHEASTERN KANSAS

by

Michael D. Staton

Kansas Geological Survey
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047-3726

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Michael D. Staton

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and the Faculty of the Graduate School
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the degree of Master of Science.

Anthony W. Walton
Professor in Charge

Roger L. Kaesler

Lawrence L. Brady
Committee Members

Anthony W. Walton
For the Department

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ABSTRACT

Rocks of the Cherokee Group of the Cherokee basin in southeastern Kansas are divided into the Krebs and overlying Cabaniss formations. These units consist of medium- to light-gray shale interbedded with dark-gray shale, rippled sandstone and siltstone, coal, underclay, and argillaceous limestone. Laterally extensive radioactive dark-gray shales serve as a basis for detailed stratigraphic correlation of the Cherokee Group.

Cross sections of the Cherokee Group indicate that the Cherokee basin in Kansas subsided during deposition of the Krebs and lower Cabaniss formations. Sediment progressively onlapped the Nemaha uplift during deposition of the Cherokee Group and eventually covered the uplift before deposition of upper Cabaniss strata.

The distribution of lithofacies of the Cherokee Group reflects numerous environmental changes in the study area due to deltaic progradation or eustatic sea-level changes. During deposition of the lower Cherokee strata between the top of the Mississippian limestone and the Bluejacket B shale (located near the base of the Cabaniss Formation), the Cherokee basin in Kansas is characterized as having a prodeltaic environment during stillstands at high sea level. Stacked channel sandstone bodies of fluvial origin represent lowstands of sea level when deltaic deposition prevailed to the south in Oklahoma.

The strata from the top of the Bluejacket B shale to the top of the V shale in the upper part of the Cabaniss Formation include five major lithologic cycles that can be recognized throughout the study area. Each lithologic cycle consists, from base to top, of marine to

non-marine shale, siltstone, sandstone, underclay, coal, and marine shale. These strata represent an upward transition from marine to non-marine deposition. The sandstone and siltstone represent non-marine deposition by crevasse splays and distributary channels that prograded across the basin from the north and east.

Between the top of the V shale and the top of the Cherokee Group, specific marine shale and limestone units laterally extend from the Cherokee basin into the Sedgwick basin, indicating that a connection of depositional environments occurred during periods of high sea level. Limestone content increases along the western and southern borders of the study area. Sandstone isolith maps for this interval do not indicate a major source of sediment.

ACKNOWLEDGMENTS

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I would like to extend my gratitude to Stephen Wai Leung Cheng, Pat Acker, Lea Ann Davidson, and Gina Ross and the Advanced Projects staff for their invaluable assistance to the study. Special thanks go to Patty Wicker for giving me moral support and keeping me in good spirits. Most of all, I would like to thank my parents, David and Susanne Staton, and grandparents, Bruce and Sally Gernon for their moral and financial support throughout my educational pursuit.

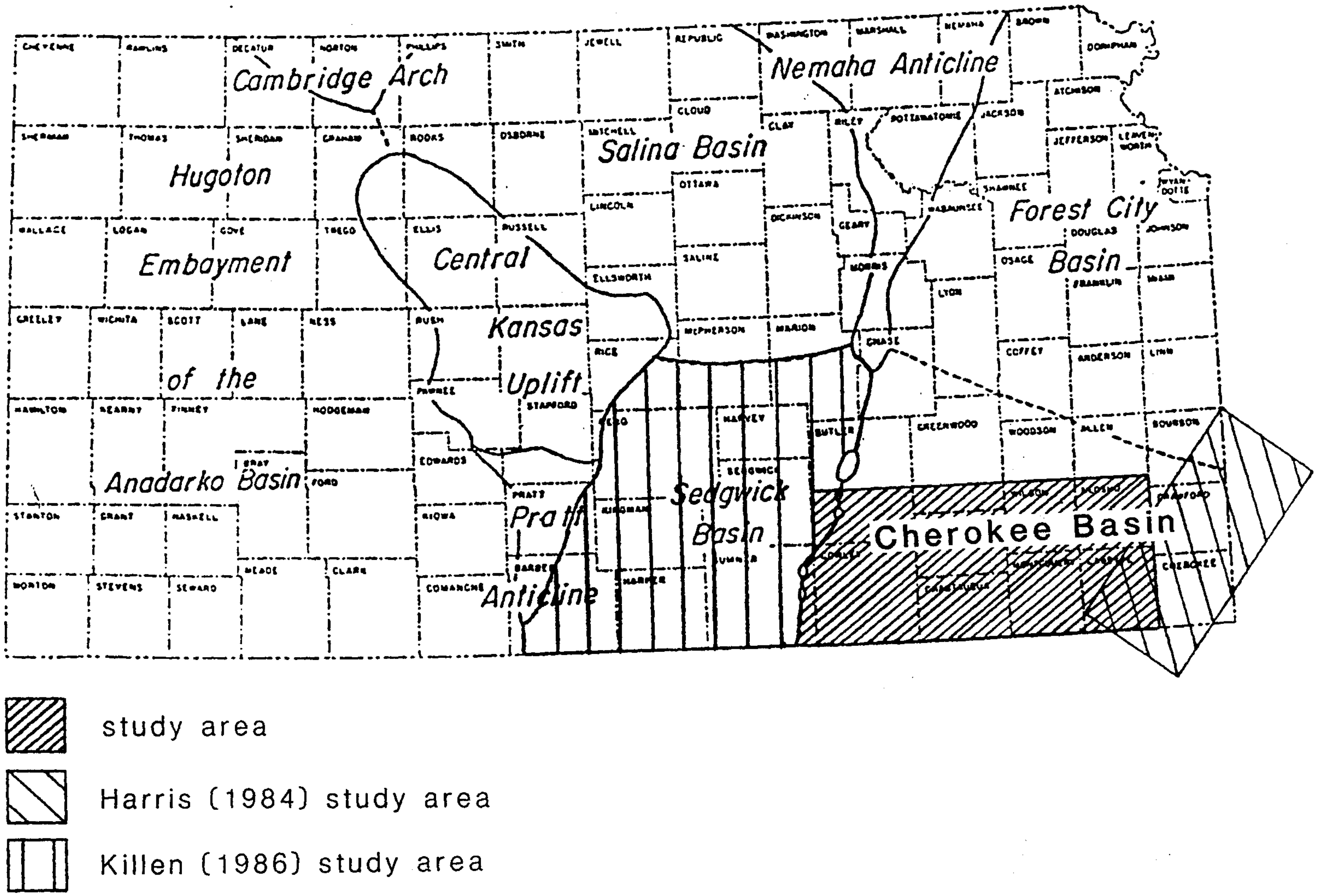
INTRODUCTION

The Cherokee Group (Desmoinesian Stage, Middle Pennsylvanian Series) consists of interbedded shales, sandstones, coals, and thin limestones that lie between the base of the Ft. Scott Limestone (Marmaton Group) and the upper unconformable surface of the Mississippian limestone (Abernathy, 1936). In Kansas, the Cherokee Group is stratigraphically divided into the Cabaniss Formation (upper) and the Krebs Formation (Jewett and others, 1968).

Purpose and Significance of Study

The primary objectives of this study are (1) to provide detailed stratigraphic correlation of the Cherokee Group in the central Cherokee basin, and (2) to interpret depositional environments from examination of sedimentary structures, and vertical and lateral lithofacies distributions. The significance of this study is to establish a thorough correlation of the Cherokee strata within the central Cherokee basin where little detailed stratigraphic information is available. This project will also connect the study areas of previous stratigraphic works of the Cherokee Group by Harris (1984) and Killen (1986) (Fig. 1). The determination of depositional environments and distribution of lithofacies will better define the regional setting of the Cherokee basin during Middle Pennsylvanian time. This research is part of a project to study the major Kansas sedimentary basins and resolve their depositional and tectonic history. Results of this research will provide information on

Figure 1 - Location of study area in relation to study areas of Harris (1984) and Killen (1986) (modified from Merriam, 1963).


Cambridge Arch
Nemaha Anticline
Hugoton
Salina Basin
Forest City
Basin
Embayment
Central
Kansas
Uplift
of the
Anadarko Basin
Sedgwick
Basin
Pratt
Anticline
Cherokee Basin
study area
Harris (1984) study area
Killen (1986) study area

distribution of coal resources in the Cherokee basin as part of a broader study by the Kansas Geological Survey in conjunction with the United States Geological Survey.

Area of Investigation

The study area covers approximately 6,000 square miles (approximately 15,600 km^2) within a ten-county area in southeastern Kansas (Fig. 2). It includes the area between Township 27 South to the Kansas-Oklahoma border and from Range 3 East to Range 22 East. The subsurface thickness of the Cherokee Group within the central Cherokee basin ranges from 110 feet (33 m) on the eastern flank of the Nemaha uplift (Butler County) to 565 feet (170 m) in southeastern Labette County.

Previous Investigations

The original reference to the Cherokee Group was made by Haworth and Kirk (1894) following description of a section along the banks of the Neosho River in southeastern Kansas. Early stratigraphic classifications of the Cherokee Group strata were based upon coal bed or sandstone distribution (Abernathy, 1936; 1937; Pierce and Courtier, 1937; Searight and others, 1953; Howe, 1956; Branson, 1957; and Searight and Howe, 1961). Abernathy (1936) subdivided the Cherokee Group in southeastern Kansas into fifteen cyclothems and proposed that each be designated as a formation. Howe (1956) partitioned the Cherokee Group into 18 formations, each extending from the top of a coal bed to the top of the next overlying coal bed.

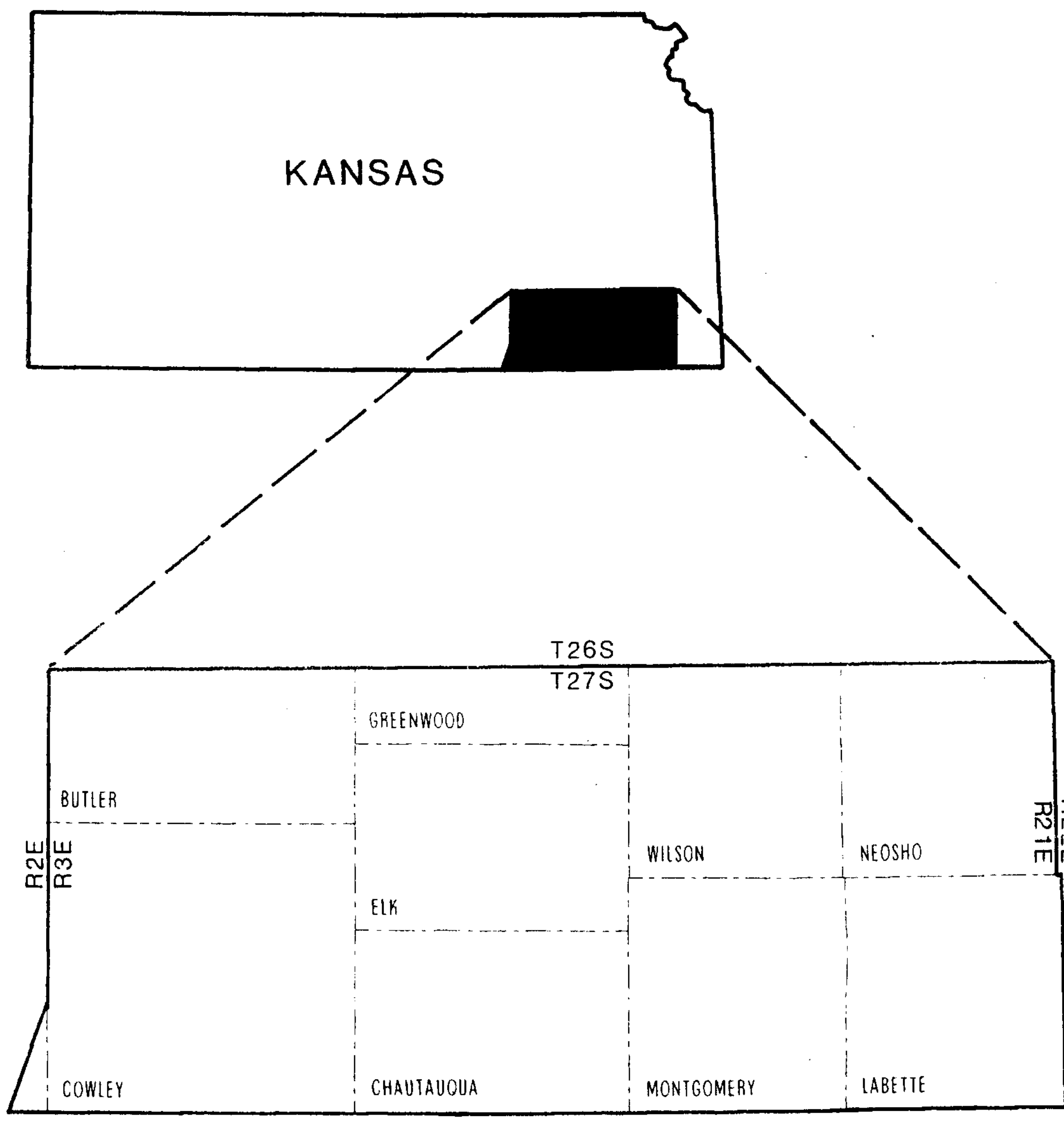


Figure 2 - Loction of study area in the state of Kansas.

Oakes (1953) discovered a time-stratigraphic break within the Cherokee strata at the top of the Seville Limestone and divided the strata into the Cabaniss Group and the Krebs Group. Due to convenience and mappability, the Cherokee Group classification was re-adopted and the Cabaniss and Krebs were relegated to subgroup status (Howe, 1956) and later, formation status (Jewett, 1959). These earlier works form the basis of the current stratigraphic classification (Jewett and others, 1968).

More recent studies of stratigraphy and depositional environments include the work of Seevers (1975), who described Cherokee strata that crop out in Cherokee County, Kansas. Brady and others (1976) summarized the stratigraphy of coal-bearing units and estimated the strippable demonstrated coal reserves of Kansas. Murphy (1978) examined middle Cherokee Group outcrops in Kansas and Missouri to establish lithofacies and compare them with lithofacies of modern depositional environments. Lardner (1984), Deneson (1985), and Brenner (in review) have studied the Lagonda interval in southeastern Kansas and suggested reclassification of stratigraphic nomenclature in the upper Cabaniss Formation. Harris (1984) examined the stratigraphy and determined the depositional environments of the Krebs Formation in southeastern Kansas. Killen (1986) correlated the stratigraphy and described the depositional environments of the Cherokee Group within the Sedgwick basin.

Several previous studies focused on the stratigraphy and distribution of sandstone units in the Cherokee Group. Bass (1934) argued that shoestring sandstones of the Cherokee Group in southeastern Kansas were deposited in offshore barrier-bar environments, due to their distribution patterns and textural and morphological characteristics. Hayes (1963) concluded that sandstone units that crop out in southwestern Missouri were of tidal-flat or tidal-channel origin due to the presence of bi-directional cross-bedding and flaser, wavy, and lenticular bedding. Visher and others (1971) suggested that a single river system, originating from the north, supplied the sediment that was deposited in the deltaic sequences of the Bartlesville Sandstone of northeastern Oklahoma. Cole (1969), Wanless and others (1970), Visher and others (1971), and Ebanks and others (1977) determined the Cherokee Group sandstones to be of fluvio-deltaic origin due to distribution patterns and sedimentary structural features. Ebanks and James (1974), Ebanks (1977), Wells (1979), and Ebanks and Weber (1982) described sandstone distributions and evaluated the heavy-oil and tar-sand potential of the Cherokee Group in southeastern Kansas and southwestern Missouri. Hulse (1978), Rofheart (1980), Woody (1983), and Bouquet (1984) studied the diagenesis and petrophysical properties of several petroleum-bearing sandstones in southeastern Kansas.

METHODS OF INVESTIGATION

This study was based upon the examination of geophysical well logs, cores, well cuttings, and outcrops. All data collected were used to make structural contour maps, isopach maps, and net sandstone, shale, limestone, and coal isolith maps of specific intervals of the Cherokee Group.

Well Log Analysis

Most of the data obtained in this project were from analyses of geophysical well logs. A total of 343 well logs, mostly from files of the Kansas Geological Survey with some donated by Cornish Wireline Services of Chanute, Kansas, were interpreted and correlated with an average spacing of two wells per township (Fig. 3). Gamma ray, neutron, and density logs were examined due to their distinct, correlatable responses and dependability for identifying lithologies.

Shale content was calculated from gamma ray logs by drawing a 50 percent shale line midway between a minimum gamma ray value for a clean carbonate or clean sandstone unit (GRcl) and a maximum gamma ray value for a normal low-uranium shale bed (GRsh). A gamma ray index (Igr) of 0.63 was established for consolidated formations containing 50 percent shale (Dresser Atlas, 1979). Substituting the values into the equation

$$Igr = \frac{GR - GRcl}{GRsh - GRcl}$$

and solving for GR,

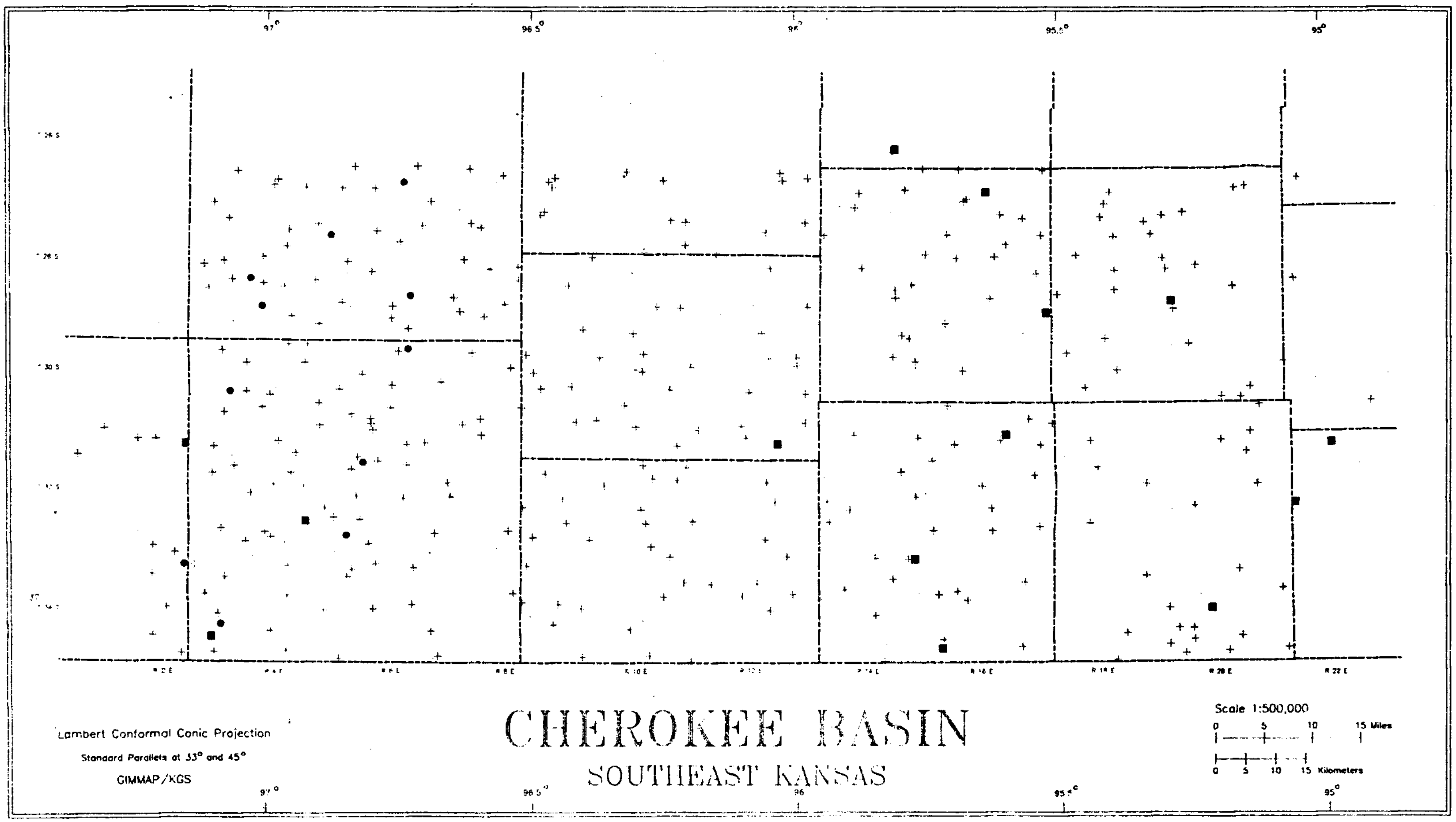


Figure 3 - Location of examined geophysical well logs (+), cores (■), and well cuttings (●).

yielded the API unit on the log where the 50 percent shale line was drawn. Gamma ray units greater than the 50 percent shale value represented shale and units less than the 50 percent shale value characterized sandstone or limestone.

Due to similar responses, sandstone and limestone were often difficult to differentiate on gamma ray and neutron logs. Density logs, however, which estimate the bulk density and porosity of a formation, showed distinguishably lower bulk-density values for sandstone than for limestone (Fig. 4). In areas where density logs did not exist, well cuttings, cores, driller's logs, and scout cards were examined to determine lithologies.

Lithologic Analysis

Detailed verbal and graphic description of cores and well cuttings provided sedimentological and stratigraphic information (Fig. 3). Cores were supplied by the Kansas Geological Survey core library in Lawrence, Kansas, and Oil field Research Laboratory of Chanute, Kansas. A total of 14 wetted cores were examined for lithology, color, texture, sedimentary structures, fossil content, and diagenesis. There were relatively few cores of the Cherokee Group from the study area, and most were extracted only from oil-producing sandstone units. Two complete cores of the Cherokee Group, previously described by Harris (1984) were analyzed. Because of the lack of long cores from the central Cherokee basin, two cores from within 4 miles (6.4 km) of the study area were examined to provide additional sedimentological data.

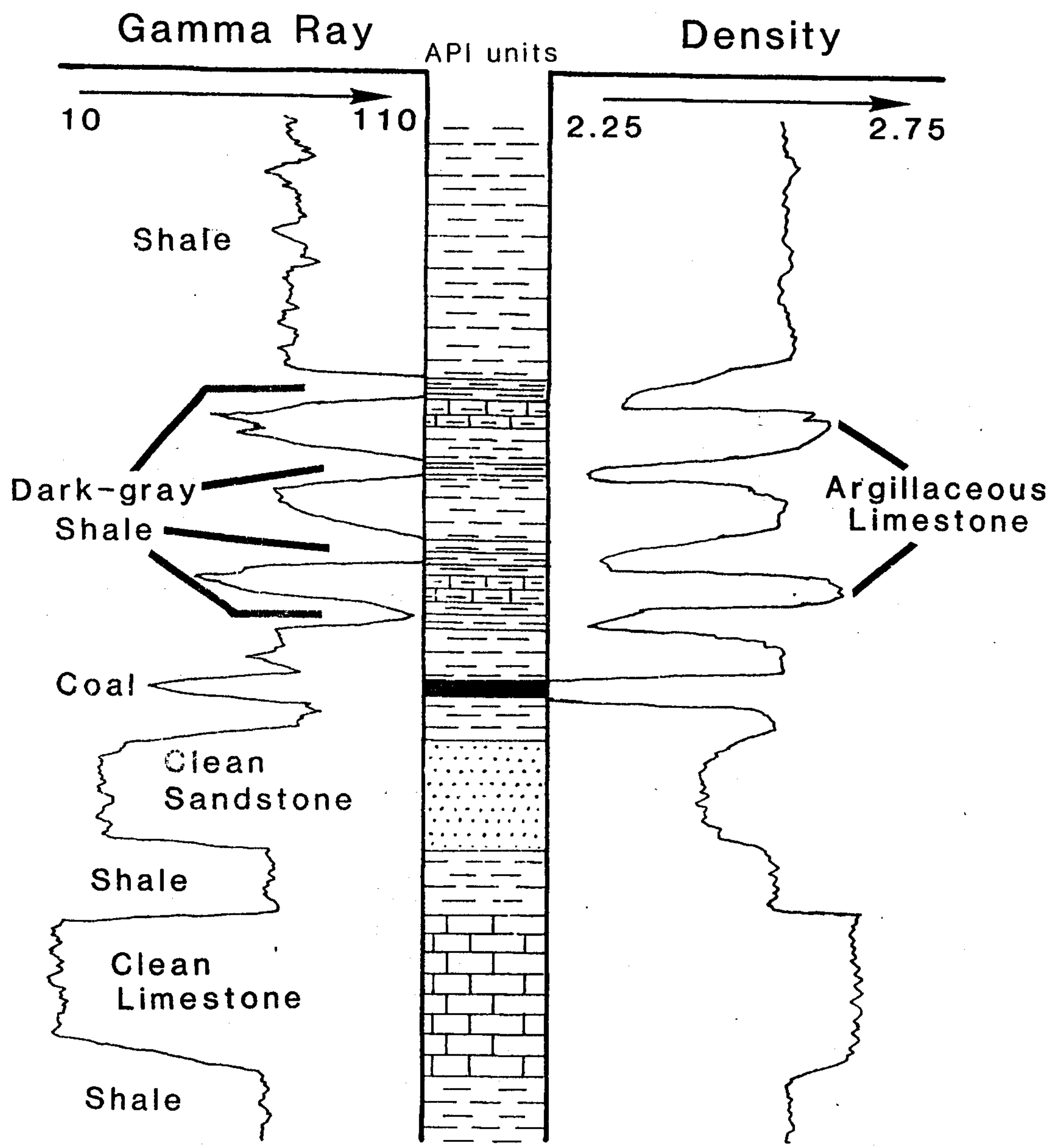


Figure 4 - Lithologic responses on a typical gamma ray - density log.

Drill cuttings were provided by the Kansas Geological Survey sample library in Wichita, Kansas. Cuttings from eleven wells that penetrated the total thickness of the Cherokee Group and their corresponding geophysical logs were thoroughly examined (Fig. 3). The samples were used primarily distinguish sandstone from limestone on the corresponding log. Sample spacing was at five foot (1.5 m) or ten foot (3.1 m) intervals, with examination and description techniques derived from Swanson (1981).

Detailed driller's logs on file at the Kansas Geological Survey were analyzed throughout the study area. The driller's logs that corresponded to available geophysical logs increased the accuracy of determining lithologies from geophysical logs.

Computer Applications

All sedimentological and stratigraphic data obtained from geophysical well logs were entered into two databases on the Data General MV 20000 mainframe computer system at the Kansas Geological Survey. The purpose of the databases is to record information from this project, a previous study (Killen, 1986), and future studies. This database format allows the combination of data from individual projects and will be used in a broader study of the major sedimentary basins in Kansas.

The first database (Fig. 5) contains the well identification number, elevation, longitude, latitude, quadrangle map identification number, and the basic information listed on the cover page of a geophysical well log. Well locations were plotted on 7.5 minute

```
                               -- CHEROKEE BASIN --
PLEASE ENTER THE DECIMAL POINT, IF ANY, AT THE POSITION POINTED BY ^.

 WELL ID              WELL NAME
 (218)      (HARRIS #2           )

          COMPANY                            FIELD
 (OLYMPIC PETROLEUM CO.     )  (MANSER               )

                    QUAD.
   LOG      CNTY    MAP      SEC    TWN    RNG      LOCATION
 (GRD  )   (CO)    (0444)   (30)   (S31)  (E 7)   (NW)(SW)(NE)


  LONGITUDE    LATITUDE      ELEV.(GL)       X            Y
 (-96.70562)  ( 37.32590)   (1409.0)     (  5.70191)  (  4.87375)
     ^             ^            ^             ^            ^

    GEOLOGIST                      COMMENT
 (M.STATON      )    (                               )

ENTERING EDIT MODE     CTRL-C: send   CTRL-R: panic
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Figure 5 - Terminal display of database #1.

topographic maps, then digitized using a Tektronix computer system to determine longitude and latitude. The second database (Fig. 6) consists of the marker bed identification number, marker bed depth, thickness to the next shallower identified marker bed, and lithologic division of an interval into thickness of shale, sandstone, limestone, and coal. Total thickness of the Cherokee Group in the well and of each lithology are calculated and displayed.

The Surface II computer graphics system (Sampson, 1978) was used to contour structure, isopach, and net isolith maps for specific intervals of the Cherokee Group. Three-dimensional block diagrams were constructed for each contoured map. Block diagrams did not show quantitative information, but were useful for three-dimensional interpretations. Surface II was also used to plot locations of wells and marker beds. Marker location maps revealed the lateral extension of each marker bed. In locations where a particular marker does not exist or cannot be recognized, a specific number (8888.8 or 9999.9) was entered as the depth of that marker. On all plots, a marker known to have not been deposited is characterized by a triangle and a marker indistinguishable on the well log by an "X". Where a channel sandstone body cuts away an underlying marker bed, the thickness of the intervals above and below the marker is not calculated, and an "X" is posted on all isopach and isolith maps of those intervals.

```
                        -- CHEROKEE BASIN --
 PLEASE ENTER THE DECIMAL POINT, IF ANY, AT THE POSITION POINTED BY ^.

 WELL ID#             GEOLOGIST                        COMMENT
  (218)            (M.STATON      )    (                                    )

      -- MARKER --                  -- LITHOLOGIC THICKNESS --
    ID     DEPTH      THK           SHALE    S. S.    L. S.    COAL
  (1000) (2644.0) (    .0)         (    .0) (    .0) (    .0) (   .0)
  ( 960) (8888.8) (    .0)         (    .0) (    .0) (    .0) (   .0)
  ( 900) (2700.0) ( 56.0)          ( 53.0) (    .0) (   3.0) (   .0)
  ( 780) (2722.0) ( 22.0)          ( 17.5) (    .0) (   4.5) (   .0)
  ( 720) (2753.0) ( 31.0)          ( 29.0) (   2.0) (    .0) (   .0)
  ( 680) (2763.0) ( 10.0)          (   8.0) (    .0) (   1.0) (  1.0)
  ( 640) (2774.0) ( 11.0)          (   9.0) (   2.0) (    .0) (   .0)
                ^         ^              ^        ^        ^       ^
                        TOTAL            TOTAL    TOTAL    TOTAL   TOTAL     CONTINUE TO
                       (260.0)          (238.5) (  9.0) (  8.5) ( 4.0)     NEW CARD (A)
                          ^                ^        ^        ^       ^
  NEW RESPECTIVE TOTALS WILL BE CALCULATED AFTER YOU SEND THIS CARD.

ENTERING EDIT MODE      CTRL-C: send    CTRL-R: panic


                        -- CHEROKEE BASIN --
 PLEASE ENTER THE DECIMAL POINT, IF ANY, AT THE POSITION POINTED BY ^.

 WELL ID#             GEOLOGIST                        COMMENT
  (218)            (M.STATON      )    (                                    )

      -- MARKER --                  -- LITHOLOGIC THICKNESS --
    ID     DEPTH      THK           SHALE    S. S.    L. S.    COAL
  ( 590) (2802.0) ( 28.0)          ( 28.0) (    .0) (    .0) (   .0)
  ( 510) (2822.5) ( 20.5)          ( 18.5) (   2.0) (    .0) (   .0)
  ( 200) (2869.0) ( 46.5)          ( 43.5) (   3.0) (    .0) (   .0)
  ( 120) (2892.0) ( 23.0)          ( 21.0) (    .0) (    .0) (  2.0)
  (    0) (2904.0) ( 12.0)         ( 11.0) (    .0) (    .0) (  1.0)
  (    0) (     .0) (    .0)       (    .0) (    .0) (    .0) (   .0)
  (    0) (     .0) (    .0)       (    .0) (    .0) (    .0) (   .0)
                ^         ^              ^        ^        ^       ^
                        TOTAL            TOTAL    TOTAL    TOTAL   TOTAL     CONTINUE TO
                       (260.0)          (238.5) (  9.0) (  8.5) ( 4.0)     NEW CARD ( )
                          ^                ^        ^        ^       ^
  NEW RESPECTIVE TOTALS WILL BE CALCULATED AFTER YOU SEND THIS CARD.

ENTERING EDIT MODE      CTRL-C: send    CTRL-R: panic
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Figure 6 - Terminal display of database #2.

REGIONAL GEOLOGIC SETTING

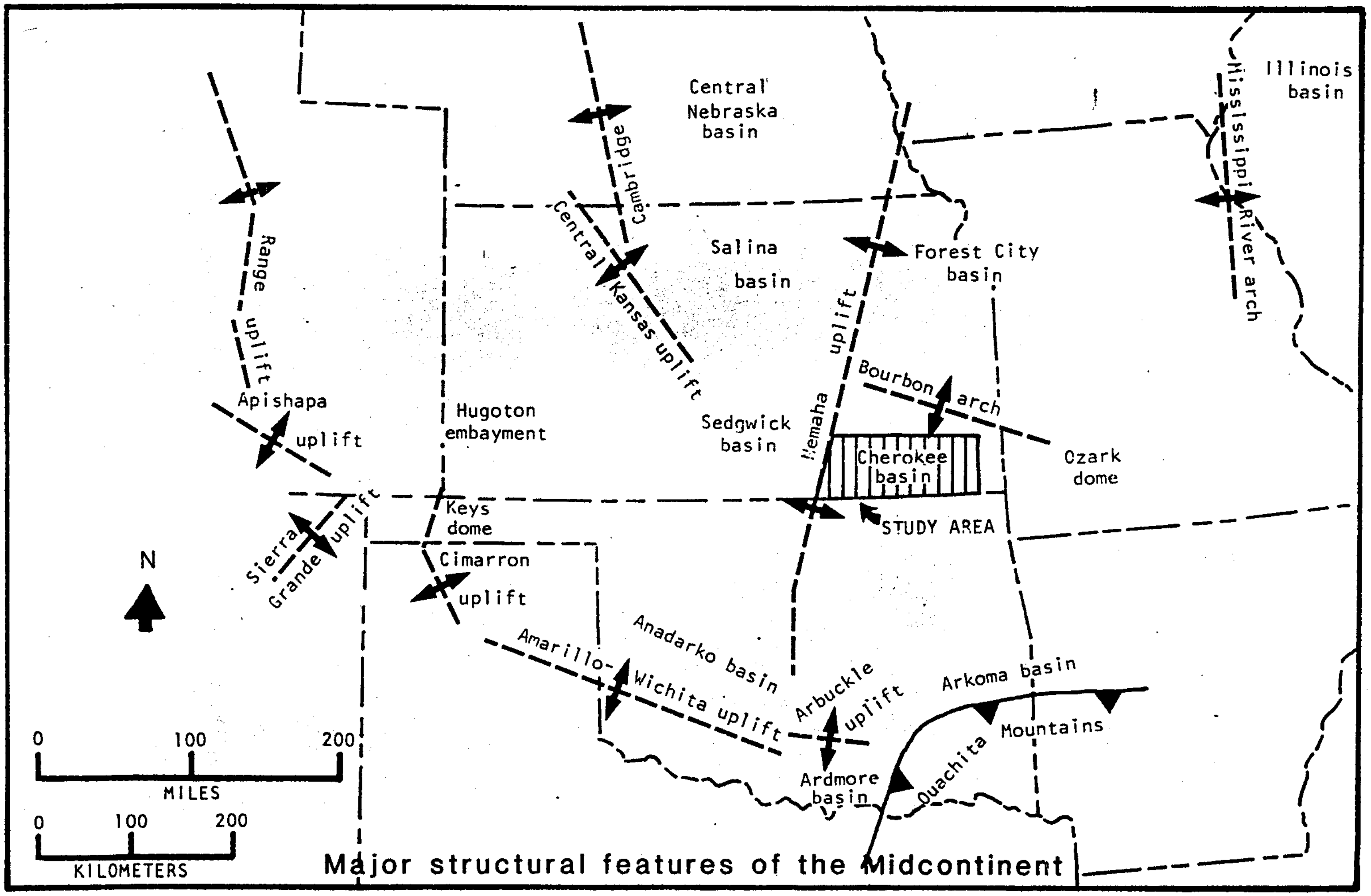
Structural Setting

During deposition of the Cherokee Group, the study area was part of the slowly subsiding, intracratonic Cherokee basin (Fig. 7). The basin is bounded by the Nemaha uplift to the west, the by Ozark uplift to the east, and by the Bourbon arch to the north (Jewett, 1951). To the south, Cherokee Group strata gradually thicken into the deeper Arkoma basin (Gould, 1927; Ham and Wilson, 1967; and Houseknecht and others, 1983).

In southeastern Kansas, northeastern Oklahoma, and southwestern Missouri, sediment of the Cherokee Group was deposited disconformably on a karst surface that developed on Mississippian limestone (Saueracker, 1966). Cherokee rocks crop out in the southeastern corner of Kansas and the adjoining areas in Oklahoma and Missouri (Harris, 1984). In southeastern Kansas, the Cherokee strata have an overall west-northwestward dip of approximately 20 to 30 feet per mile (4 to 6 m per km) (Ebanks and others, 1977).

The structural framework of the Cherokee basin was directly influenced in early to middle Desmoinesian time by the orogenic activity of the Ouachita system to the south (Ham and Wilson, 1967). This tectonic activity resulted in a number of uplifts and high-angle fault systems in the Midcontinent, including the Nemaha ridge, Ozark dome, and Bourbon arch. The Arkoma basin developed due to rapid subsidence, which occurred adjacent to the uplifting Ouachita Mountains (Frezon and Dixon, 1975). North of the Arkoma basin, such

Figure 7 - Location of study area and major structural features of the Midcontinent (modified from Wanless, 1969).



Major structural features of the Midcontinent shallow structural basins as the Cherokee and Forest City basins formed by gradual subsidence.

Stratigraphic Setting

In southeastern Kansas, the Cherokee Group consists mainly of shale and sandstone with minor amounts of coal, underclay, and thin limestone beds (Jewett, 1959). The Cherokee Group contains the earliest Pennsylvanian cyclic strata in the Midcontinent (Howe, 1956). Deposition of Cherokee strata occurred during a major transgression that was interrupted by minor progradational pulses of sedimentation. This interpretation is supported by the successive onlap of younger rocks onto positive structural features, the lateral continuity of thin marine and non-marine beds, and the transition from predominantly clastic sediments to carbonates during the Desmoinesian Age (Ham and Wilson, 1967; Visher and others, 1971; Ebanks and James, 1974; and Rascoe and Adler, 1983).

Early stratigraphic studies of the Cherokee Group in southeastern Kansas were based on the correlation of cyclic deposits from the top of one coal bed to the top of the next higher coal bed (Abernathy, 1926; Moore, 1949; Howe, 1956) (Fig. 8). Each cyclic sequence was designated as a formation. In order to correlate discontinuous sandstones from outcrops to the subsurface, informal stratigraphic intervals were established (Ebanks and others, 1977; Hulse, 1978) (Fig. 8). The present study and other recent works (Harris, 1984; Killen, 1986) use radioactive dark-gray shales as marker beds to establish and correlate stratigraphic intervals. The formal

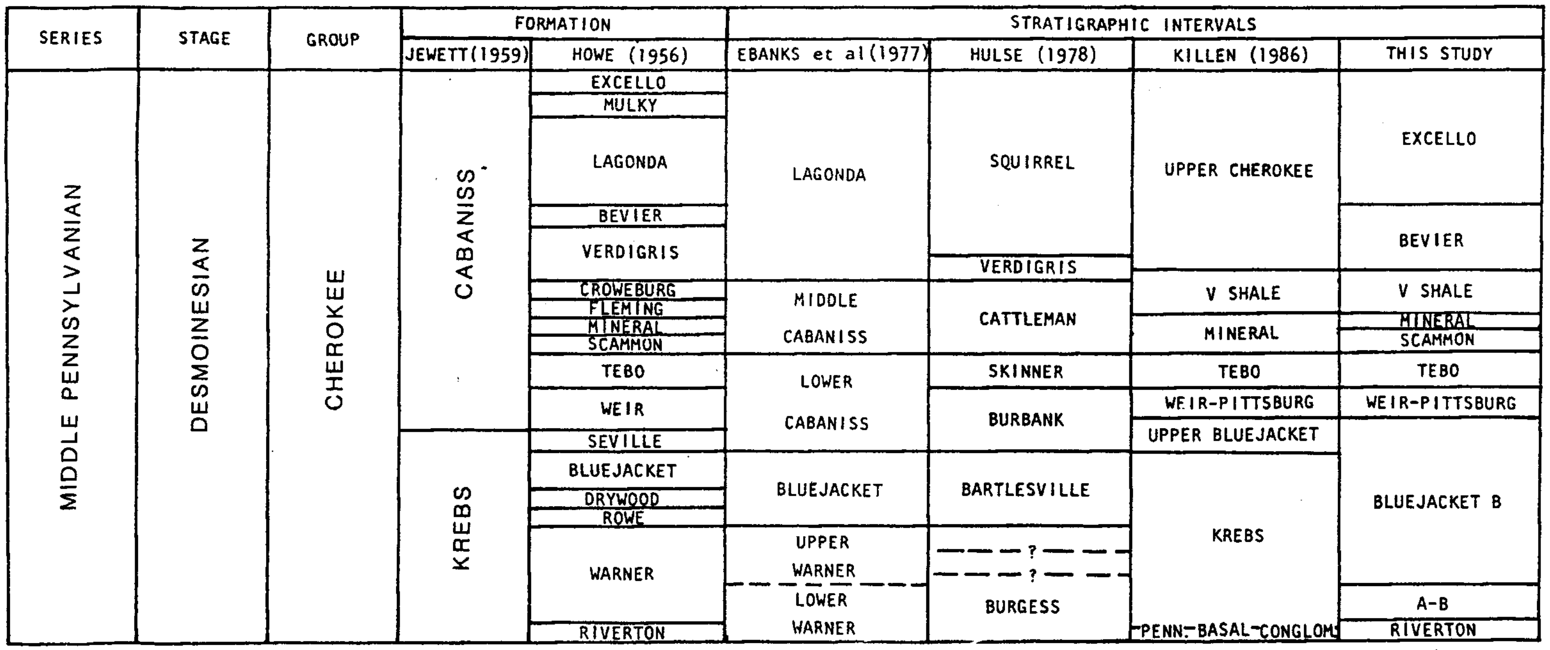


Figure 8 - Stratigraphic classifications of the Cherokee Group in southeastern Kansas (modified from Woody, 1983).

stratigraphic classification of the Cherokee Group in southeastern Kansas by the Kansas Geological Survey is illustrated in Figure 9.

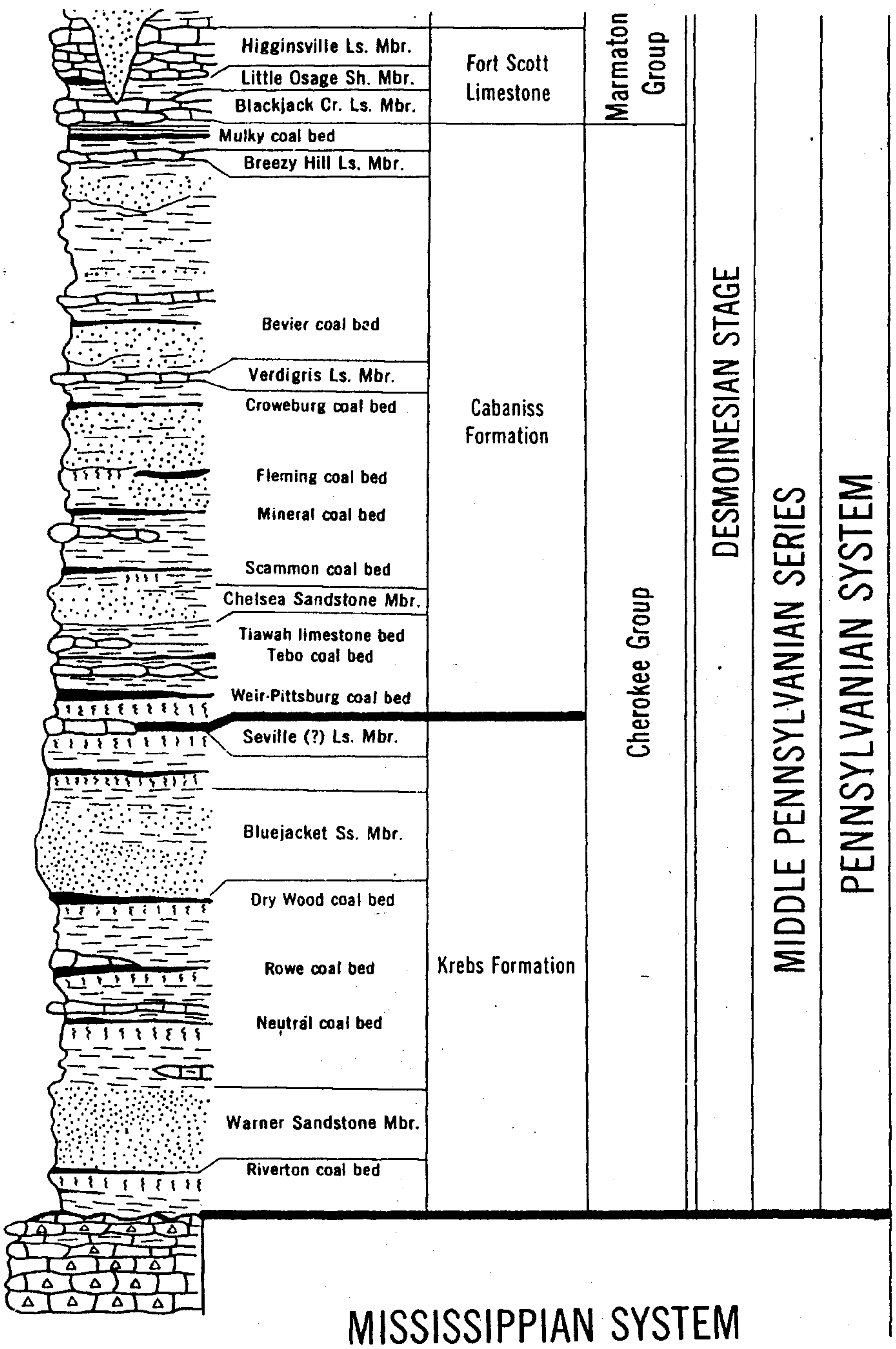


Figure 9 - Formal stratigraphic classification of the Cherokee Group (modified from Zeller, 1968).

STRATIGRAPHY

Dark-gray shale beds are the most laterally persistent units in the Cherokee basin and are used as stratigraphic markers in this study. These shales have a high uranium content and are easily recognized on gamma ray logs. Within the study area, these marker beds typically overlie coal beds or seatrock units where the coal bed is absent. Correlations were extended from Crawford County westward into the Sedgwick basin to stratigraphically link previous studies by Harris (1984) and Killen (1986) and to show that certain marker beds could be correlated in the Cherokee and Sedgwick basins (Fig. 10 and Plate 1). A network of closed-loop cross sections were constructed to reinforce stratigraphic correlations (Fig. 11). A composite section of the Cherokee Group in southeastern Kansas (Fig. 12) reveals the stratigraphic location of marker beds and other units used in this study and includes the formal or informal nomenclature of these units. Informal units that were designated in this study are underlined at first mention in the text.

Twelve stratigraphic markers were established and correlated in this study: (1) the Excello shale (the dark-gray shale that marks the top of the Cherokee Group; Howe, 1956, (used by the Iowa Geological Survey to designate the base of the Marmaton Group; Ravn and others, 1984), (2) the <u>Iron Post shale</u> (the dark-gray shale above the Iron Post coal bed), (3) the <u>Bevier shale</u> (the dark-gray shale above the Bevier coal bed), (4) the V shale (the dark-gray shale that lies below the Verdigris Limestone Member and above the Croweburg

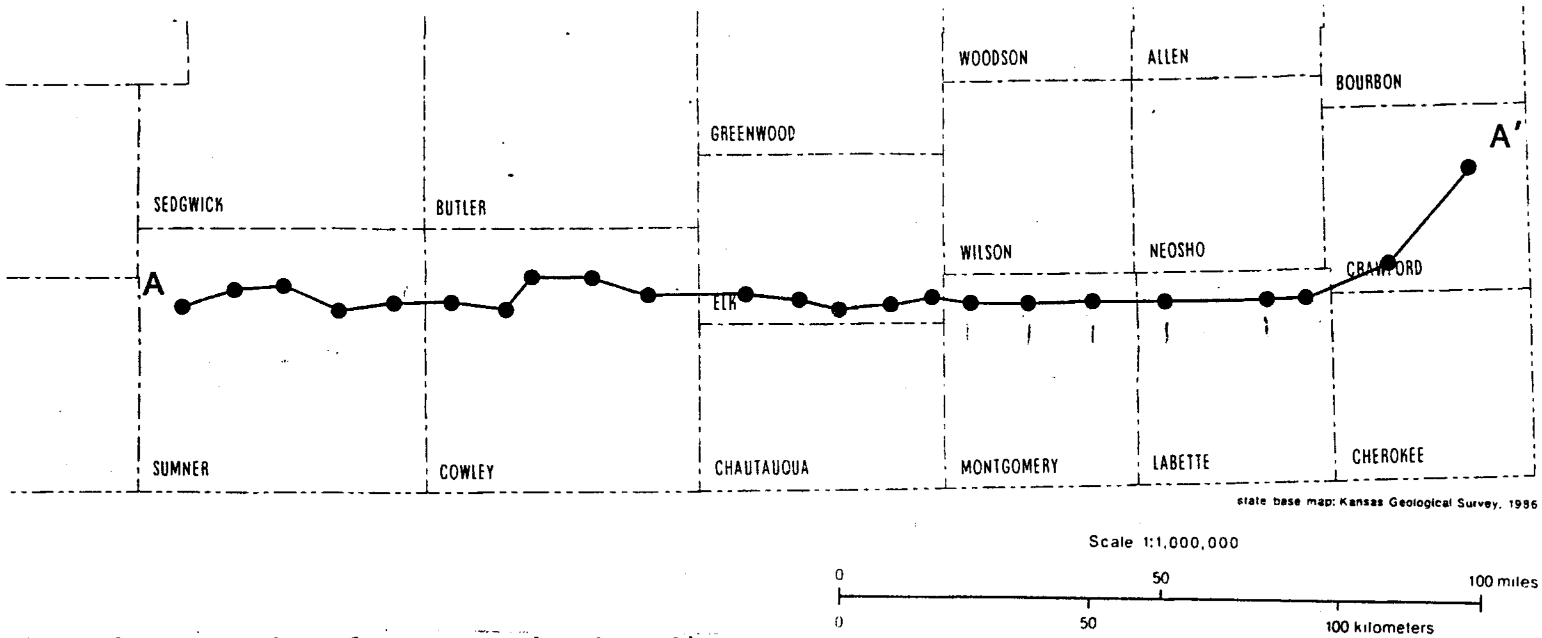


Figure 10 - Location of cross section A to A'.

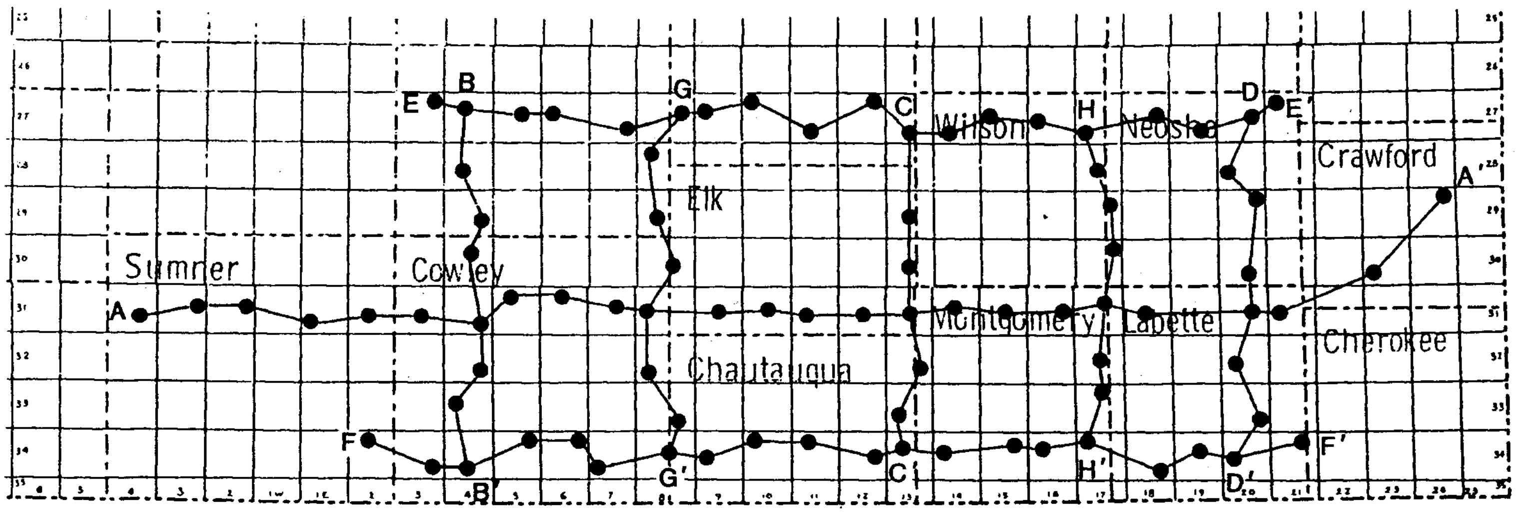
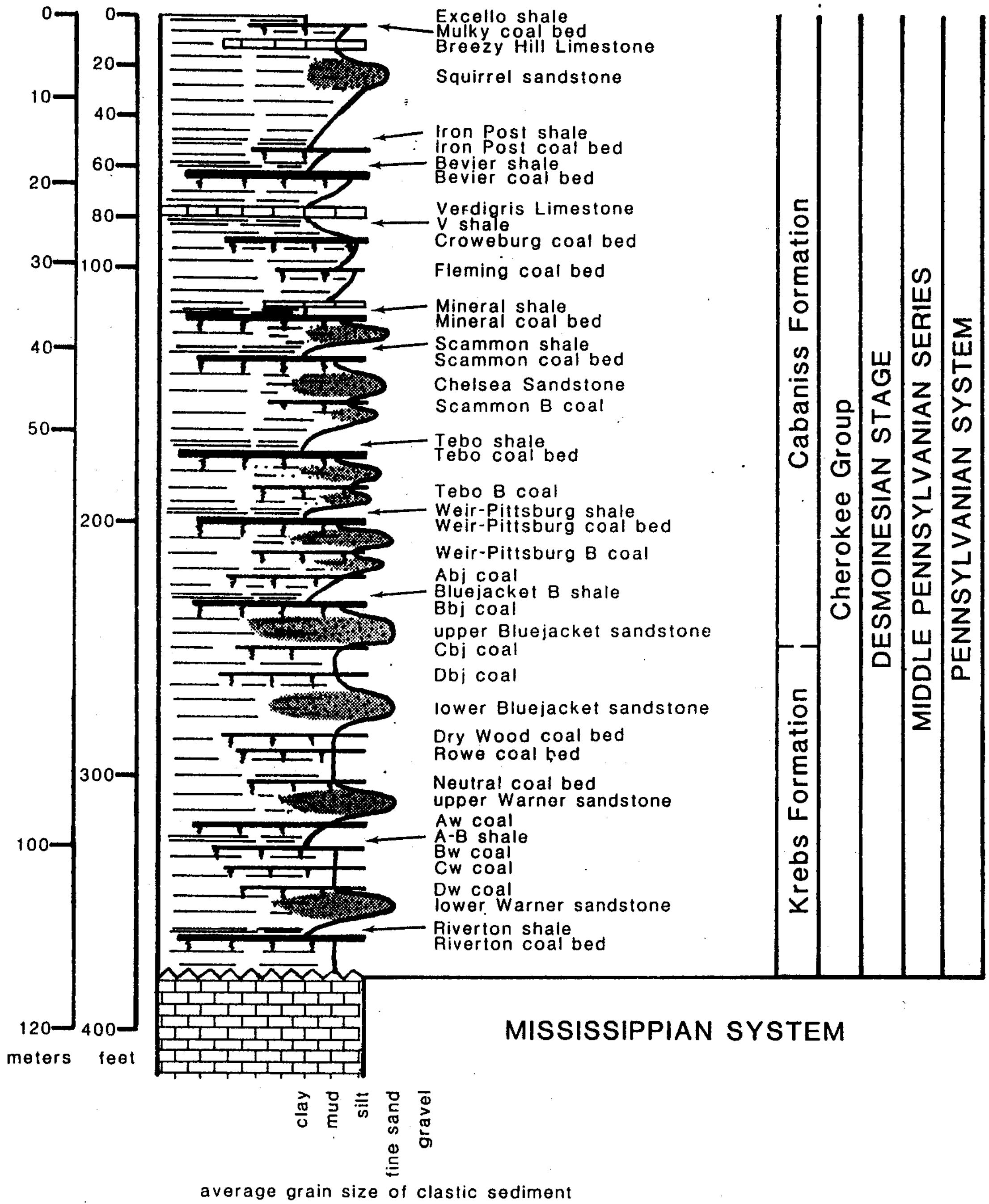


Figure 11 - Closed loop network of cross sections in study area.

Figure 12 - Composite section of the Cherokee Group in southeastern Kansas (modified from Harris, 1984).

COMPOSITE SECTION OF THE CHEROKEE GROUP, SOUTHEASTERN KANSAS



coal bed; Schlinsog and Angino, 1983), (5) the Mineral shale (the dark-gray shale above the Mineral coal bed), (6) the Scammon shale (the dark-gray shale above the Scammon coal bed), (7) the Tebo shale (the dark-gray shale above the Tebo coal bed), (8) the Weir-Pittsburg shale (the dark-gray shale above the Weir-Pittsburg coal bed), (9) the Bluejacket B shale (the dark-gray shale above the Bbj coal; Harris, 1984), (10) the A-B shale (the dark-gray shale that lies between the Aw and Bw coal beds; Harris, 1984), (11) the Riverton shale (the dark-gray shale above the Riverton coal bed), and (12) the top of Mississippian limestone. The A-B shale marker occurs between the Aw and Bw coals if both beds are present or above a coal if only one is present and can not be distinguished as either Aw or Bw. Within the study area, the two coal beds typically lie less than ten feet apart.

Marker beds were assigned sequential identification numbers, corresponding with Killen (1986), that were entered into the second database. The marker at the top of the Cherokee Group (the Excello shale) was designated number 1000, and the base of the group (the top of the Mississippian limestone) was 0. The remaining marker beds were identified with a number corresponding to stratigraphic position within the Cherokee Group: the Iron Post shale - 960, Bevier shale - 900, V shale - 780, Mineral shale - 720, Scammon shale - 680, Tebo shale - 640, Weir-Pittsburg shale - 590, Bluejacket B shale - 510, A-B shale - 200, and the Riverton shale - 120. The Reese Wingard Phillips # 1 gamma ray - neutron log depicts normal Cherokee Group log responses and can be used as a type log for correlation in the Cherokee basin (Fig. 13).

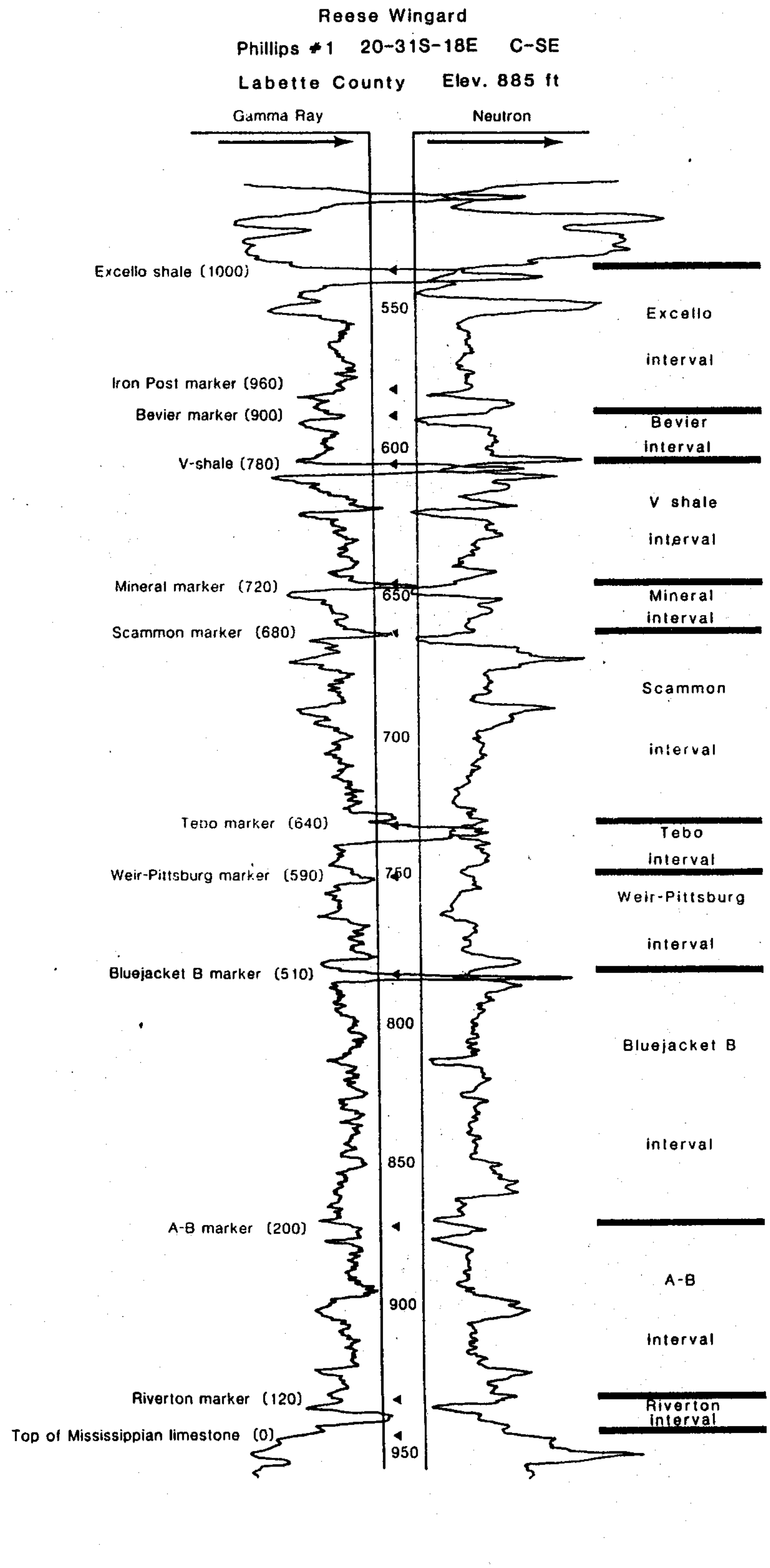
Except for the Iron Post shale, marker beds were distinguishable throughout most of the study area. The Iron Post shale and the underlying coal were recognizable only in the south-central and northwestern portions of the study area (Fig. 14). The A-B marker is not present in areas having thick upper Warner sandstone deposits (Ebanks and others, 1977).

The top of the Seville Limestone Member marks the boundary between the Krebs and Cabaniss formations (Jewett, 1959). The Seville Limestone could not be recognized on geophysical well logs. Due to widespread mappability, the Tebo shale might be considered as a possible boundary between the Krebs and Cabaniss formations. This radioactive shale is easily distinguishable on gamma ray logs throughout the subsurface of the Sedgwick (Killen, 1986) and Cherokee basins (Fig. 15). The Tebo shale is also recognizable in outcrop due to association with the Tebo coal and underclay unit and the overlying Tiawah limestone.

Riverton Interval - (0 - 120)

The interval from the top of the Mississippian limestone to the top of the Riverton shale ranges in thickness from 4 to 30 feet (1.2 to 9 m) (Fig. 16). Variable thickness patterns are probably due to deposition on top of the Mississippian limestone unconformity. The interval consists mainly of light- to dark-gray shale interbedded

Figure 13 - Type gamma ray - neutron log of the Cherokee Group in the Cherokee basin with the designated stratigraphic intervals.


Reese Wingard
Phillips #1 20-31S-18E C-SE
Labette County Elev. 885 ft
Gamma Ray
Neutron
Excello shale (1000)
Iron Post marker (960)
Bevier marker (900)
V-shale (780)
Mineral marker (720)
Scammon marker (680)
Tebo marker (640)
Weir-Pittsburg marker (590)
Bluejacket B marker (510)
A-B marker (200)
Riverton marker (120)
Top of Mississippian limestone (0)
550
600
650
700
750
800
850
900
950
Excello interval
Bevier interval
V shale interval
Mineral interval
Scammon interval
Tebo interval
Weir-Pittsburg interval
Bluejacket B interval
A-B interval
Riverton interval

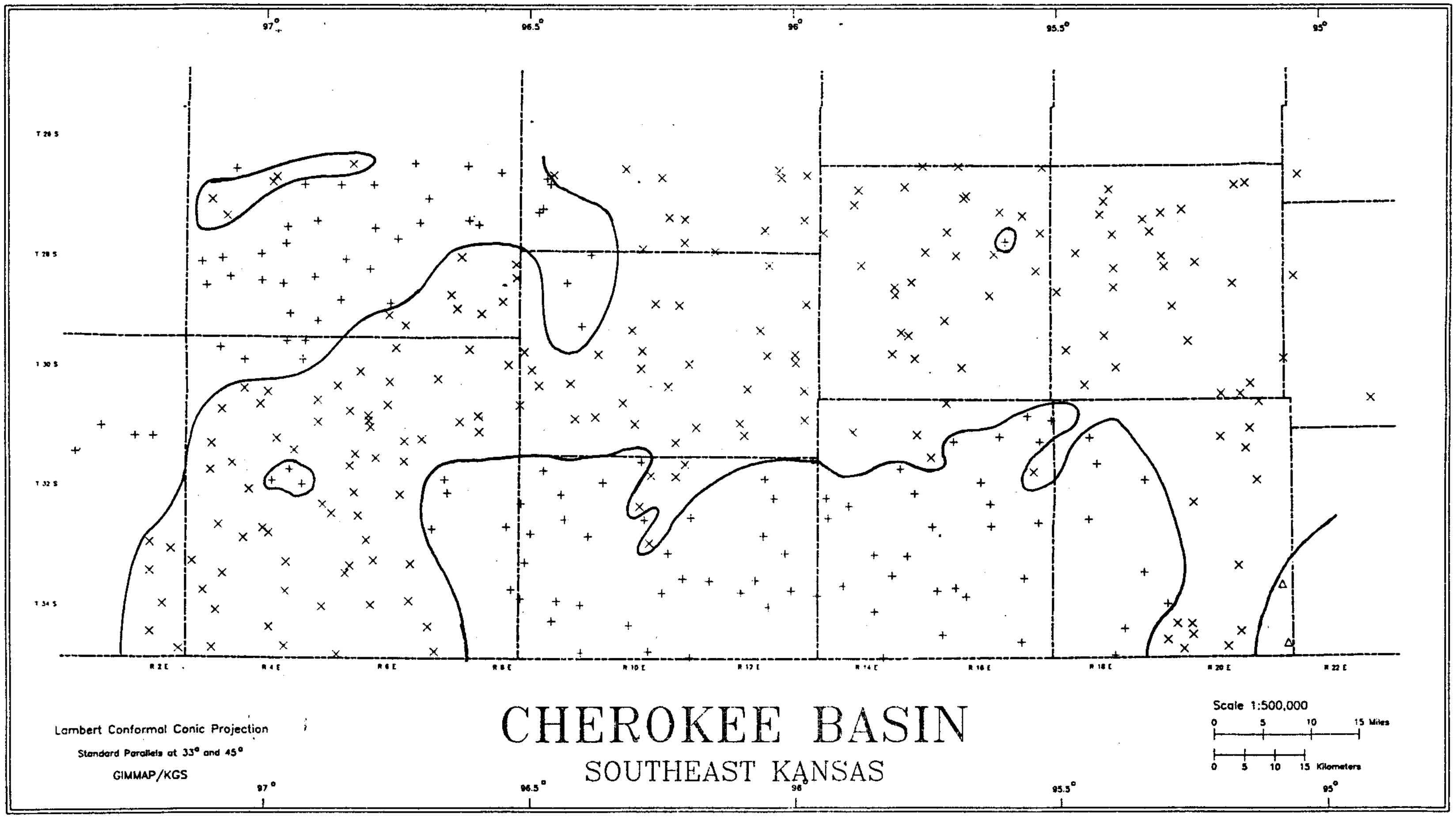


Figure 14 - Location of the Iron Post marker bed. (+: marker present, X: marker not recognized, Δ: marker not present)

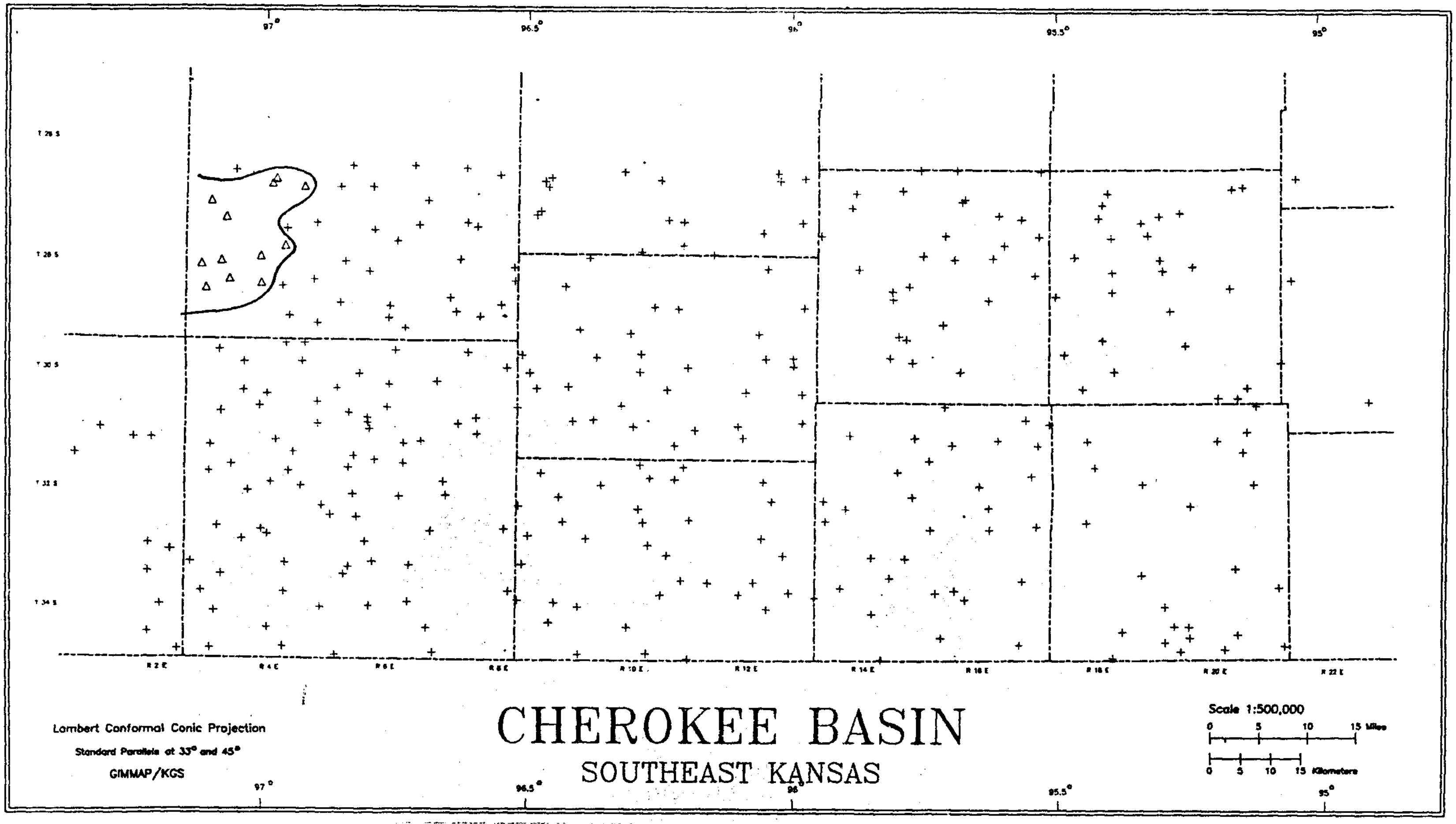


Figure 15 - Location of the Tebo marker bed. (+: marker present, Δ: marker not present)

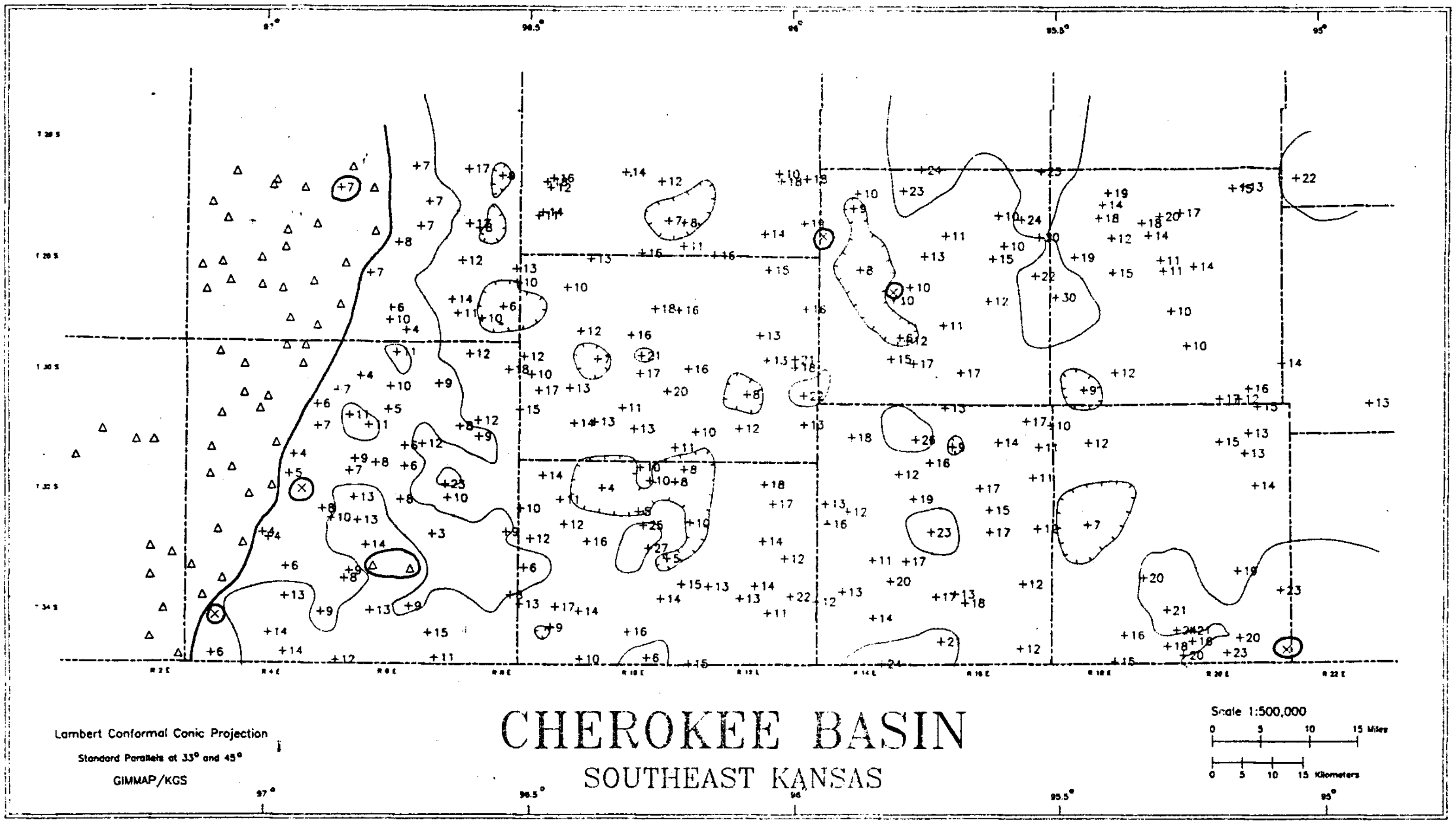


Figure 16 - Isopach map of the Riverton interval; contour interval = 10 feet. (: interval thickness indeterminable, : total interval not present)

with locally occurring siltstone, sandstone, and coal units. A thin sandstone is present locally at the base of the interval.

The Riverton marker is recognizable on most logs due to a high gamma ray response and association with the underlying Riverton coal bed. The Riverton coal is the first laterally extensive coal bed above the Mississippian limestone and ranges in thickness from 0.5 to 3 feet (15 to 90 cm).

A-B Interval - (120 - 200)

The A-B interval extends from the top of the Riverton shale to the top of the A-B shale and progressively thickens eastward from a feather edge on the Nemaha uplift to 73 feet (22 m) at the northeastern corner of the study area (Fig. 17). The interval consists mostly of light- to dark-gray shale interbedded with laterally discontinuous sandstone, siltstone, and coal units. The A-B shale is present throughout most of the study area, but does not exist in areas of thick upper Warner sandstone deposits. The lower Warner sandstone (Ebanks and others, 1977), which occurs between the Riverton shale and the overlying Dw coal (Harris, 1984), ranges in thickness from 2 to 25 feet (0.6 to 8 m) and is erratically distributed. Three coal beds informally named Dw, Cw, and Bw, listed in ascending stratigraphic order (Harris, 1984), are useful for correlation when thick enough to be identified on well logs.

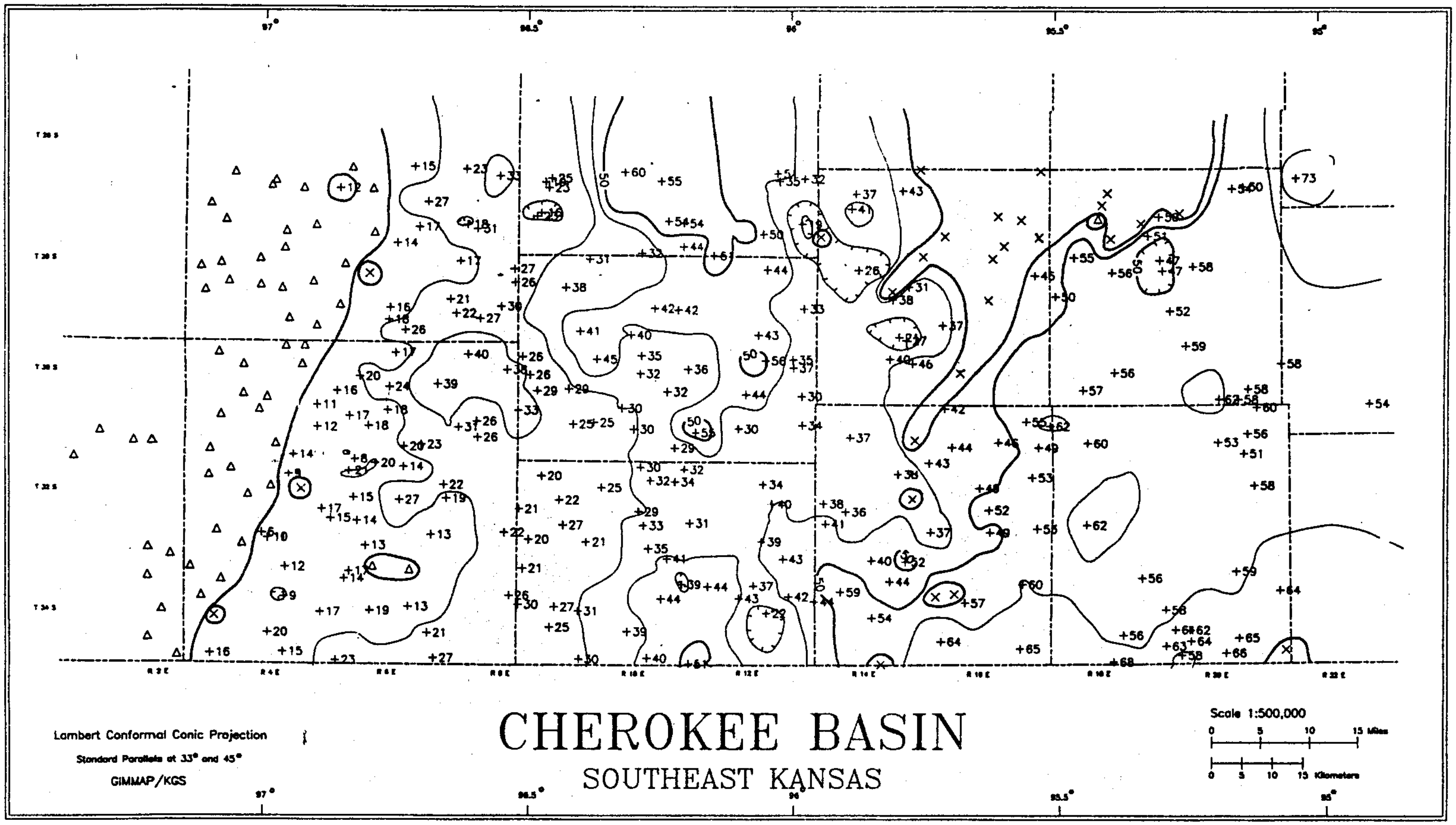


Figure 17 - Isopach map of the A-B interval; contour interval = 10 feet. (X: interval thickness indeterminable, Δ: total interval not present)

Bluejacket B Interval - (200 - 510)

The Bluejacket B shale is often highly radioactive, but can be difficult to identify on gamma ray logs when the underlying Bbj coal (Harris, 1984) is not present. The marker bed occurs near a distinct lithologic change from underlying shale-dominated strata to overlying coarsening-upward sequences.

The Bluejacket B interval extends from the top of the A-B shale to the top of the Bluejacket B shale and ranges in thickness from 20 to 148 feet (6 to 44 m) (Fig. 18). In local areas of thick sandstone accumulation, the interval increases in thickness up to 196 feet (59 m). The interval consists mainly of light- to dark-gray shale interbedded with sandstone, siltstone, coal, and thin limestone units. The upper Warner sandstone lies below the Neutral coal and above the Aw coal and ranges in thickness from 2 to 75 feet (0.6 to 23 m). The lower Bluejacket sandstone (Ebanks and others, 1977) is stratigraphically located below the Cbj coal (Harris, 1984) and above the Drywood coal bed and ranges in thickness from 2 to 80 feet (0.6 to 24 m). The upper Bluejacket sandstone (Ebanks and others, 1977) ranges in thickness from 2 to 50 feet (0.6 to 15 m) and is the most laterally persistent sandstone in the study area. The upper Bluejacket sandstone occurs between the overlying Bbj coal and the underlying Cbj coal.

The Aw, Neutral, Rowe, Dry Wood, Dbj, Cbj, and Bbj coal beds, listed in ascending stratigraphic order, are laterally persistent units throughout most of the study area. These beds, however, are difficult to trace in the subsurface because (1) they are frequently values are in the 60's

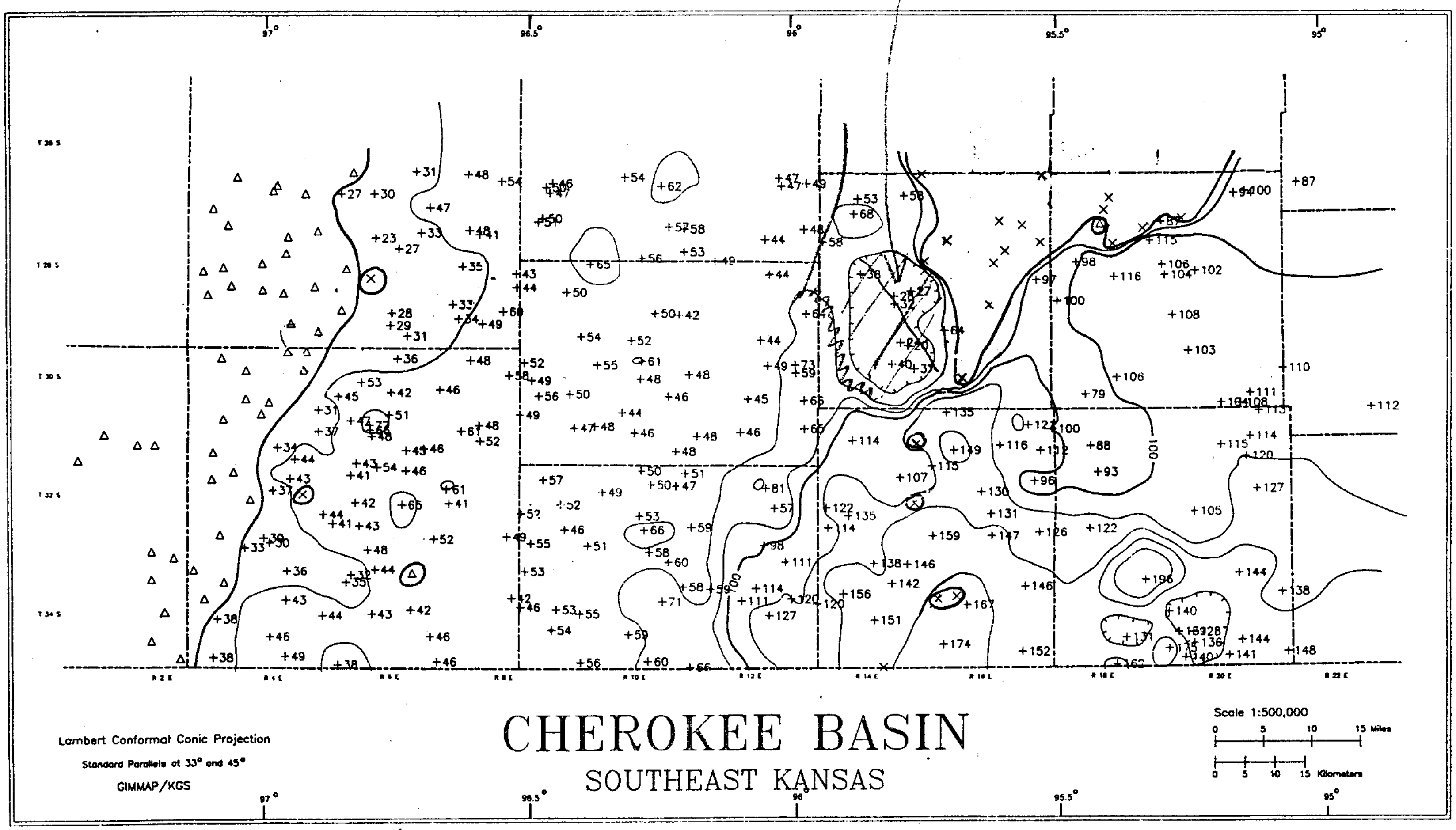


Figure 18 - Isopach map of the Bluejacket B interval; contour interval = 20 feet. (X: interval thickness indeterminable, Δ: total interval not present)

too thin to induce a distinguishable response on geophysical well logs, (2) they are absent due to non-deposition or erosion in areas of thick sandstone accumulation, and (3) they are difficult to differentiate and identify in areas where only a few coals are present.

The Seville Limestone marks the top of the Krebs Formation (Jewett and others, 1968) and immediately overlies the Cbj coal bed. Although the Seville Limestone is laterally continuous in outcrops and cores (Harris, 1984), the bed is too thin to create a strong limestone response on well logs and is not recognizable in the study area.

<u>Weir-Pittsburg Interval</u> - (510 - 590)

The Weir-Pittsburg interval extends from the top of the Bluejacket B shale to the top of the Weir-Pittsburg shale and ranges in thickness from 8 to 60 feet (2.4 to 18 m) (Fig. 19). The interval consists mainly of light- to dark-gray shale with laterally intermittent sandstone, siltstone, limestone, and coal units. The Weir-Pittsburg shale exhibits a recognizable gamma ray response throughout most of the study area. The Weir-Pittsburg coal bed lies directly below the Weir-Pittsburg shale and ranges in thickness from 0.5 to 4 feet (15 to 120 cm). The Weir-Pittsburg coal, as well as the underlying <u>Weir-Pittsburg B</u> and Abj coals, are laterally continuous, but thin and difficult to trace in the central and western portions of the study area. An unnamed sandstone unit lies stratigraphically above the Abj coal and below the Weir-Pittsburg

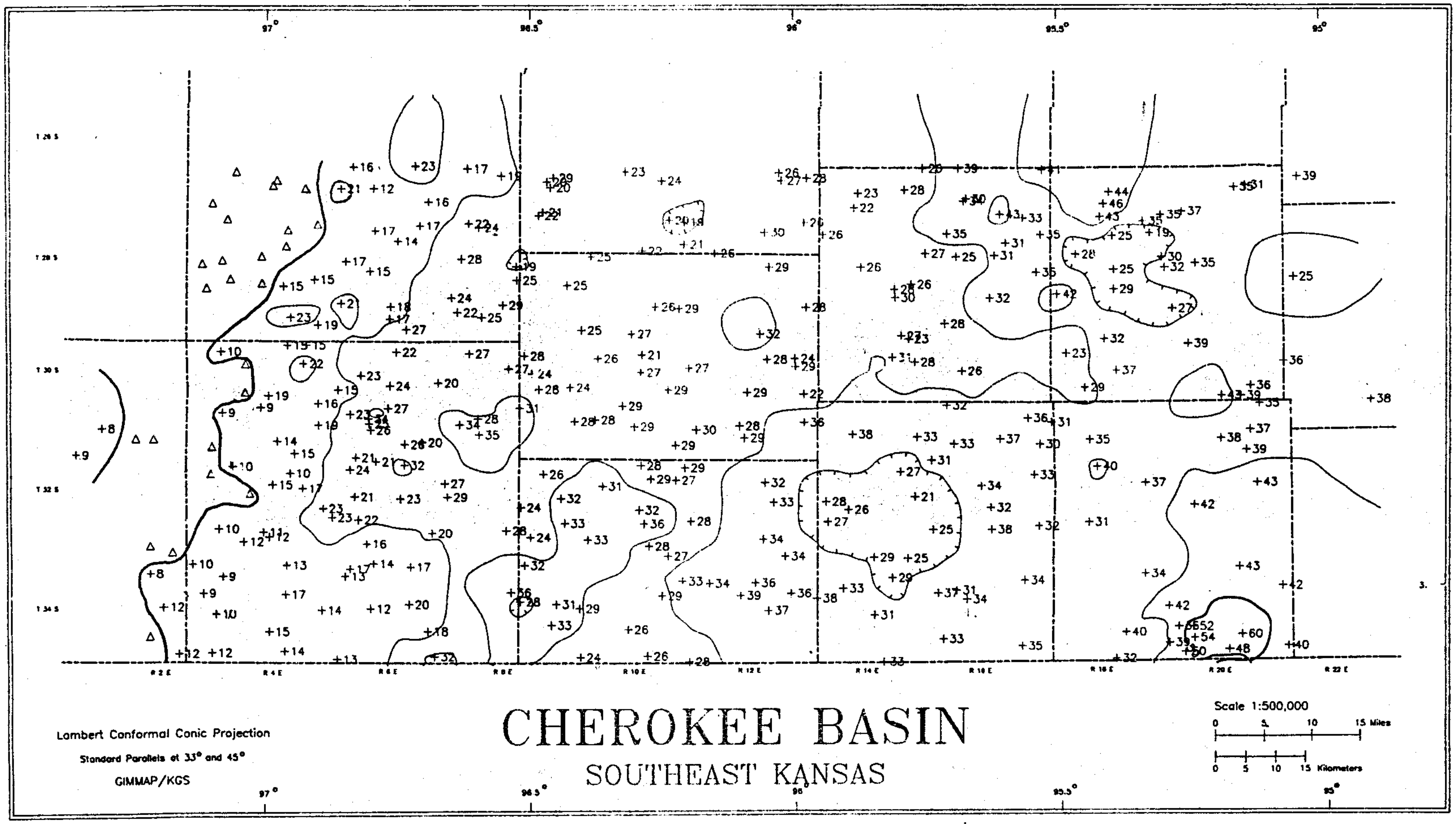


Figure 19 - Isopach map of the Weir-Pittsburg interval; contour interval = 10 feet. (Δ: total interval not present)

coal and is present locally in the study area. The sandstone ranges in thickness from 2 to 20 feet (0.6 to 6 m) and may correlate with the Bluejacket Sandstone Member in its type area in northeastern Oklahoma (Harris, 1984). Drill cuttings from the western third of the study area show minor amounts of argillaceous limestone within the interval.

Tebo Interval - (590 - 640)

The Tebo shale is a radioactive dark-gray shale that invokes a recognizable gamma ray response throughout the study area. Except on local structural highs of the Nemaha uplift, the Tebo marker extends across the uplift and is traceable in the Sedgwick basin (Killen, 1987). In outcrop, the Tebo shale contains abundant phosphatic nodules.

The Tebo interval extends from the top of the Weir-Pittsburg shale to the top of the Tebo shale and ranges in thickness from 10 to 55 feet (3 to 17 m) (Fig. 20). The interval consists mainly of light- to dark-gray shale interbedded with thin sandstone, siltstone, limestone, and coal units. An unnamed sandstone occurs locally in the basin and ranges in thickness from 1 to 6 feet (0.3 to 1.8 m). The Tebo coal bed occurs in most of the study area and ranges in thickness from 0.5 to 4 feet (15 to 120 cm). The Tebo B coal lies near the stratigraphic middle of the interval and is locally recognized in the eastern and southern regions of the Cherokee basin.

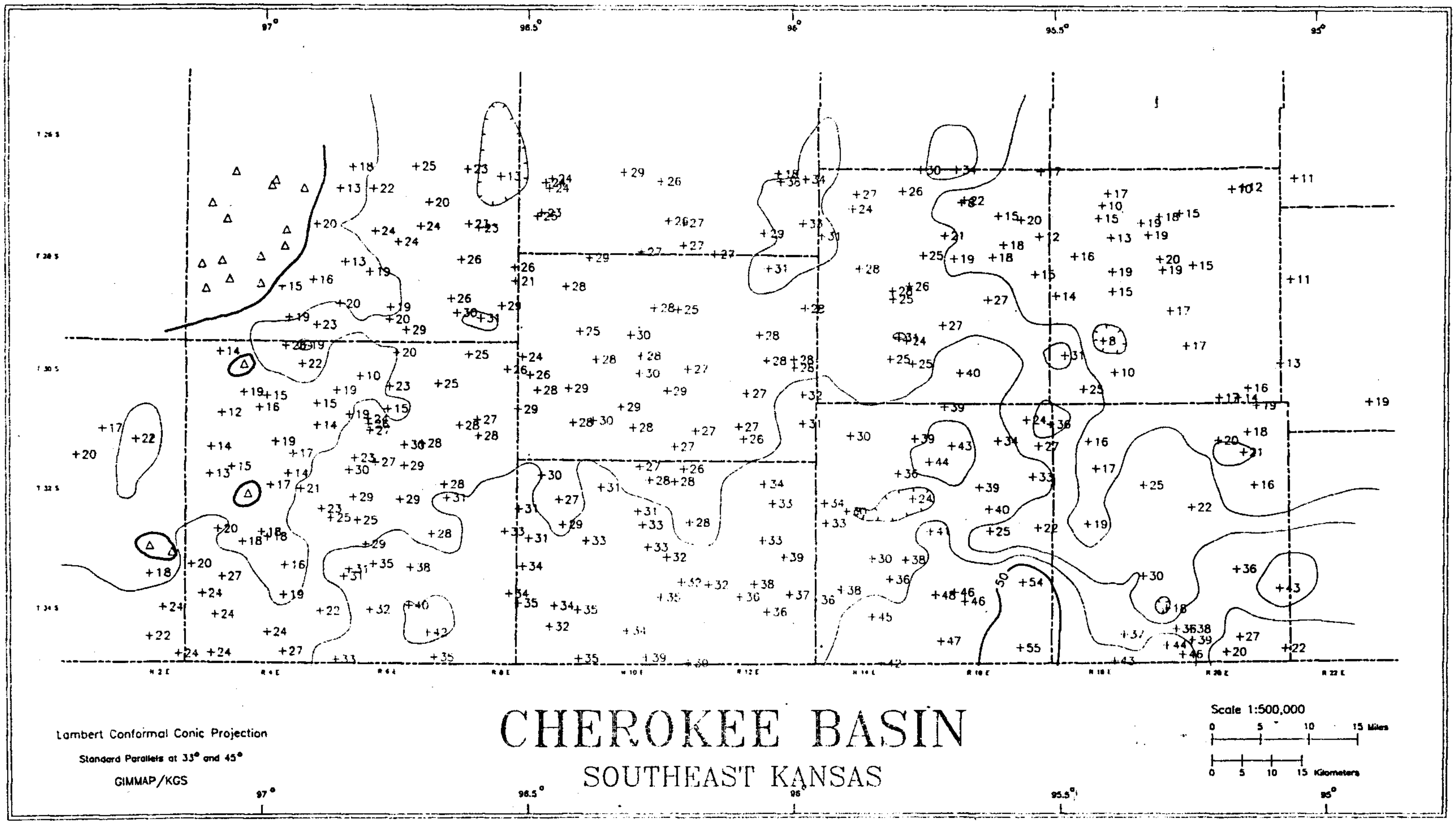


Figure 20 - Isopach map of the Tebo interval; contour interval = 10 feet. (Δ: total interval not present)

Scammon Interval - (640 - 680)

The Scammon shale occurs throughout most of the study area. Identification of the Scammon marker bed is aided by its stratigraphic location between the underlying Tebo and overlying Mineral marker beds, which are easily recognized on gamma ray logs throughout the Cherokee basin.

The Scammon interval extends from the top of the Tebo shale to the top of the Scammon shale and ranges in thickness from 3 to 70 feet (0.9 to 21 m) (Fig. 21). Thickness of the interval progressively increases eastward from along the Nemaha uplift to the eastern edge of the study area. The interval consists mainly of light- to dark-gray shale interbedded with siltstone, sandstone, and coal units. The Tiawah limestone bed, which stratigraphically occurs directly above the Tebo shale, is present in outcrops in eastern Cherokee and Crawford counties (Howe, 1956) but is not present in cores in western Cherokee County (Harris, 1984) or on geophysical well logs from the study area. The Chelsea Sandstone Member typically lies less than five feet (1.5 m) below the Scammon coal bed and ranges in thickness from 1 to 12 feet (0.3 to 4 m). The Chelsea Sandstone is occasionally represented by two sandstone bodies that are separated by an unnamed, laterally discontinuous coal bed informally referred to in this study as the Scammon B coal. The Scammon coal bed is widespread in the study area and ranges in thickness from 0.5 to 2 feet (15 to 60 cm).

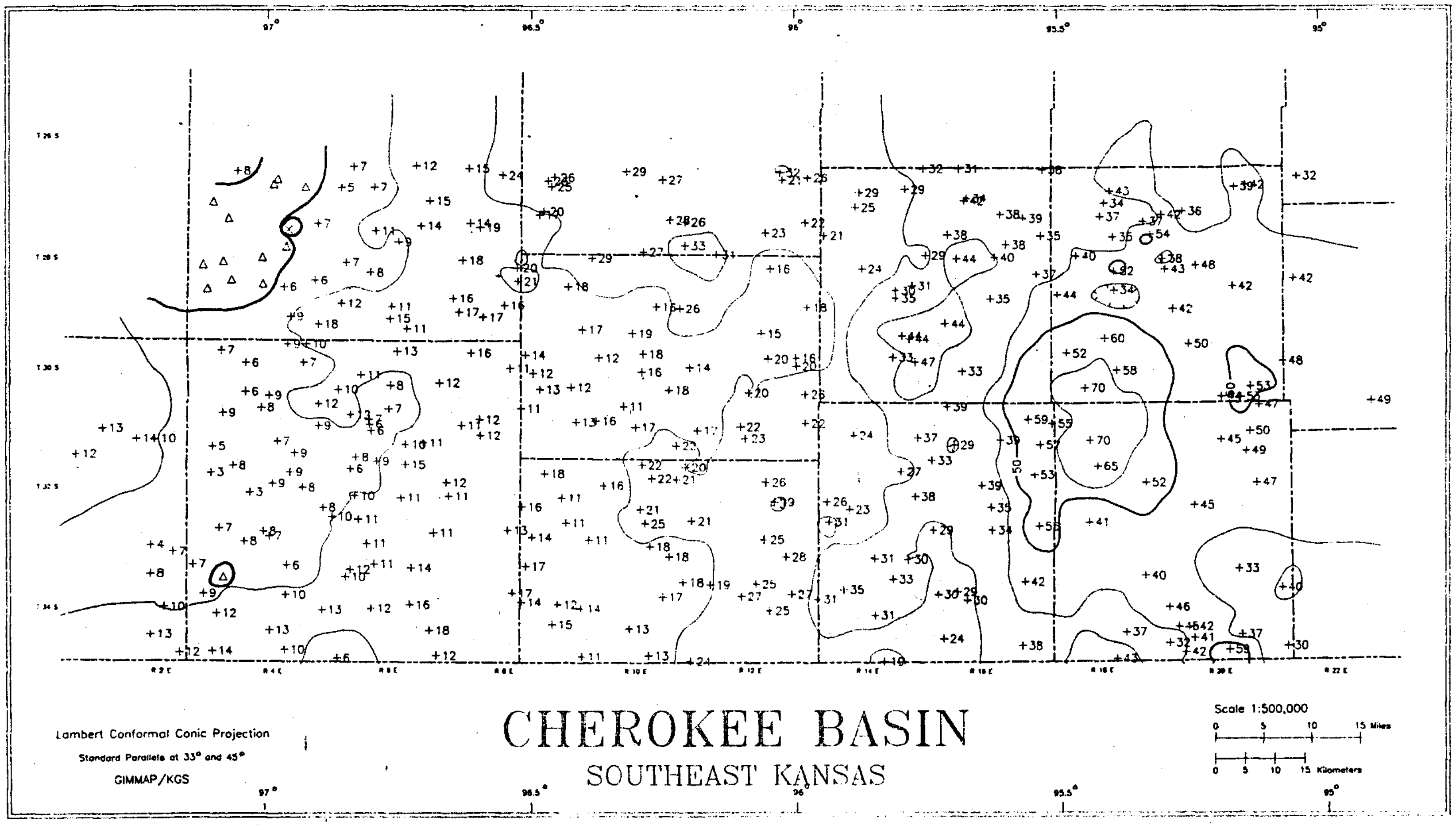


Figure 21 - Isopach map of the Scammon interval; contour interval = 10 feet. (X: interval thickness indeterminable, Δ: total interval not present)

Mineral Interval - (680 - 720)

The Mineral interval extends from the top of the Scammon shale to the top of the Mineral shale and ranges in thickness from 4 to 31 feet (1.2 to 9 m) (Fig. 22). Thickness of the interval increases eastward from the Nemaha uplift to the southeastern corner of the study area. The interval consists mainly of light- to dark-gray shale interbedded with siltstone, sandstone, and coal units.

An unnamed sandstone occurs locally below the Mineral coal bed and ranges in thickness from 1 to 5 feet (0.3 to 1.5 m). The Mineral coal is present throughout most of the study area and ranges in thickness from 0.5 to 3 feet (15 to 90 cm). The Mineral shale is a radioactive dark-gray shale that can be recognized throughout the study area.

V shale Interval - (720 - 780)

The V shale is a radioactive dark-gray shale bed that is easily identified on gamma ray logs throughout the study area and into the Sedgwick basin. In outcrop, the V shale contains phosphatic nodules and calcareous concretions. The V shale stratigraphically correlates with the Oakley shale in Iowa (Deneson, 1985) and the Mecca Quarry shale in Indiana (Coveney, 1985).

The V shale interval extends from the top of the Mineral shale to the top of the V shale and ranges in thickness from 23 to 61 feet (6.9 to 18 m) (Fig. 23). The interval consists of light- to dark-gray shale interbedded with thin sandstone, siltstone, limestone, and coal units. A thin unnamed limestone bed that lies

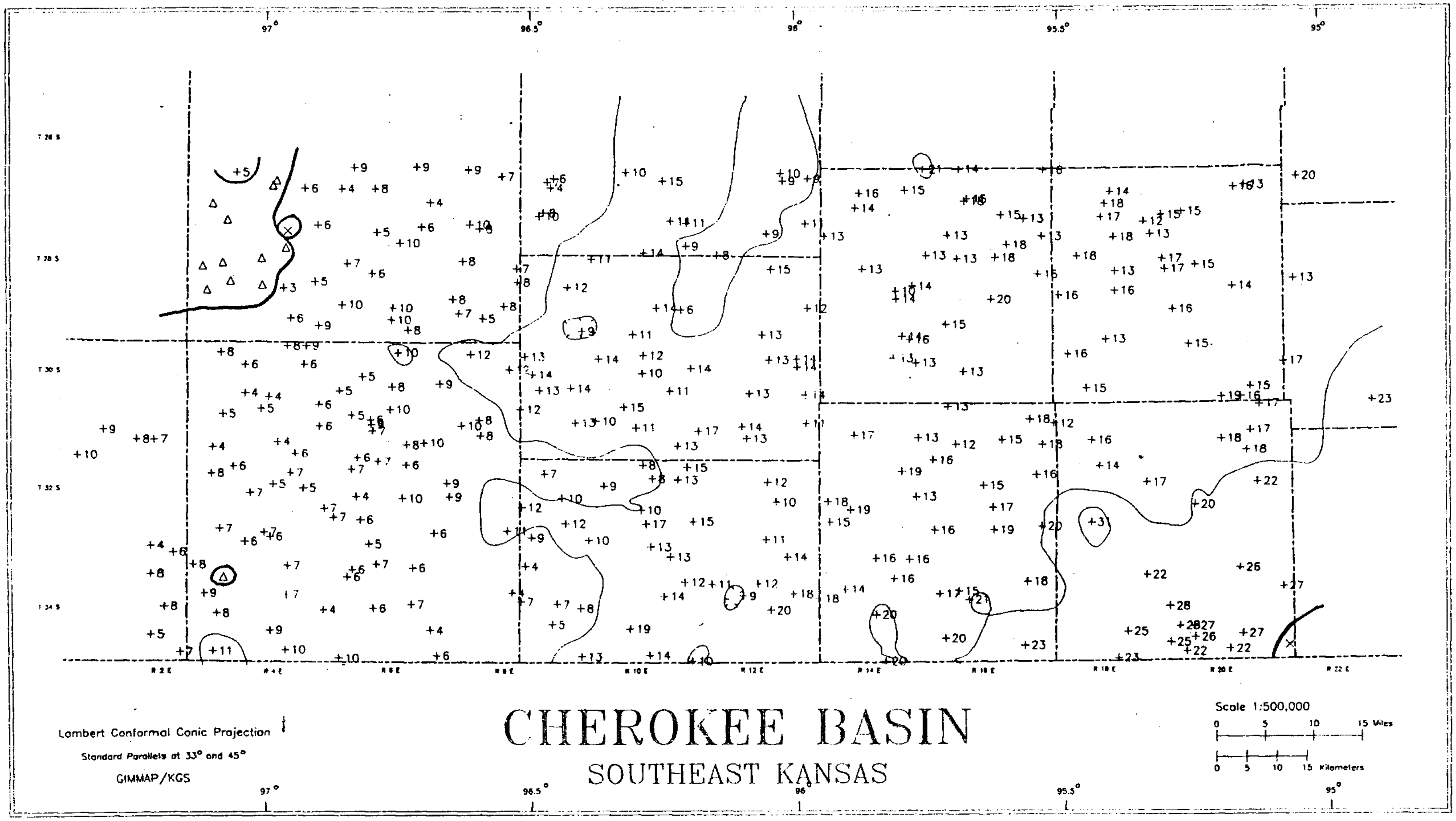


Figure 22 - Isopach map of the Mineral interval; contour interval = 10 feet. (X: interval thickness indeterminable, Δ: total interval not present)

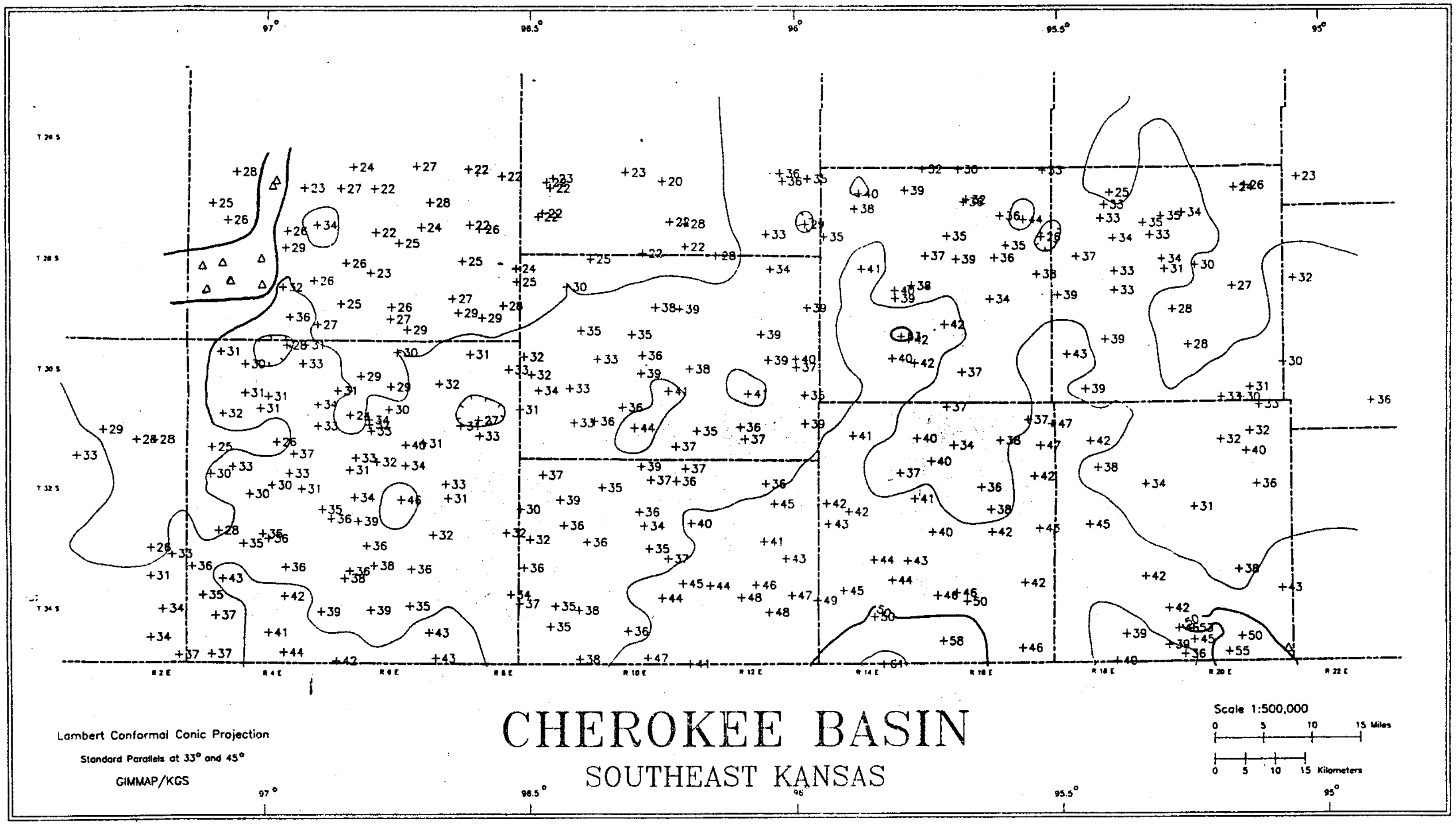


Figure 23 - Isopach map of the V shale interval; contour interval = 10 feet. (Δ: total interval not present)

immediately above the Mineral shale exists in the western half of the study area. The Fleming coal bed stratigraphically lies near the middle of the interval and is present only in the eastern part of the Cherokee basin. In the western part of the study area, well logs and drill cuttings show the presence of an unnamed argillaceous limestone bed, ranging in thickness from 1 to 5 feet (0.3 to 1.5 m), that lies directly below the V shale or, below the Croweburg coal bed where it is present. The Croweburg coal bed occurs locally in the study area and ranges in thickness from 0.5 to 3 feet (15 to 90 cm).

<u>Bevier Interval</u> - (780 - 900)

The Bevier interval extends from the top of the V shale to the top of the Bevier shale and ranges in thickness from 10 to 34 feet (3 to 10 m) (Fig. 24). The interval consists mainly of light- to dark-gray shale and limestone interbedded with coal and locally occurring siltstone and sandstone. The Verdigris Limestone Member lies immediately above the V shale and extends laterally throughout the Cherokee basin and into the Sedgwick basin. The Verdigris Limestone is laterally continuous in the study area and occurs in outcrops as a mudstone to wackestone with crinoids and brachiopods. The Bevier shale is recognizable in the Cherokee basin due to a high gamma ray response and association with the underlying Bevier coal bed. The Bevier coal bed ranges in thickness from 0.5 to 3 feet (15 to 90 cm) and laterally persists in most of the study area.

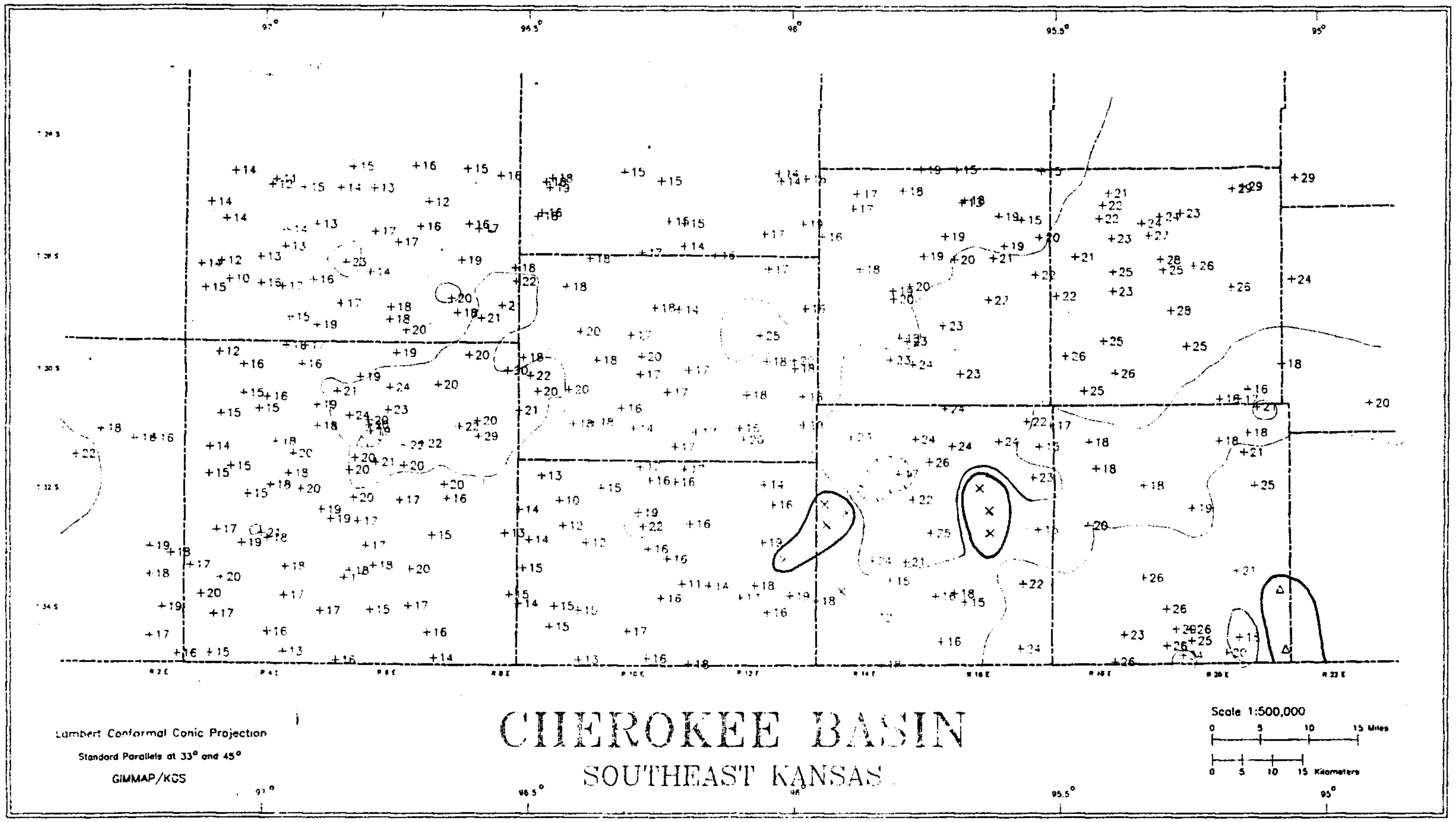


Figure 24 - Isopach map of the Bevier interval; contour interval = 10 feet. (X: interval thickness indeterminable, Δ: total interval not present)

Excello Interval - (900 - 1000)

The Excello interval extends from the top of the Bevier shale to the top of the Excello shale and ranges in thickness from 20 to 114 feet (6 to 34 m) (Fig. 25). The interval consists of light- to dark-gray shale interbedded with sandstone, siltstone, limestone, and coal units. Along the Nemaha uplift, the interval consists mainly of shale and argillaceous limestone beds. The Iron Post coal bed occurs only in the northwestern and south-central parts of the study area and lies 2 to 15 feet (0.6 to 5 m) above the Bevier shale. The Iron Post shale is usually recognized due to its association with the underlying Iron Post coal. The informally named Squirrel sandstone (Moore, 1949) is a laterally discontinuous unit that stratigraphically lies below the Breezy Hill Limestone Member and ranges in thickness from 2 to 30 feet (0.6 to 9 m). The Breezy Hill Limestone is continuous in outcrop in southeastern Kansas (Howe, 1956), but in the subsurface occurs mainly in the southern part of the study area. The Mulky coal bed exists locally in the study area and lies between the overlying Excello shale and the Breezy Hill Limestone. The Excello shale is a highly radioactive dark-gray shale that is laterally persistent within the study area and throughout the midcontinent (Ravn and others, 1984). In outcrops, the Excello shale is fissile and contains abundant phosphatic nodules.

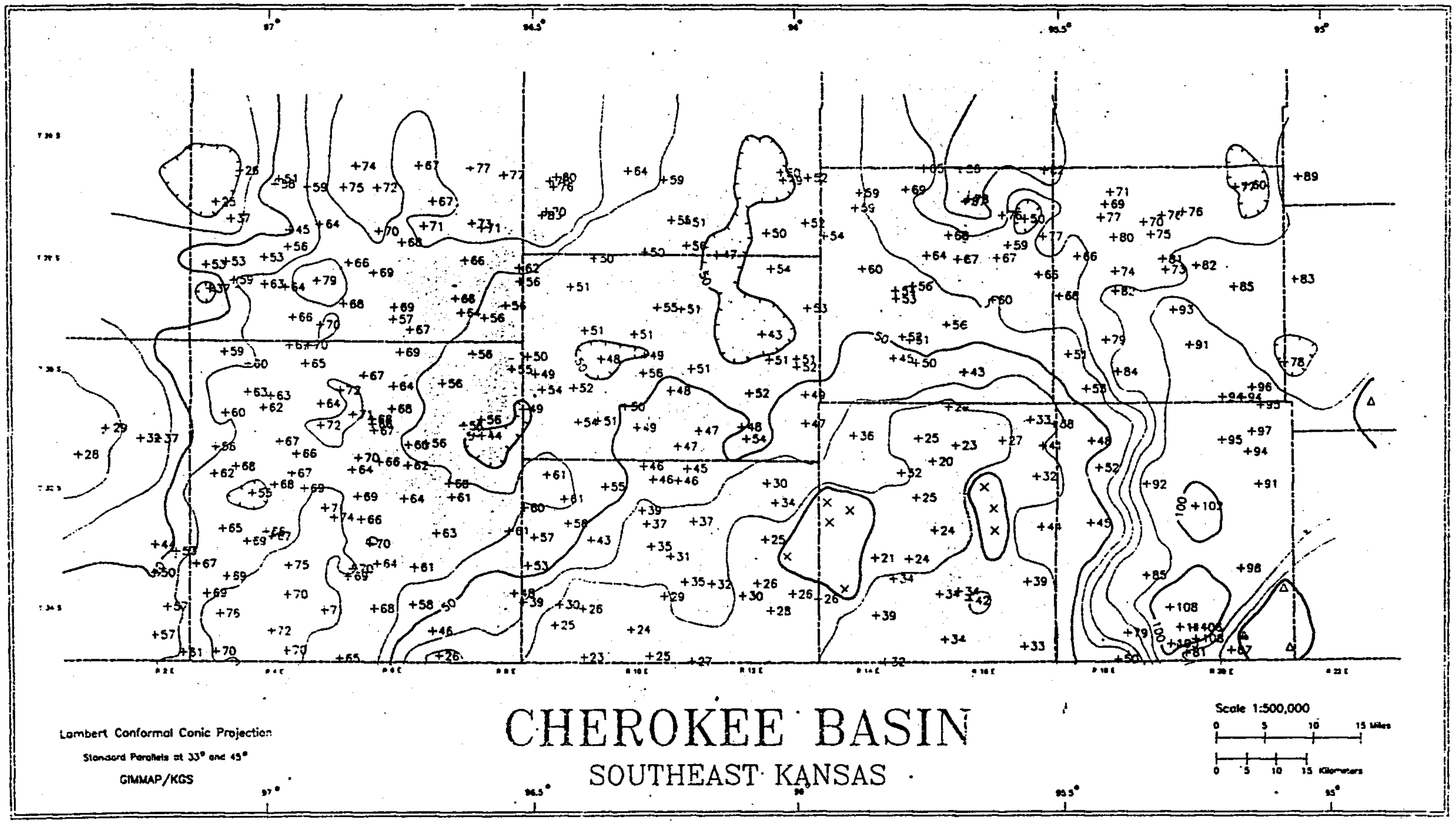


Figure 25 - Isopach map of the Excello interval; contour interval = 10 feet. (X: interval thickness indeterminable, Δ: total interval not present)

LITHOFACIES DEVELOPMENT AND ISOLITH MAPPING

Lithofacies

Detailed descriptions of cores and well cuttings are listed in Appendices B and D. All of the lithofacies of the Cherokee strata could not be established from lithologic analyses due to the limited availability of cores. Most of the sedimentologic characteristics observed in cores and well cuttings, however, corresponded to lithofacies developed by Harris (1984) for the Krebs Formation along the outcrop belt in southeastern Kansas (Table 1). Upper Cabaniss lithofacies on top of and immediately east of the Nemaha uplift where little sandstone was deposited corresponded to lithofacies established by Killen (1986). Several outcrops beyond the eastern edge of the study area were analyzed to establish a more complete lithologic picture.

Harris (1984) used grain size, primary sedimentary structures, trace and body fossils, diagenetic features, and color to establish lithofacies. On the other hand, lithofacies recognized by Killen (1986) in the Sedgwick basin were based on well log analyses to determine percentages of limestone and shale within a designated stratigraphic interval. In this study, lithofacies based on lithology were deduced from well log analyses. Grain size, primary sedimentary structures, trace and body fossils, diagenetic features, and color were used to classify specific lithofacies.

Table 1: Summary of lithofacies in Cherokee Group in southeastern Kansas*

(I). Mudrocks

(A). 1. Dark-gray shale - Clayshale and mudshale containing minor amounts of quartz silt. Color: very dark gray (N2) to medium-dark gray (N4) (Goddard and others, 1980). Fossils: brachiopods, bivalves, gastropods, abundant plant fragments, and locally, horizontal burrows less than 1 cm in diameter. Diagenetic features: calcareous cement and pyrite, clay ironstone, and calcareous concretions. Contacts: lower - sharp, upper - gradational into medium- to light-gray or lenticular-bedded shales.

This study - The dark-gray shale lithofacies is frequently observed in cores, well cuttings, and outcrops.

(A). 2. Dark-gray shale - Clayshale and mudshale containing minor amounts of quartz silt. Color: very dark gray (N2) to dark gray (N3). Diagenetic features: phosphatic nodules, and pyritic and calcareous concretions. Contacts: lower - sharp; upper - sharp.

This study - This dark-gray lithofacies is highly radioactive and has a range of 110 to >200 API units on gamma ray logs. Dark-gray shale beds are easily recognized on gamma ray logs and used as marker beds in this study. This lithofacies is occasionally observed in cores, well cuttings, and outcrops.

(B). <u>Medium- to light-gray shale</u> - Mudshales are most common and consist of clay with minor amounts of quartz silt and mica. Color: medium gray (N5) to very light gray (N8). Fossils: Abundant plant fragments, and locally, brachiopods and other marine fauna. Diagenetic features: Pyrite and clay ironstone concretions and calcareous cement. Contacts: lower and upper - often gradational within a coarsening-upwards sequence.

<u>This study</u> - The medium- to light-gray shale lithofacies is frequently present in cores, well cuttings, and outcrops. Pyrite and clay ironstone concretions, calcareous cement, and horizontal burrowing are local features.

(C). <u>Lenticular-bedded shale</u> - Dark- to medium-gray (N3-N5) mudshale interlaminated with thin (less than 1 cm) light gray (N7) lenses of silt to very fine-grained quartz sand. Sedimentary structures: isolated ripples of sandstone and siltstone and convolute bedding. Fossils: abundant plant fragments and horizontal and vertical burrows, and rarely, marine body fossils. Diagenetic features: calcareous cement and pyrite and clay ironstone concretions. Contacts: lower - gradational with dark- or medium-gray shales; upper - gradational with sandstone, siltstone, shale, or mudstone.

<u>This study</u> - The lenticular-bedded shale lithofacies is occasionally present in cores and outcrops. Calcareous cement is not a common feature.

(D). Mudstone and claystone - Shales consisting of mud and clay that contain laminar bedding greater than 10 mm thick. This bedding distinguishes mudstone and claystone from thinner-bedded mudshale and clayshale (Potter, Maynard, and Pryor, 1980). Color: dark gray (N3) to very light gray (N8). Sedimentary structures: lack fissility. Fossils: abundant plant fossils and root marks, and rarely, marine fossils. Contacts: lower - gradational; upper - sharp.

This study - The mudstone and claystone lithofacies is frequently observed in cores, well cuttings, and outcrops.

(II). Sandstones and Siltstones

(A). Wavy-bedded sandstone and siltstone - Units containing approximately equal amounts of interlaminated or interbedded, light-gray (N7) sandstone or siltstone and medium- to dark-gray (N5 to N3) mudshale. Sedimentary structures: small-scale unidirectional current ripples, low-angle wave ripples, and convolute bedding. Fossils: plant fragments, occasional marine fauna, and burrows of various types. Diagenetic features: clay ironstone nodules, siderite spherulites, and zones of calcareous cement. Contacts: lower - gradational or intercalating; upper - often gradational with flaser-bedded to rippled siltstone and sandstone.

This study - The wavy-bedded sandstone and siltstone lithofacies is occasionally identified in cores and outcrops.

(B). Flaser-bedded sandstone and siltstone - Light- to medium-gray (N7 to N5), very fine-grained sandstone to siltstone, with thin (less than 1 cm) laminae of dark- to medium-gray (N3 to N5) mudstone. Sedimentary structures: ripples, less than three centimeters high. Fossils: locally occurring plant fossils and vertical and horizontal burrows. Contacts: lower - gradational or intercalating, and locally, sharp or scoured; upper - gradational.

This study - The flaser-bedded sandstone and siltstone lithofacies is occasionally observed in cores and outcrops.

(C). Rippled sandstone and siltstone - Units that range in grain size from quartz-rich, fine-grained sand to silt. Color: medium gray (N5) to very light gray (N8). Sedimentary structures: unidirectional current ripples, less than five centimeters high, and locally, wave-formed ripples. Fossils: plant fragments and vertical and horizontal burrows. Contacts: lower and upper - sharp or gradational.

This study - The rippled sandstone and siltstone lithofacies is frequently observed in cores and outcrops. Scoured lower contacts are present locally and wave-formed are only observed in outcrops.

(D). Large-scale cross-bedded sandstone - Sandstone composed of fine- to very fine-grained, quartz-rich sand. Color: light gray (N7) to medium gray (N5). Sedimentary structures: low-and high-angle sets of unidirectional cross beds range from one foot (30 cm) to over 3 feet (0.9 m) high, and locally, planar and trough-shaped cross beds. Fossils: plant fragments. Contacts: lower - often sharp and scoured; upper - sharp or gradational.

This study - The large-scale cross-bedded sandstone lithofacies is occasionally observed in outcrop, but was not recognized in cores.

(E). Mud-clast conglomerate - Unit consisting of locally derived mud clasts, coal clasts, reworked siderite or clay-ironstone concretions, and plant fossils within a matrix of fine- to very fine-grained sandstone. Sedimentary structures: clasts, up to five centimeters in diameter, commonly aligned parallel to bedding. Contacts: lower - scoured; upper - gradational with cross-stratified or rippled sandstone.

This study - Clasts range up to 18 centimeters in diameter. The mud-clast conglomerate lithofacies is rarely identified in cores and outcrops.

(F). Structureless sandstone and siltstone - Units composed of very fine-grained quartz-rich sandstone or siltstone with varying amounts of mud matrix. Color: medium gray (N5) to light gray (N7). Fossils: plant fossils and burrows. Contacts: lower and upper - gradational.

This study - The structureless sandstone and siltstone lithofacies is frequently observed in cores and outcrops.

(III). Other Lithologies

(A). Argillaceous limestone - Argillaceous lime wackestone to packstone. Color: dark gray (N3) to light gray (N6). Fossils: brachiopods, bivalves, gastropods, bryozoans, and crinoid stems. Sedimentary structures: vague low-angle cross-stratification. Contacts: lower - sharp or scoured; upper - sharp or gradational.

This study - The argillaceous limestone facies is occasionally observed in well cuttings, outcrops, and cores. In the western half of the study area, the limestones are mud dominated and classified as lime mudstones (Dunham, 1962). Low-angle cross-stratification is not present.

(B). Coal - Coals are high volatile bituminous in rank, banded, and moderately bright. Color: black (N1). Diagenetic features: calcite, pyrite, and sulfate minerals in cleats, joints, and fractures, and abundant pyrite concretions. Contacts: lower and upper - mainly sharp but occasionally intercalating.

This study - The coal lithofacies is frequently present in cores and outcrops.

(C). Seatrock - Units composed of claystone, mudstone, siltstone, sandstone, or argillaceous limestone. Fossils: abundant plant and root fragments. Diagenetic features: clay ironstone and pyrite concretions. Contacts: lower - gradational; upper - sharp.

This study - The seatrock lithofacies is frequently observed in cores and outcrops. Seatrock or underclay units commonly occur directly below coal beds, but may be found where coal is not present.

*Lithofacies established by Harris (1984) for the Krebs Formation in southeastern Kansas.

Isolith Mapping

Shale, sandstone, limestone, and coal were the lithofacies that were mapped. Isolith maps depict the lateral and vertical distribution of the lithofacies. These maps were created for each stratigraphic interval, but more distinct distribution trends were apparent on maps combining adjacent intervals.

Shale - Shale is the most abundant lithology in the Cherokee Group in southeastern Kansas. On gamma ray logs, average shale values range from 70 to 100 API units. Highly radioactive shales used as marker beds range from 110 to >200 API units on a gamma ray log. Total shale thickness ranges from 51 to 525 feet (15.3 to 158 m) (Fig. 26). In each mapped interval, shale thickens progressively eastward from the Nemaha uplift to the eastern edge of the study area, corresponding with changes in total thickness of the Cherokee Group.

Sandstone - Clean sandstones have an average range of 35 to 60 API units on gamma ray logs and 2.27 to 2.52 grams per cubic centimeters on density logs. Total sandstone thickness ranges from 0 to 189 feet (0 to 57 m) (Fig. 27). A three-dimensional block diagram of cumulative sandstone thickness (Fig. 28) demonstrates a linear north-south depositional trend in the eastern half of the study area. In areas outside of the depositional trend, sandstone accumulation is thin and laterally discontinuous, with thick deposits occurring locally. These deposits may be parts of linear accumulations that were missed by the low sampling density (1 to 3 wells per township) employed in this study. The total percentage of sandstone in the

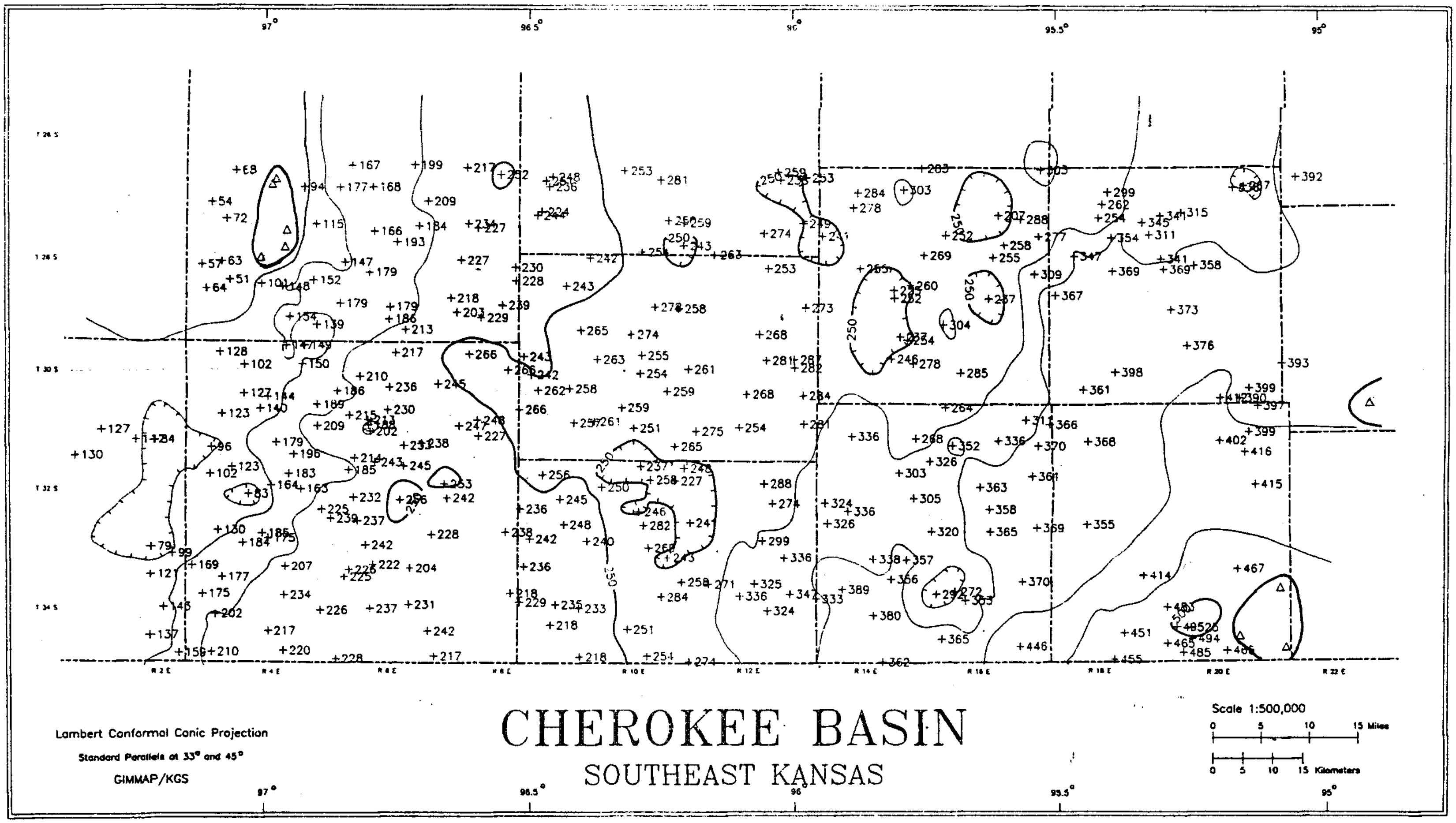


Figure 26 - Total shale isolith map of the Cherokee Group; contour interval = 50 feet. (Δ: total interval not present)

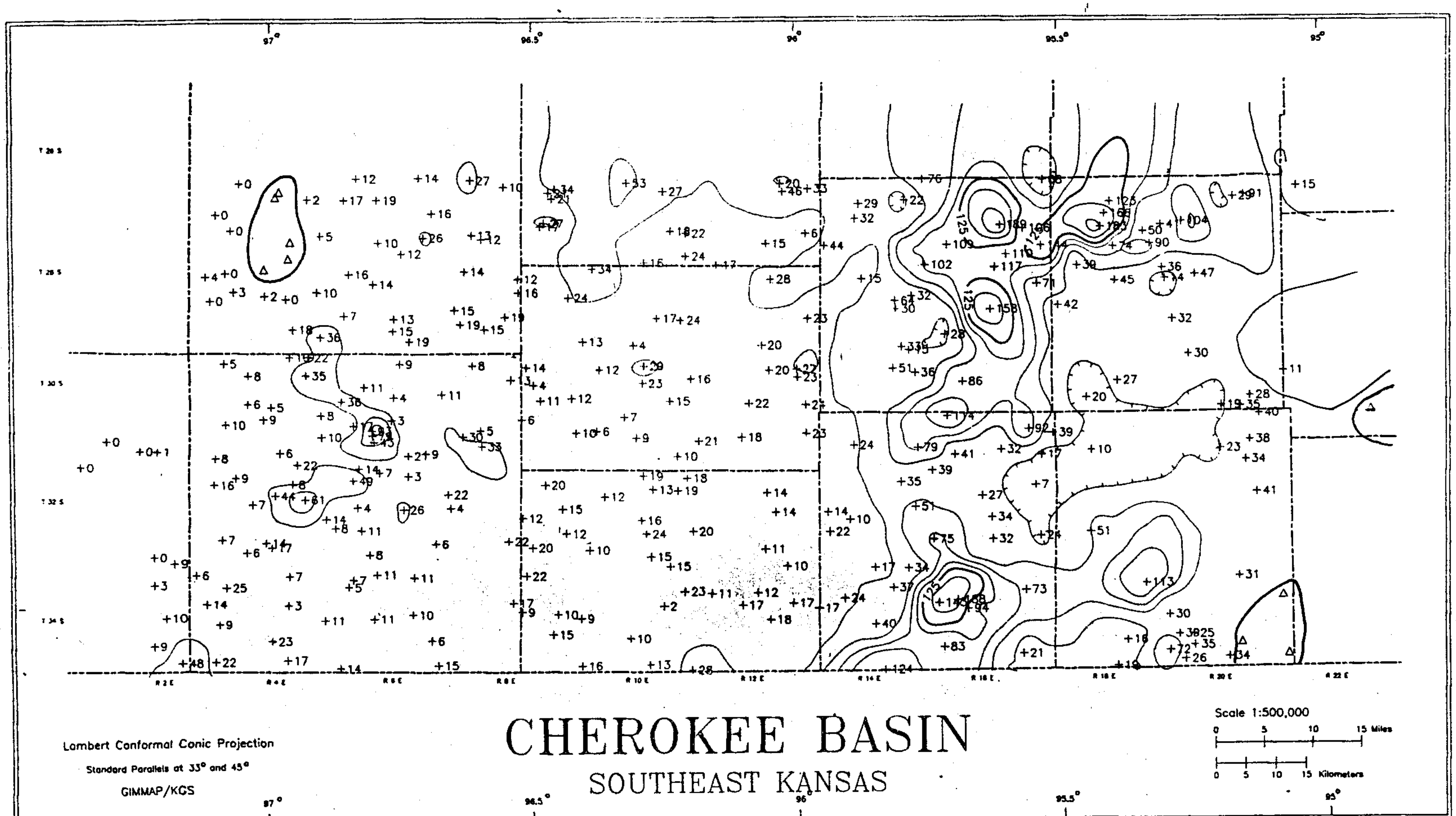
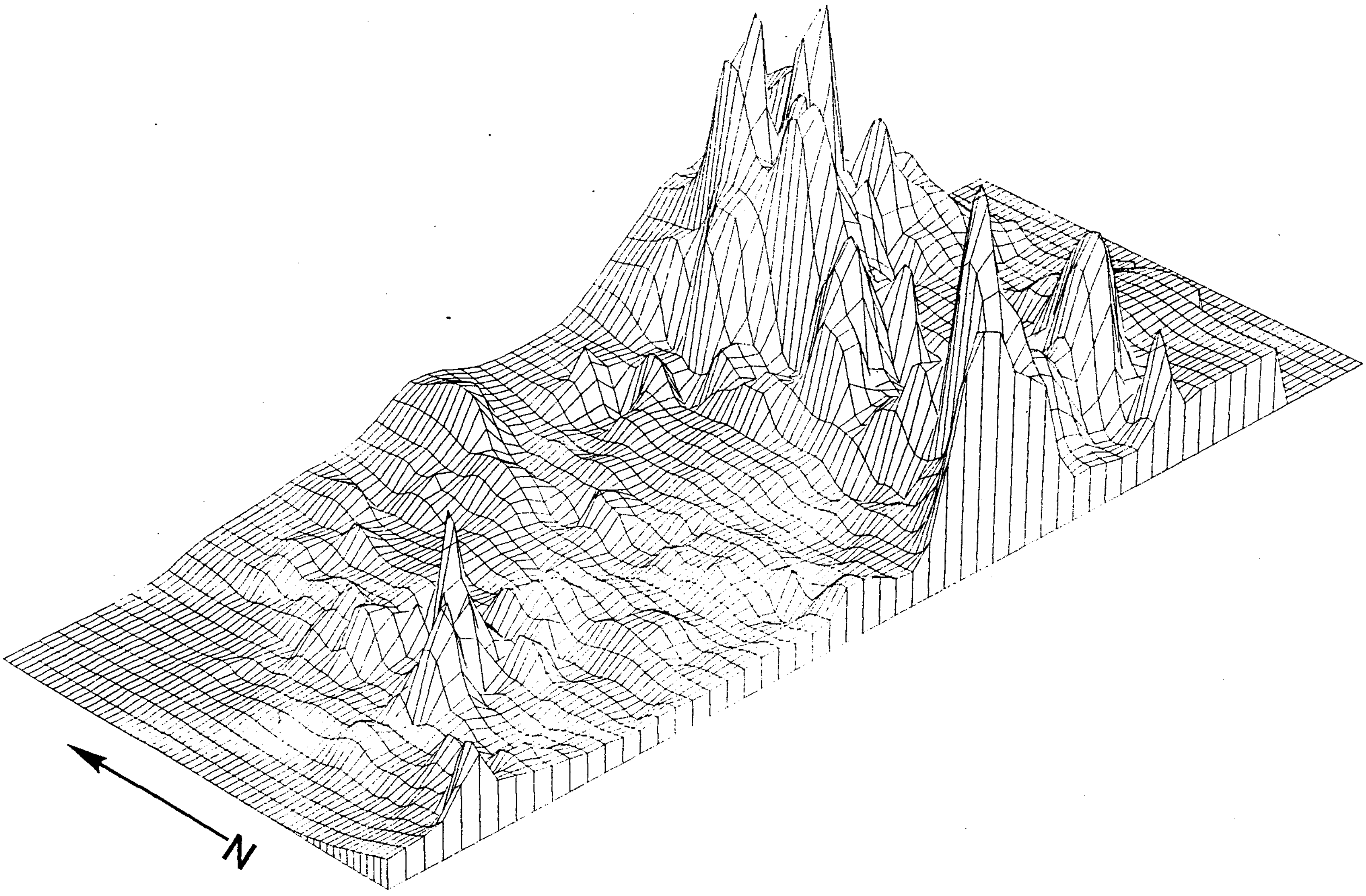


Figure 27 - Total sandstone isolith map of the Cherokee Group; contour interval = 25 feet. (Δ: total interval not present)

Figure 28 -- Block diagram of the total sandstone isolith map of the Cherokee Group.


N

Cherokee Group is typically less than 10 percent but increases up to 45 percent in areas of thick sandstone accumulation.

Limestone - Clean limestones have a range of 10 to 40 API units on gamma ray logs and 2.6 to 2.85 g/cm^3 on density logs. Total thickness of limestone ranges from 0 to 31 feet (0 to 9 m) (Fig. 29). The total limestone isolith map shows a slight increase in total limestone thickness to the west and south. The percentage of limestone increases up to 20 percent as the thickness of the total Cherokee Group decreases westward across the Nemaha uplift and limestone content increases. Most limestone occurs in the upper Cabaniss strata between the V-shale marker bed and the top of the Cherokee Group. Individual limestone beds below the V-shale marker are typically less than 2 feet (0.6 m) thick.

Coal - Individual coal beds are widespread within the study area but difficult to trace on geophysical logs because most are less than 2 feet (0.6 m) thick. Coals have an average range of 40 to 70 API units on gamma ray logs and 1.8 to 2.35 g/cm^3 on density logs. Total coal thickness ranges from 0 to 25 feet (0 to 8 m) (Fig. 30) and constitutes less than 5 percent of the total thickness of the Cherokee Group. The total coal isolith map demonstrates that the areas of thickest accumulation are localized and that a distinct depositional pattern does not exist.

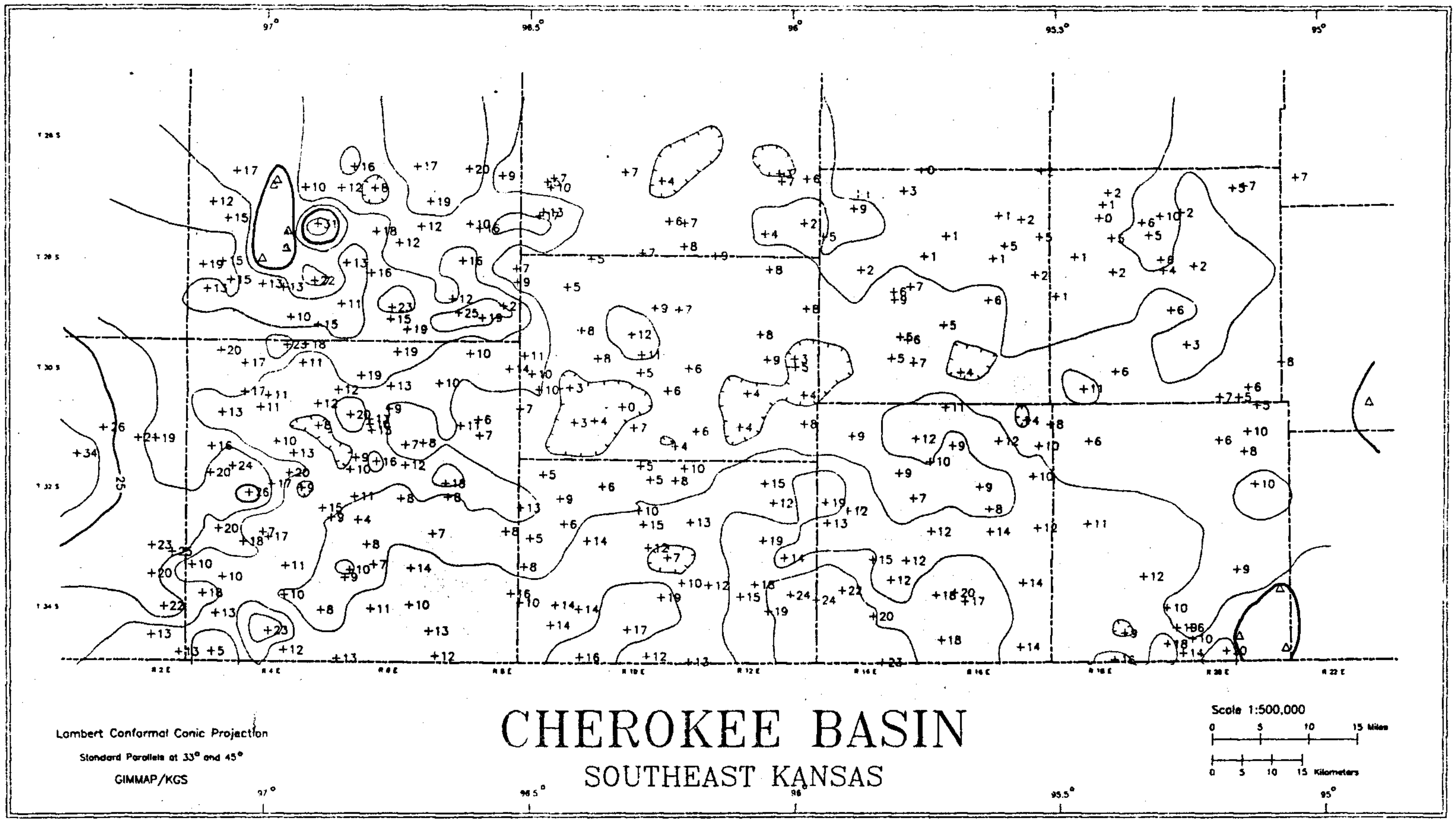


Figure 29 - Total limestone isolith map of the Cherokee Group; contour interval = 5 feet. (Δ: total interval not present)

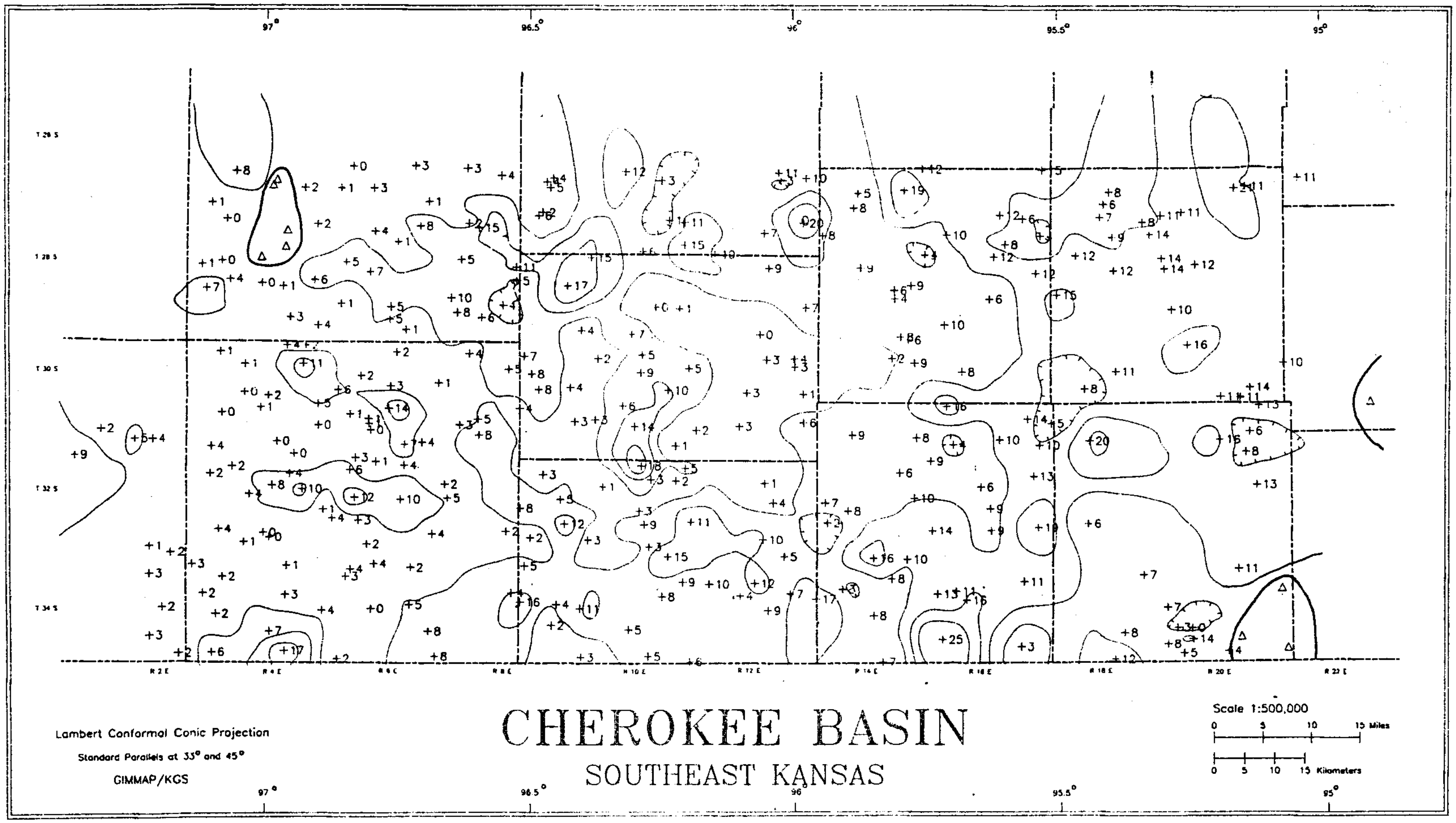


Figure 30 - Total coal isolith map of the Cherokee Group; contour interval = 5 feet. (Δ: total interval not present)

ENVIRONMENTAL INTERPRETATIONS

Interpretations of the depositional environments of the Cherokee Group were based upon lithologic classification of well log signatures, vertical and horizontal distributions of lithofacies, and study of sedimentary textures and structures in cores, well cuttings, and outcrops. The study area was divided into six regions for convenience in describing sedimentological patterns (Fig. 31). The Cherokee Group was partitioned into three vertical sections that were recognized by distinct large-scale lithologic changes (Fig. 32). Section 1 consists of the strata between the top of the Mississippian limestone and the top of the Bluejacket B shale, roughly corresponding to the Krebs Formation. Section 2 contains the strata between the top of the Bluejacket B shale and the top of the V-shale. Section 3 consists of the strata between the top of the V-shale and the top of the Excello shale.

Section 1 (Mississippian limestone to Bluejacket B shale)

In Regions II through VI, Section 1 typically consists of medium- to light-gray shale interbedded with dark-gray shale, rippled sandstone and siltstone, underclay, and coal. Thick sandstone units that contain fining-upward sequences from conglomeratic to very fine-grained sand are locally present in Region VI along the Nemaha uplift. In places along the Nemaha uplift, a thin sandstone that may be the Pennsylvanian basal conglomerate (Nodine-Zeller, 1981) lies on top of the Mississippian limestone. In Regions IV and V (R7E through

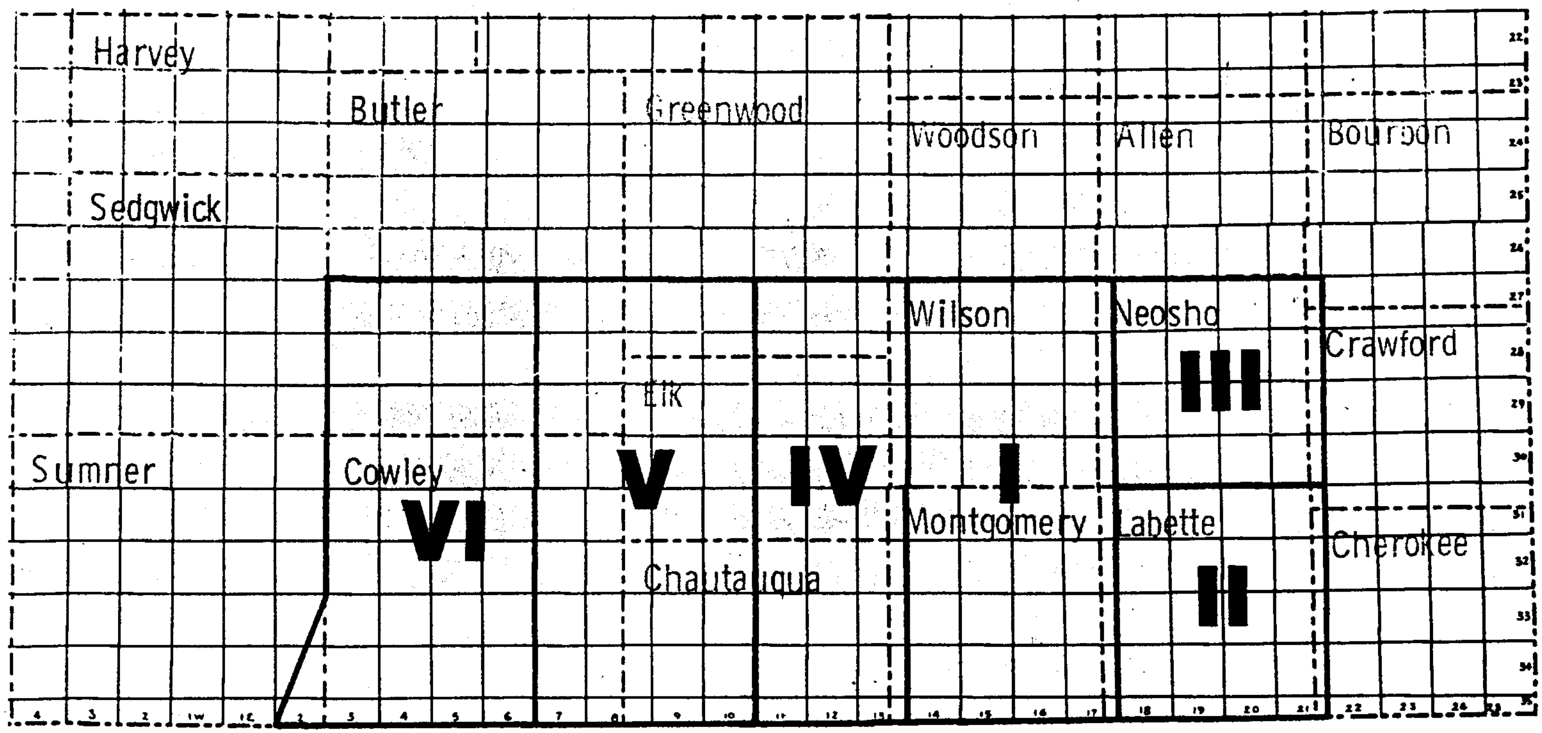
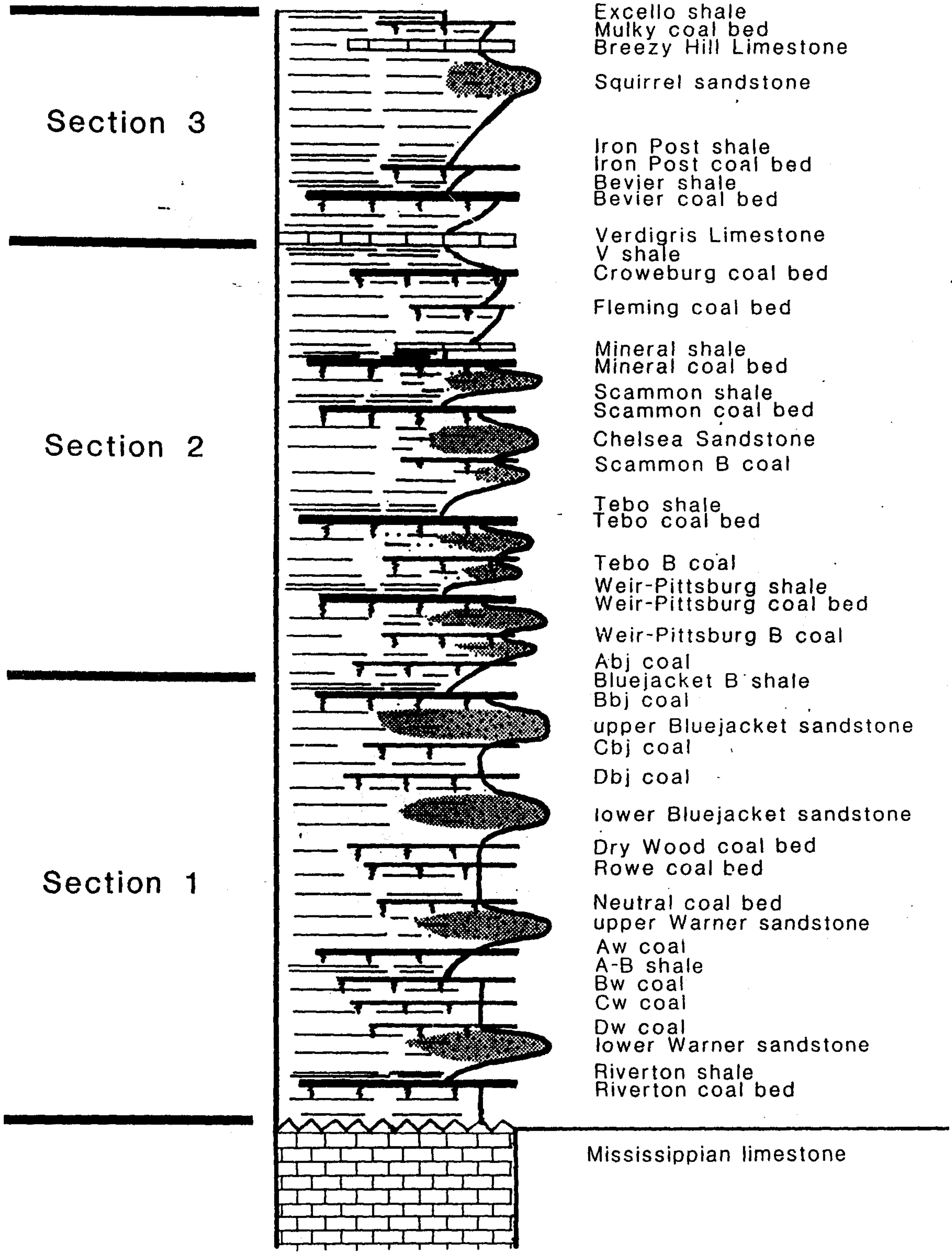


Figure 31 - Location of the six designated regions within the study area.

Figure 32 - Location of the three designated sections in the Cherokee Group.


Section 3
Section 2
Section 1
Excello shale
Mulky coal bed
Breezy Hill Limestone
Squirrel sandstone
Iron Post shale
Iron Post coal bed
Bevier shale
Bevier coal bed
Verdigris Limestone
V shale
Croweburg coal bed
Fleming coal bed
Mineral shale
Mineral coal bed
Scammon shale
Scammon coal bed
Chelsea Sandstone
Scammon B coal
Tebo shale
Tebo coal bed
Tebo B coal
Weir-Pittsburg shale
Weir-Pittsburg coal bed
Weir-Pittsburg B coal
Abj coal
Bluejacket B shale
Bbj coal
upper Bluejacket sandstone
Cbj coal
Dbj coal
lower Bluejacket sandstone
Dry Wood coal bed
Rowe coal bed
Neutral coal bed
upper Warner sandstone
Aw coal
A-B shale
Bw coal
Cw coal
Dw coal
lower Warner sandstone
Riverton shale
Riverton coal bed
Mississippian limestone

R13E), sandstone is absent from most wells or present in units less than 5 feet (1.5 m) thick. Thin limestone beds occur locally in all of the regions.

In Region I, the northern half of Region III, and local areas of Region II (R14E to R20E and T27S to the Kansas-Oklahoma border), Section 1 is dominated by the rippled-sandstone lithofacies (Table 1). This rippled sandstone typically occurs within a thick, fining-upwards sequence that consists of conglomeratic sand at the base up to very fine-grained sand and exhibits unidirectional ripples and abundant plant fragments. Structureless sands are common and the base of the sequence is usually marked by a scoured surface. These thick, fining-upward sandstone bodies are commonly stacked on top of each other and separated by scoured surfaces (Fig. 33). The stacked sandstone units stratigraphically occur between the Riverton shale and the Bluejacket B shale and range up to 179 feet (54 m) in total thickness. Below the thick sandstone deposits, and in local areas in Region I where the thick sandstones are not present, the strata consist mainly of the medium- to light-gray shale lithofacies interbedded with dark-gray shale, rippled sandstone and siltstone, underclay, and coal.

Interpretation: Section 1 is typically dominated by medium- to light-gray shale that contains locally occurring horizontal burrows, calcareous cement, plant fragments, and pyrite concretions, indicating deposition in a prodeltaic environment (Visher and others, 1975). The thick sandstone bodies in Regions I, II, III, and VI represent fluvial distributary channel deposits (Coleman and

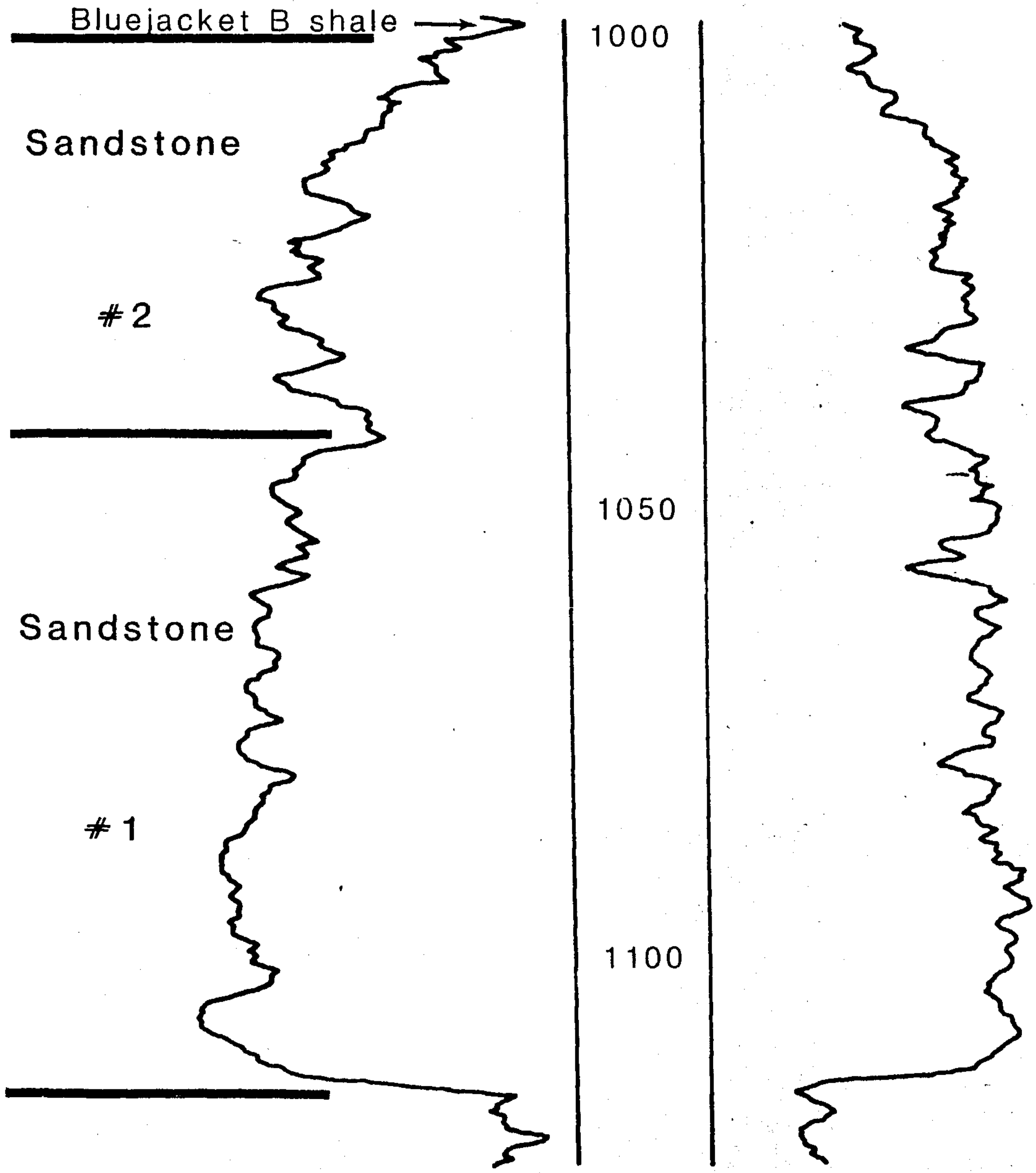


Figure 33 - Gamma ray - neutron log response for stacked sandstone bodies. Markan Oil, Gilchrist #1, 12-28S-16E, Wilson County.

Gagliano, 1965; Coleman and Wright, 1975). The distribution of these thick sandstone units shows linear north-south patterns of deposition, and each body represents a major progradation that occurred across the study area. Very fine-grained rippled sandstone units containing abundant plant fragments occur locally in each region and characterize crevasse-splay deposition (Coleman and Prior, 1980) during periods of progradation. In Regions IV and V (R7E through R13E), sandstone is usually not present, or individual units are thin indicating that during periods of progradation this area may have been occupied by a restricted bay (Brown, 1979). Underclays are common throughout the study area, suggesting laterally extensive subaerial exposure during periods of progradation or marine regression (Visher and others, 1975). Numerous coal beds occur throughout the study area, indicating deposition in laterally extensive marsh or swamp environments in a delta plain that developed during periods of major progradation of the delta system or during early stages of marine transgression (Wanless and others, 1969).

Section 2 (Bluejacket B shale to V shale)

Throughout the study area, geophysical log responses show that the strata in Section 2 consists of five major lithologic cycles. A cycle typically consists of a coarsening-upward sequence from medium- to light-gray shale to rippled siltstone or very fine-grained sandstone, overlain by an underclay and coal, and capped by a dark-gray shale (Fig. 34). The next coarsening-upward sequence lies on top of the dark-gray shale and begins the next cycle. A thin

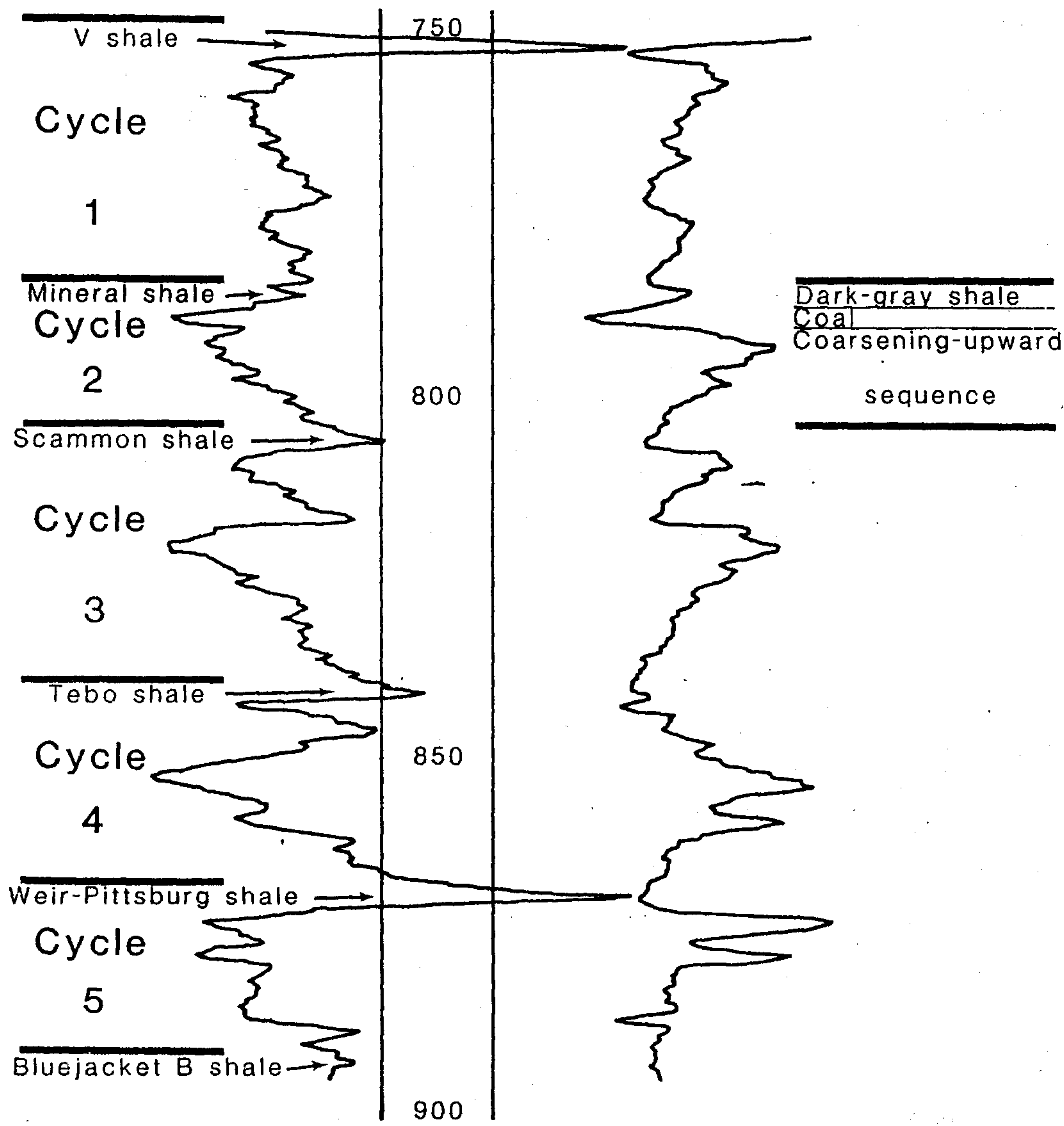


Figure 34 - Gamma ray - neutron log response for the five sedimentary cycles. Caravel Energy, Hyde #1, 10-29S-16E, Wilson County.

fining-upward sequence from the rippled sandstone or siltstone to medium- to light-gray shale is commonly present below the coal or underclay. Minor cycles interrupt some major cycles.

Rippled sandstone and siltstone are typically less than 10 feet (3 m) thick, but occur locally up to 25 feet (8 m) thick and contains scoured lower contacts and abundant plant fragments. Many of the thicker sandstone units lie within the Weir-Pittsburg interval. Limestone beds occur locally in Regions IV, V, and VI and are most common within the V shale interval.

Interpretation: The medium- to light-gray shale contains abundant plant fragments, locally occurring marine fauna (Table 1), calcareous cement, and pyrite nodules indicating both marine and non-marine influence (Eliot, 1978). Local sandstone bodies ranging in thickness from 8 to 20 feet (2.4 to 6 m) represent fluvial distributary channels (Brown and others, 1973) that are too small to be continuously mapped by the well log coverage (1 to 3 wells per township). The rippled sandstone and siltstone characterize crevasse-splay deposition (Coleman and Prior, 1980) during periods of deltaic progradation. Underclays indicate laterally extensive subaerial exposure (Visher and others, 1975) during periods of progradation or marine regression. Coal beds represent deposition in marsh or swamp environments that formed during deltaic progradation or during early stages of marine transgression (Wanless and others, 1969). Dark-gray shale beds contain marine fossils (Table 1), calcareous cement, and pyrite nodules and represent laterally extensive marine deposition (Heckel, 1977).

Section 3 (V shale to Excello shale)

Section 3 consists mainly of the medium- to light- gray shale lithofacies interbedded with dark-gray shale, argillaceous limestone, sandstone, underclay, and coal. The Verdigris Limestone thickens from east to west across the study area and contains abundant brachiopods, bryozoans, and crinoids. In Regions I through IV (R11E to R22E), the Verdigris Limestone is commonly less than 2 feet (0.6 m) thick and underlies a coarsening-upwards sequence of shale to siltstone or locally occurring sandstone. The coarsening-upward sequence is overlain by an underclay and the Bevier coal. In Regions V and VI (R3E to R11E), the Verdigris Limestone ranges up to 10 feet (3 m) thick and directly underlies the Bevier coal.

Medium- to light-gray shale is the dominant lithology between the Bevier and Iron Post coals, but rippled sandstone occurs locally in Regions I and III, and argillaceous limestone is present in Regions V and VI. Above the Iron Post coal, laterally discontinuous sandstones are typically less than 10 feet (3 m) thick but range up to 25 feet (8 m). Within the Excello interval, density logs and well cuttings show that one to two thin argillaceous limestone beds occur in Regions V and VI and thicken along the Nemaha uplift. The Breezy Hill Limestone is laterally extensive in the southern half of the study area and in Region VI, thickening southward up to 16 feet (5 m). The Excello shale is a dark-gray shale that extends throughout the basin.

Interpretation: The Verdigris Limestone characterizes marine deposition that extended throughout the study area but was more dominant in the western regions. Between the Verdigris Limestone and the Bevier coal, deltaic progradation or marine regression occurred only in Regions I, II, and III. The laterally extensive Bevier coal indicates that a marsh or swamp environment existed throughout most of study area. Each of the limestone beds in Regions V and VI represents a period of marine deposition. The increase in total limestone content of Section 3 along the Nemaha uplift indicates a diminished influence of terrigenous sedimentation. Sandstone bodies within the Excello interval represent progradational events that extended locally in the basin. The Iron Post coal characterizes deposition in marsh or swamp environments in the northwestern and southern portions of the study area. The Breezy Hill Limestone suggests marine deposition in the southern half of the basin and in Region VI. The Excello shale contains marine fauna (Table 1), calcareous cement, and pyrite nodules, representing laterally extensive marine deposition (Heckel, 1977).

Within Section 3, depositional environments of the Cherokee and Sedgwick basins were connected during periods of high sea level. The evidence for this statement is: 1) specific marine units in Section 3 extend laterally from the Cherokee basin into the Sedgwick basin; 2) the Nemaha uplift was buried with sediment before deposition of the V shale (Fig. 35), 3) the Nemaha uplift was not a high positive structure by the time of Cherokee deposition (Merriam, 1963), and 4) the depositional environment of the upper Cabaniss strata in the Sedgwick basin was a carbonate shelf (Killen, 1986).

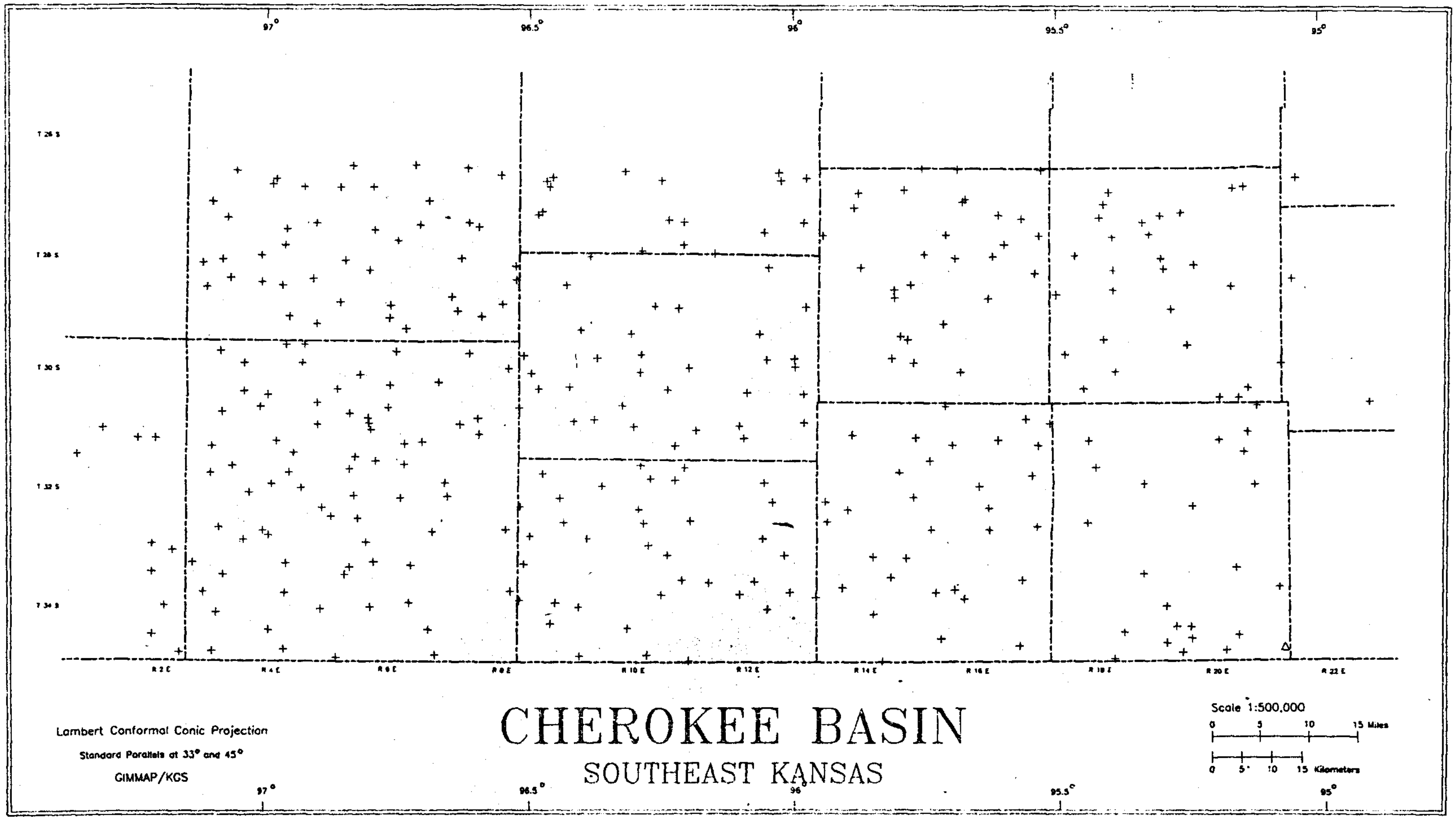


Figure 35 - Location of the V shale marker bed. (+: marker present)

Controls of Sea-level Fluctuations

Vertical and lateral distributions of lithofacies reflect numerous widespread strandline shifts in the Cherokee basin. These shifts can occur as a result of large-scale change in ocean volume or large-scale change in the shape of the ocean floor (Ball, 1985).

Contemporaneous epeirogenic deformation of the shallow Cherokee basin significantly affected sedimentation of the Cherokee Group. Less subsidence occurred along the Nemaha uplift and allowed for the encroachment of shallow water environments upon the structure. Rates of subsidence increased to the southeastern corner of the study area to produce a slightly steepened depositional slope. The basin, however, was filling during deposition of the Cherokee Group and eventually overlapped the Nemaha uplift before the V shale was deposited. These relatively slow rates of deformation compared to sedimentation indicate that local tectonism was not the major cause of sea-level fluctuation in the Cherokee basin. Moreover, Sloss and Speed (1974) determined that tectonic movement is too slow to cause the high-frequency changes of relative sea level associated with cyclic sedimentation.

Dark-gray marine shales that extend through the Midcontinent and underclays that are present throughout the study area indicate widespread rhythmic flooding and subaerial exposure during deposition of the Cherokee Group. Periodic eustatic changes of sea level due to continental glaciation in Gondwana are the most plausible for producing widespread rhythmic flooding and subaerial exposure of a broad, gently dipping shelf (Watney, 1985).

A rough estimate of the duration of each of the five designated cyclothems in Section 2 is 390,000 years. This calculation is based upon the assumption that the length of the Desmoinesian Age is 10 million years (van Eysinga, 1978), and that the sedimentation rates were relatively constant throughout the Desmoinesian. The Cherokee Group is estimated to be 65% of the thickness of the Desmoinesian Stage, and Section 2 is roughly 30 percent of the thickness of the Cherokee Group. This result is similar to Heckel's (1980) estimation that the approximate frequency of Upper Pennsylvanian eustatic sea-level cycles is one per 400,000 years.

Source of Sediment

The overall distribution of sandstone in Section 1 indicates that sediment prograded across the basin from north to south (Fig. 36). The channel sandstone belt in Region I corresponds with the distribution of the Bartlesville Sandstone in northern Oklahoma (Visher and others, 1971). Paleocurrent measurements made along outcrops of the Bartlesville Sandstone indicate a general north-to-south flow (Visher and others, 1971). The distributary channel pattern in Region VI roughly corresponds to an elongate shoestring sandstone body to the northeast in Greenwood County (Rich, 1923; Bass, 1936; and Hulse, 1978). The distribution of sandstone in Section 1 (Fig. 36) indicates some sediment influx from east of the study area into Regions II and III. An eastward source for Krebs Formation sediments in southeastern Kansas was also proposed by Ebanks and others, (1977) and Harris (1984). Along the Nemaha

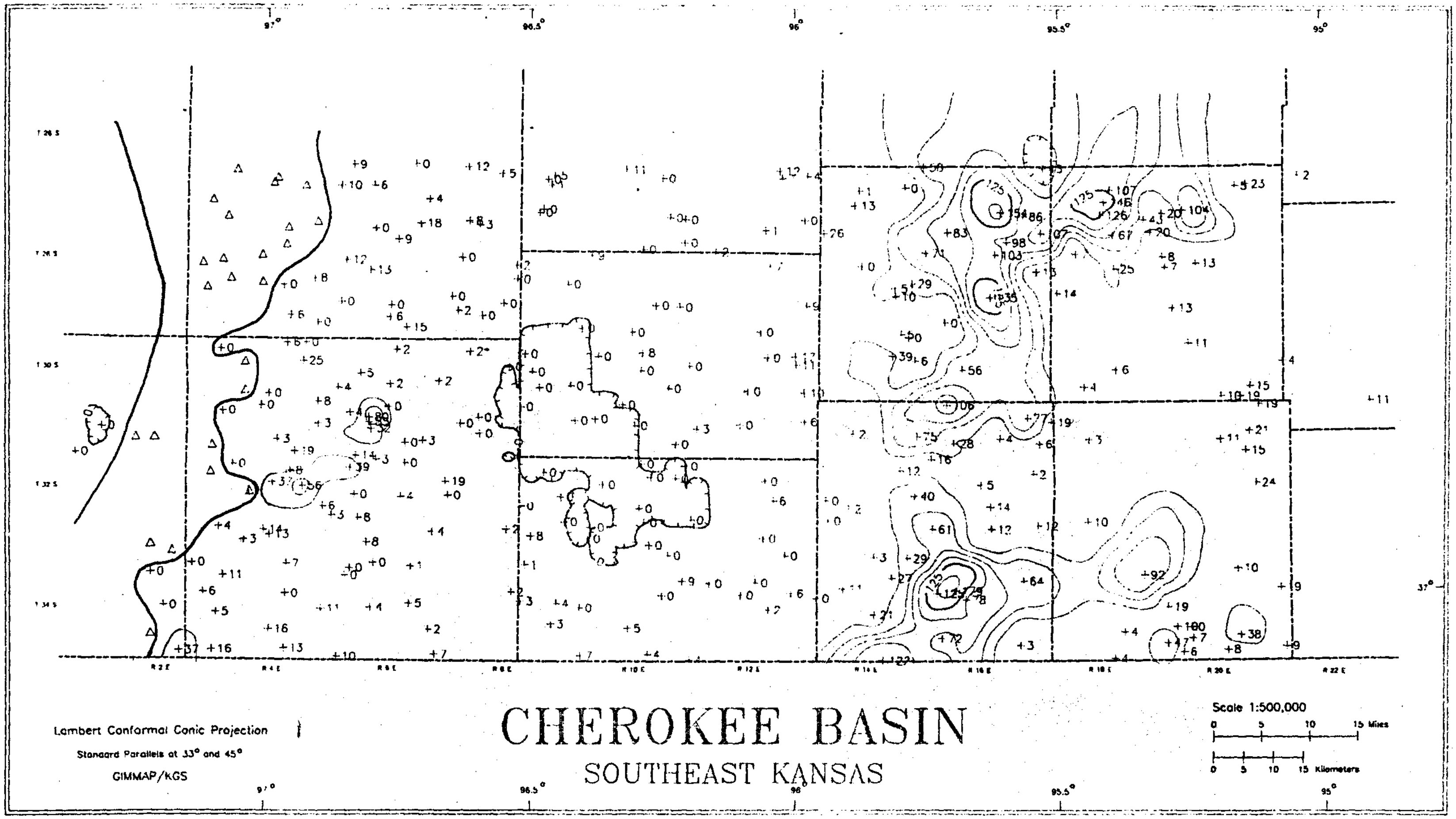


Figure 36 - Sandstone isolith map for Section 1; contour interval = 25 feet. (Δ: total section not present)

uplift, thin sandstone bodies that overlie the Mississippian limestone possibly formed as detritus from the uplift was deposited into depressions in the unconformable karst surface of the limestone.

In Section 2, the Weir-Pittsburg interval contains thick fluvial sandstone deposits within the channel belt in Region I, which probably had a northern source. Overall distribution of sandstone for Section 2 is irregular and reveals possible sediment influences from the north and east (Fig. 37).

Section 3 contains laterally discontinuous sandstone units within all regions of the study area. Overall sandstone distribution of Section 3 shows no distinct source of sediment (Fig. 38).

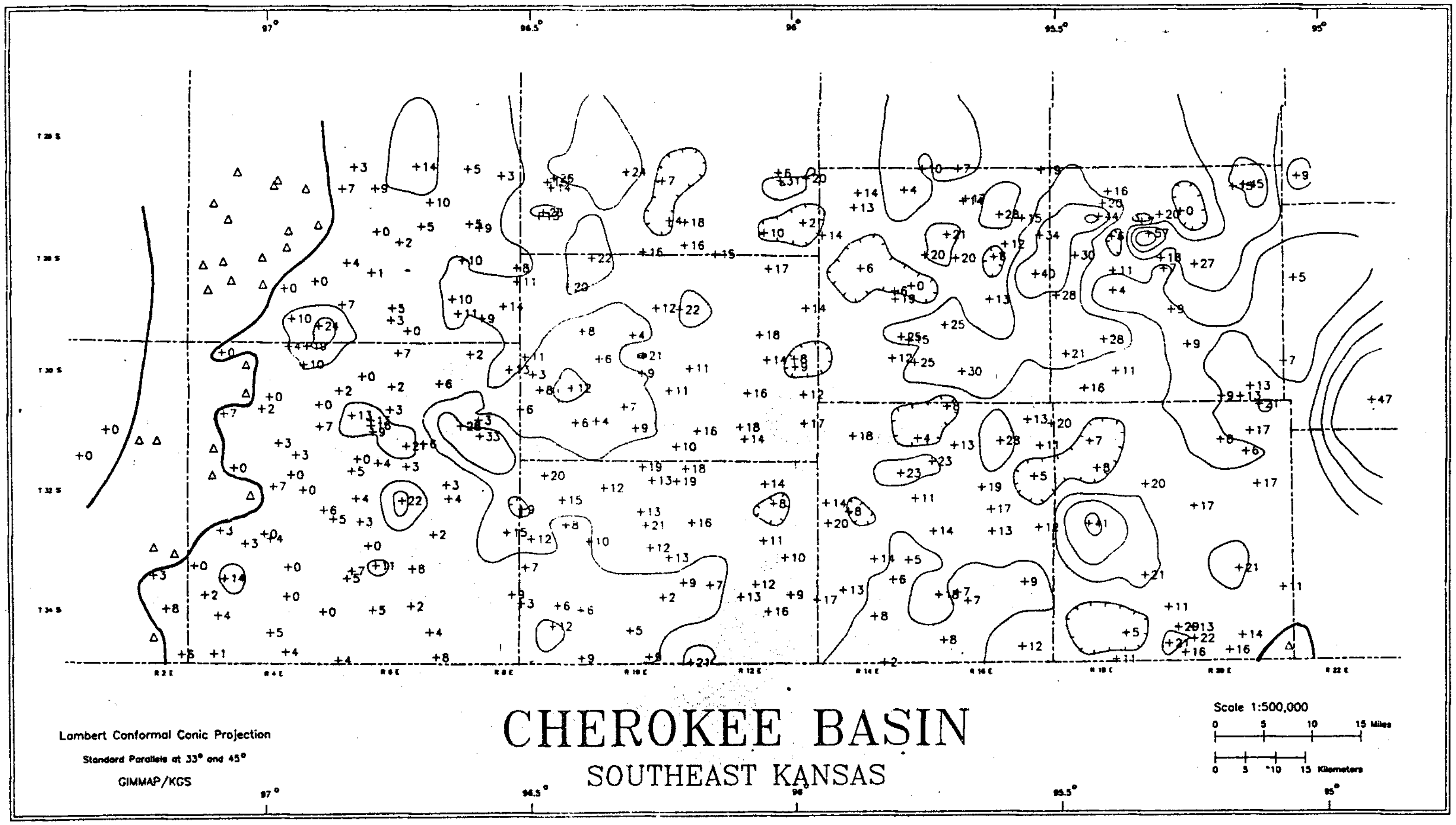


Figure 37 - Sandstone isolith map for Section 2; contour interval = 10 feet. (Δ: total section not present)

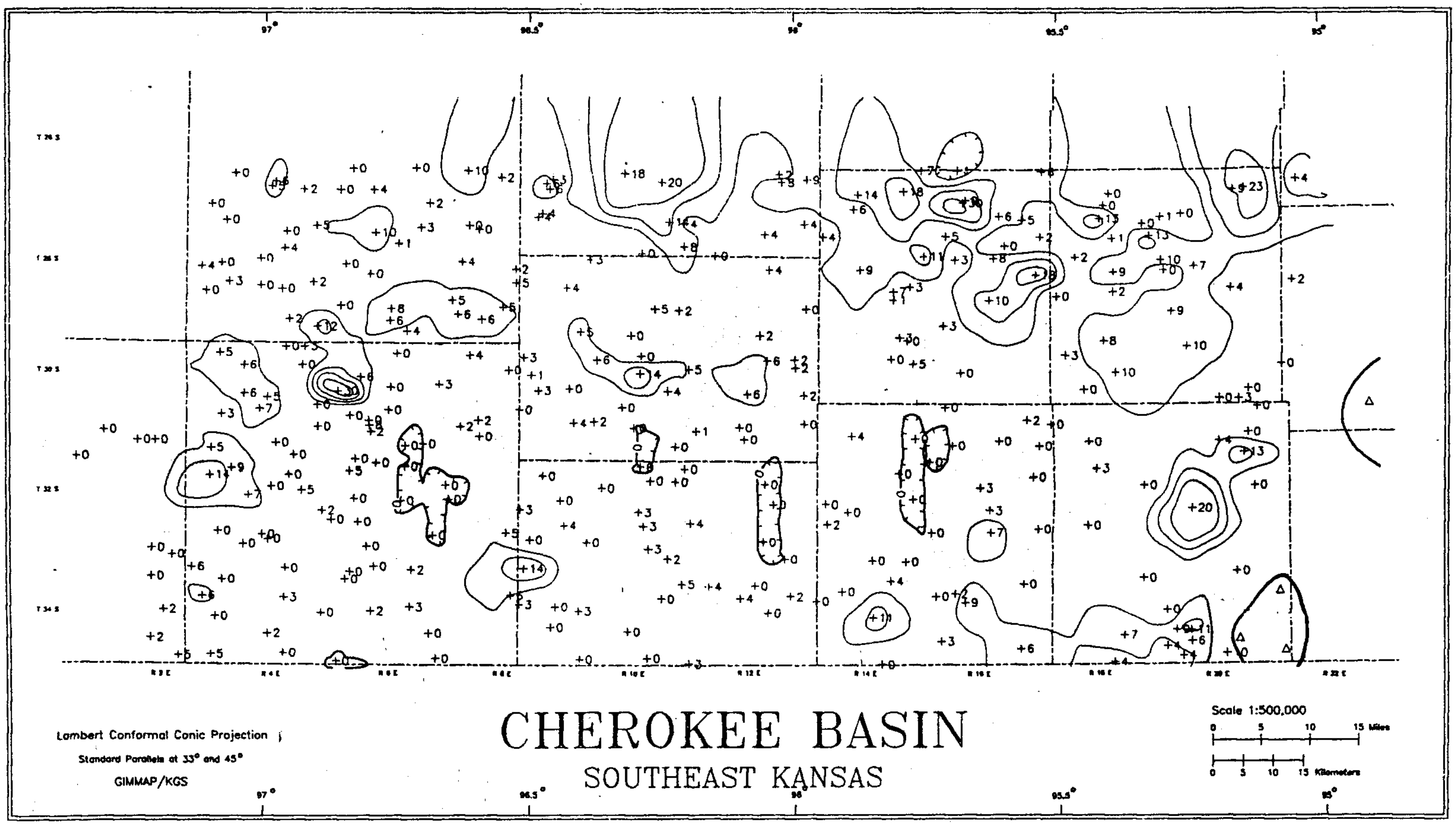
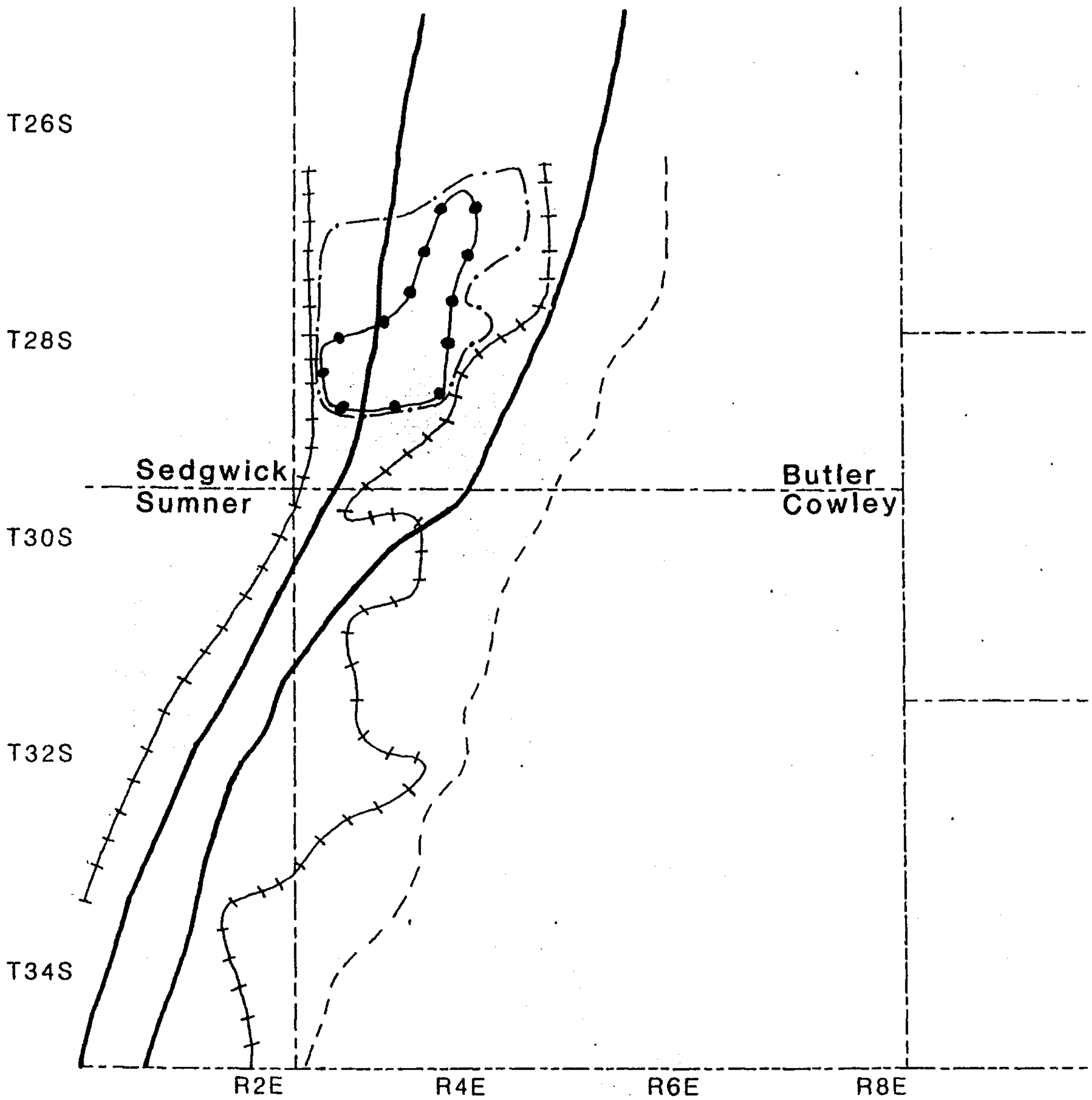


Figure 38 - Sandstone isolith map for Section 3; contour interval = 5 feet. (Δ: total section not present)

BASIN DEVELOPMENT

Maps of marker locations show the lateral extent of each marker. A synthesis of these maps indicates a progressive onlap of sediment onto the Nemaha uplift (Fig. 39). The lateral extent of specific marker beds exhibit linear patterns of non-deposition that parallel the uplift. These patterns exist for markers up section in the Krebs Formation, but occur progressively farther west as surface elevations rise on the uplift. Above the Bluejacket B shale, the areas of non-deposition correspond to structural highs. The V shale marker extends across the uplift and into the Sedgwick basin, indicating that sediment had buried the uplift prior to deposition of the V shale.

Cross sections (Plates 1-4) reveal that the Cherokee basin subsided during deposition of the Krebs and lower Cabaniss formations. An isopach map of the Cherokee Group shows that the strata progressively thickened from west to southeast across the study area (Fig. 40). A structure map of the top of the Mississippian limestone (Fig. 41) shows a general dip across the study area from east to west. This trend does not correspond with the west-to-southeast depositional trend, indicating that tectonic movement occurred within the basin after deposition of the Cherokee Group.



-- Riverton marker
—·— Tebo marker
—+— Bluejacket B marker
—●— Mineral marker
▬ approximate outline of the Nemaha uplift (Sims, 1985)

Figure 39 - Lateral extent of specific marker beds in relation to the Nemaha uplift.

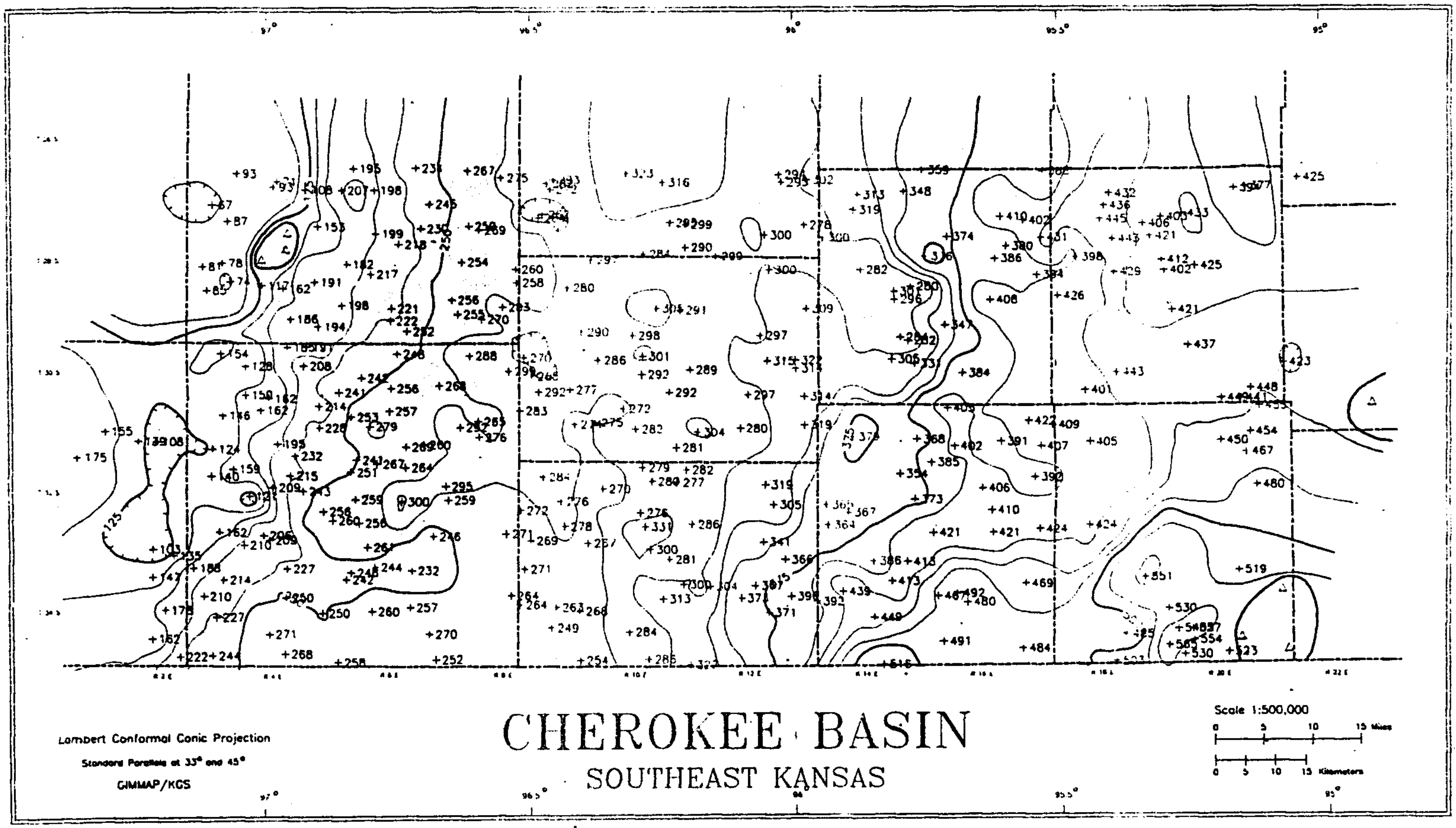


Figure 40 - Total isopach map of the Cherokee Group; contour interval = 25 feet. (Δ: total interval not present)

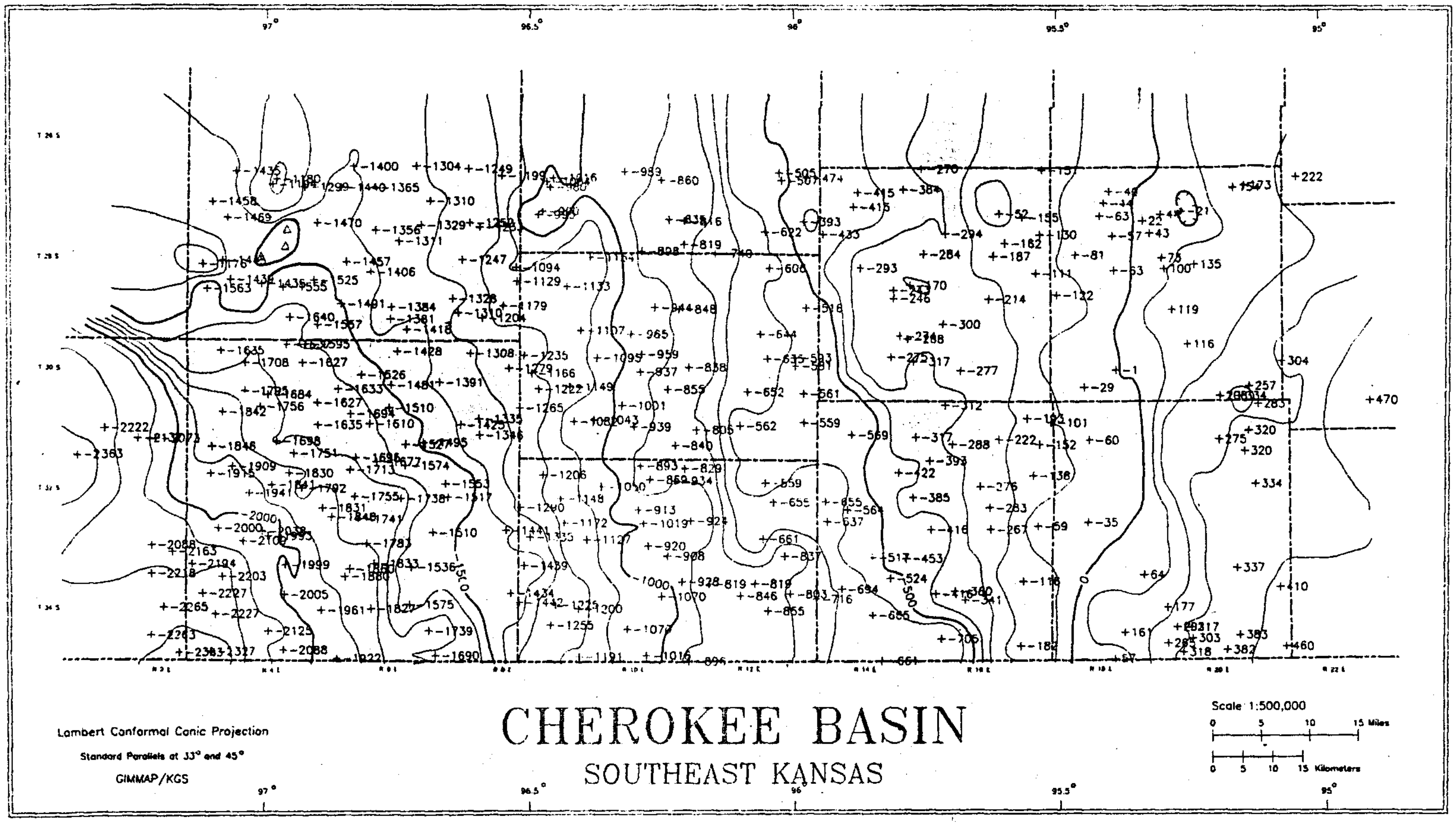


Figure 41 - Structure map of the top of the Mississippian limestone; contour interval = 100 feet. (Δ: Mississippian limestone not present)

SUMMARY

Detailed stratigraphic correlations of radioactive dark-gray shales of the Cherokee Group were extended throughout the Cherokee basin and into the Sedgwick basin. The Cherokee Group was divided into ten stratigraphic intervals on the basis of these markers.

Interpretations of depositional environments of the Cherokee Group were based on lithologic classification of well log signatures, vertical and horizontal lithofacies distributions, and the study of sedimentary textures and structures in cores, well cuttings, and outcrops. The distributions of lithofacies show numerous environmental changes due to deltaic movement or eustatic changes of sea level. Strata from the top of the Mississippian limestone to the top of the Bluejacket B shale (Section 1) consist mainly of medium- to light-gray shale interbedded with dark-gray shale, rippled sandstone and siltstone, underclay, and coal. During deposition of Section 1, the basin was the site of prodeltaic environments during high stands of sea level. Within Region I, the northern half of Region III, local areas of Region II, and along the Nemaha uplift in Region VI, Section 1 contains thick sandstone bodies of fluvial origin that represent progradations that advanced across the basin from north to south. The overall sandstone distribution trend for Section 1 is mainly from north to south, with east-west channels crossing Regions II and III.

Five major lithologic cycles are recognized in the strata between the top of the Bluejacket B shale and the top of the V shale (Section 2). A coarsening-upward sequence from medium- to light-gray shale to

rippled siltstone and sandstone occurs at the base of a cycle. The medium- to light-gray shale shows marine and non-marine influence, and the overlying rippled siltstone and sandstone characterize non-marine distributary channel and interdistributary crevasse-splay deposition. The coarsening-upward sequence is overlain by an underclay, indicating subaerial exposure during periods of marine regression or deltaic progradation. Directly above the underclay, a coal represents the formation of a laterally extensive marsh or swamp environment. A dark-gray shale marks the top of the cycle and characterizes marine deposition. Sandstone isolith maps for Section 2 reveal an influx of sediment from north and east of the study area.

Strata between the top of the V shale and the top of the Excello shale (Section 3) consist mainly of medium- to light-gray shale interbedded with dark-gray shale, argillaceous limestone, rippled sandstone and siltstone, underclay, and coal. Limestone content is greater along the western and southern borders of the study area, reflecting a diminished influx of terrigenous sedimentation. Specific marine shale and limestone beds within Section 3 laterally extend from the Cherokee basin into the Sedgwick basin, indicating that depositional environments were connected when sea level was high. The distribution of sandstone in Section 3 does not reveal a major source area.

Sediment of the Cherokee Group progressively lapped onto the Nemaha uplift and covered the uplift prior to deposition of the V shale. Cross sections reveal that the Cherokee basin subsided during deposition of the Krebs and lower Cabaniss formations. The Cherokee Group thickens eastward from the Nemaha uplift to the deepest part of the Cherokee basin in Kansas in the southeastern corner of the study area. Structure maps indicate that the current regional westward dip of the area represents tectonic movement that occurred after deposition of the Cherokee Group.

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APPENDIX A

List of Cores

Location	Spot	Well Name	Operator	County
23-26S-14E	SW-NW-SE	Scott 6AO	Colt	Woodson
6-27S-16E	SW-SW-NE	Braman 7-3	Farrar	Wilson
26-28S-19E	NW-NW	Knight W-36	Tesoro	Neosho
30-29S-17E	C-NE	H. Estes #7	DiCo	Wilson
25-31S-2E	NE-NW-SW	Reitz #1	Derby	Sumner
28-31S-12E	SW-SE-SW	Hadlock #2	Independent	Elk
25-31S-16E	NW-NW-SW	Holt #9	Holt	Montgom.
22-31S-22E	NW-NW-SW	P&M #10	P&M	Cherokee
24-32S-4E	NW-SE-NE	Kukuk #25	Sinclair	Cowley
12-32S-21E	NE-NE-NE	P&M #11	P&M	Cherokee
17-33S-15E	C-NE-NE	Hoffman #1	JEB	Montgom.
30-34S-3E	SW-SW-NW	Weir #1	Sinclair	Cowley
20-34S-20E	NE-NE-NE	Murphy #1	U.S./ERDA	Labette
3-35S-15E	C-S2-NW	Cannon #1-C	Collins	Montgom.

All cores are in the collection of the Kansas Geological Survey, Lawrence, Kansas.

APPENDIX B

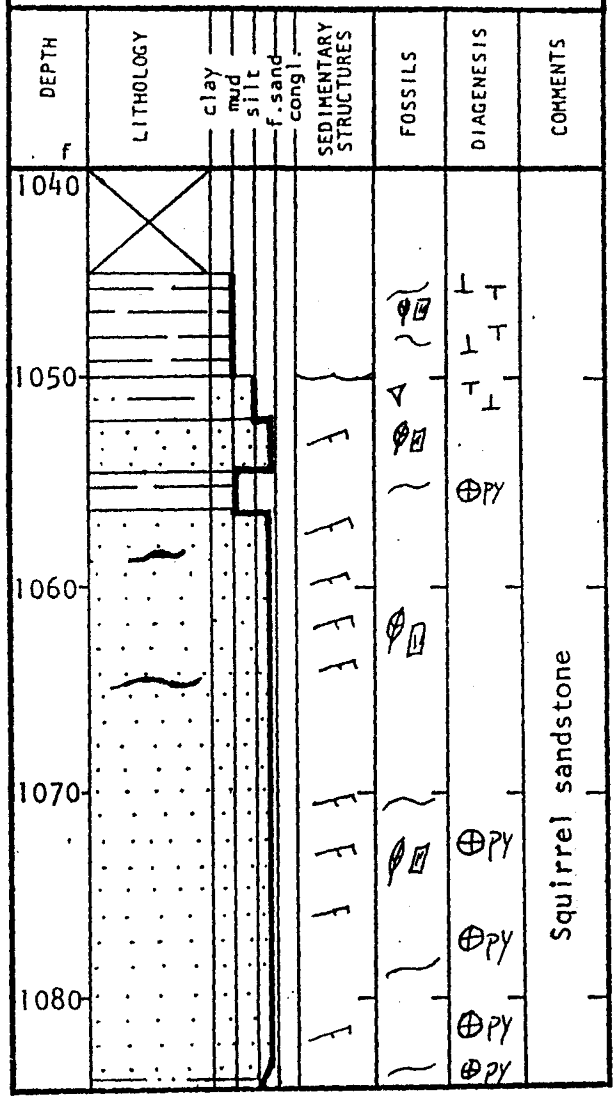
Graphic Descriptions of Cores

(Original verbal descriptions at a scale of 1 inch = 1 foot are on file with the Geologic Investigations section at the Kansas Geological Survey).

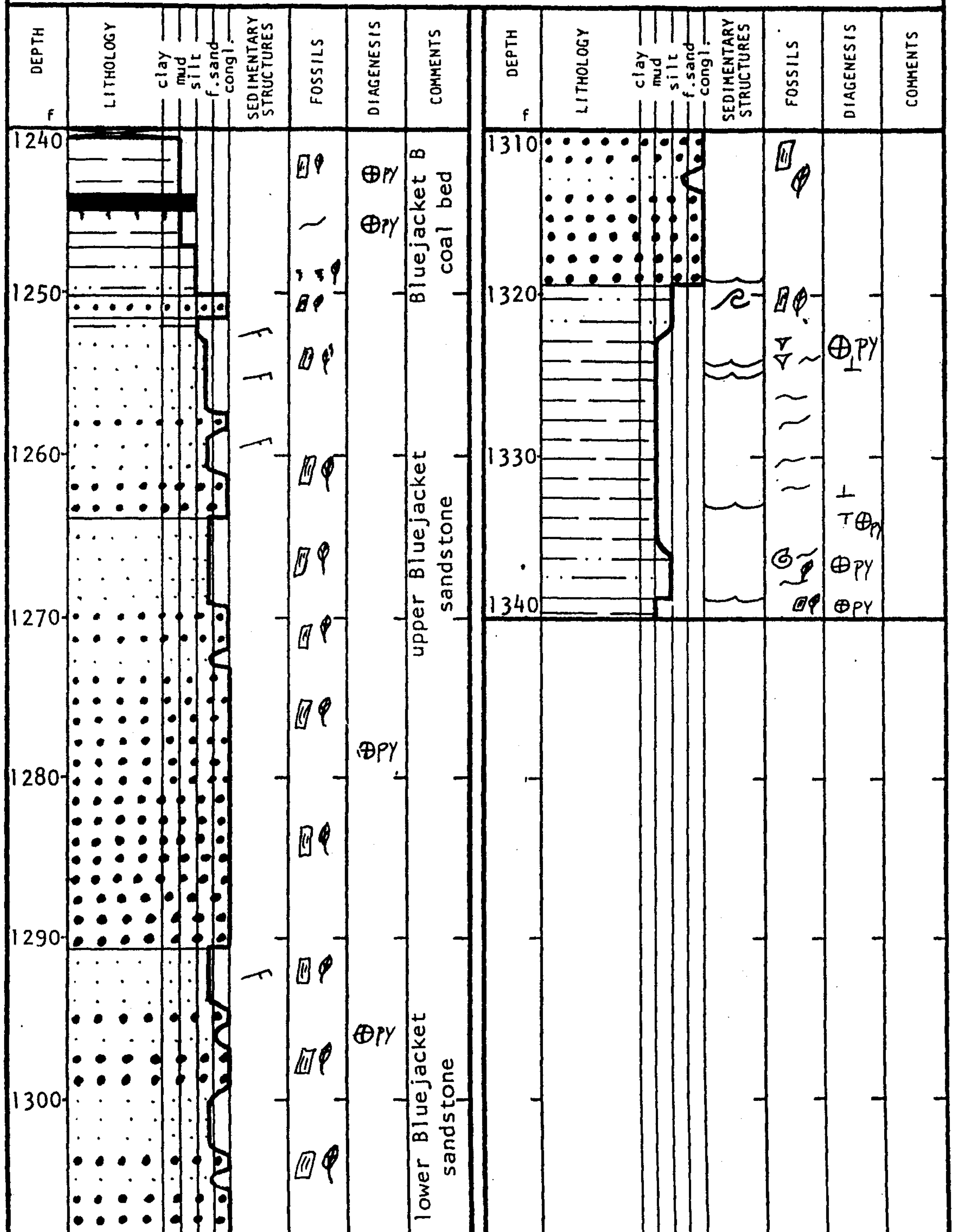
EXPLANATION OF SYMBOLS

dark gray shale	asymmetric ripples
light to medium gray shale	scour surface
mudstone	convolute bedding
siltstone	plant fragments
sandstone	brachiopods
mud-clast conglomerate	gastropods
coal	burrows
argillaceous limestone	rootlets
limestone	pyrite concretions
lenticular bedding	clay ironstone concretions
wavy bedding	calcareous cement
flaser bedding	siderite spherulites
no core recovery	

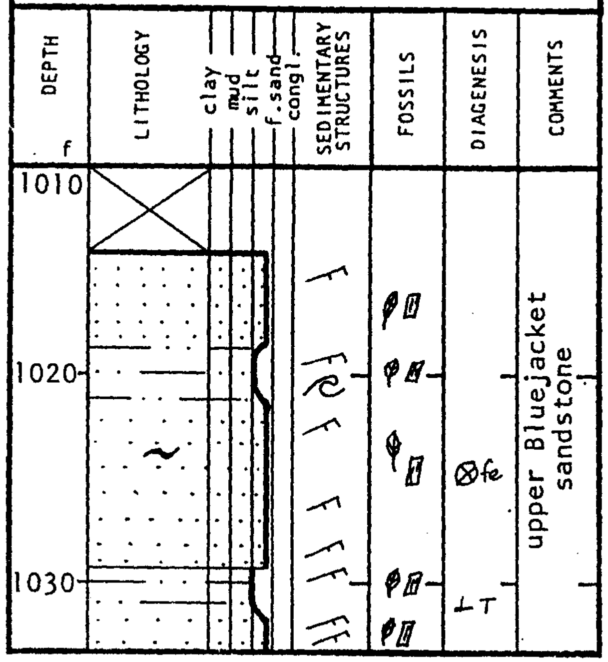
Scott 6AO Core #1
SW NW SE Sec. 23 T26S R14E
Woodson County, Kansas
Surface elevation: 926 feet



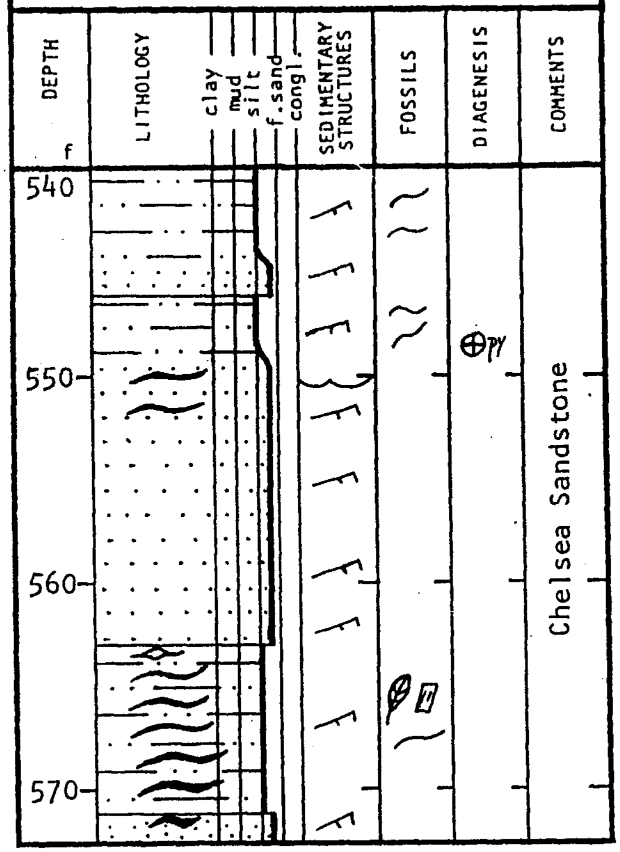
Scott 6A0 Core #2
SW NW SE Sec. 23 T26S R14E
Woodson County, Kansas
Surface elevation: 926 feet



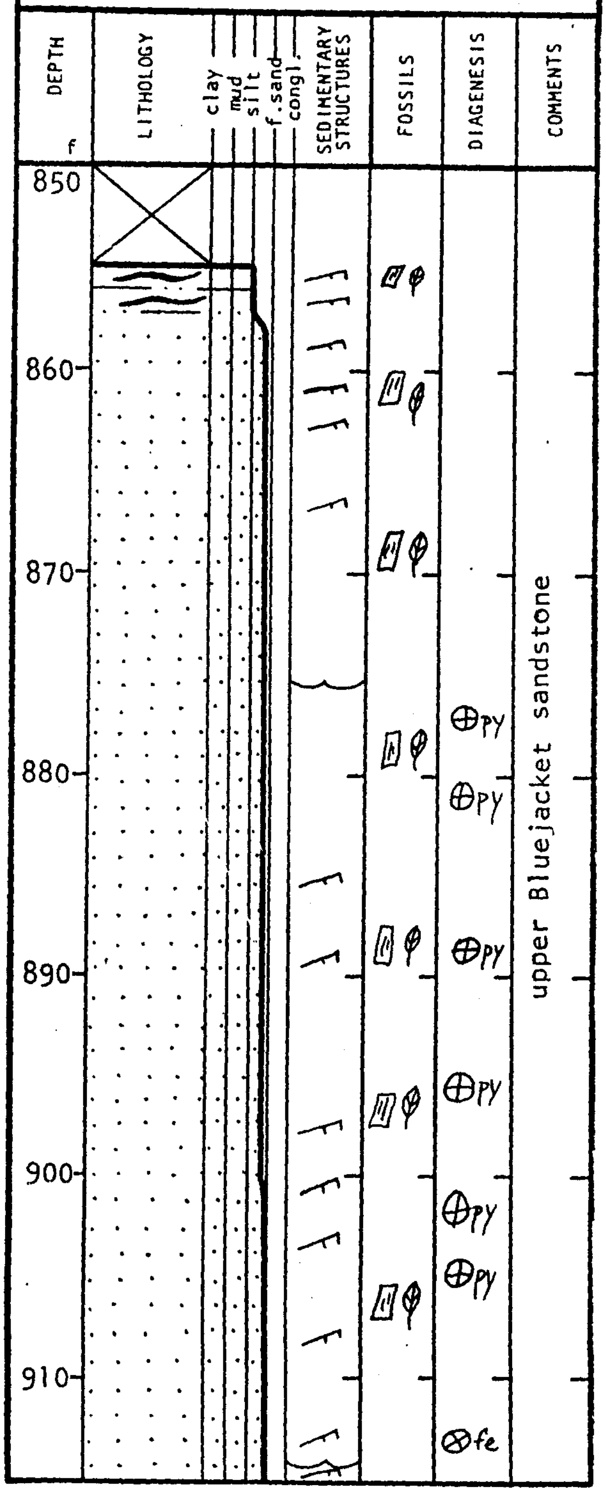
Braman 7-3
SW SW NE Sec. 6 T27S R16E
Wilson County, Kansas
Surface elevation: 900 feet

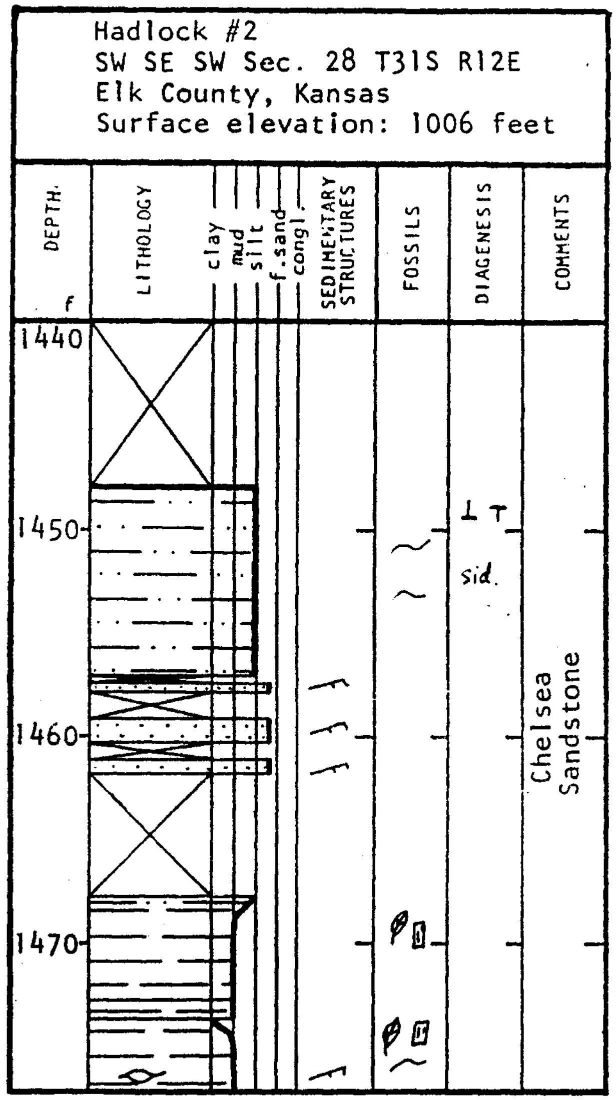


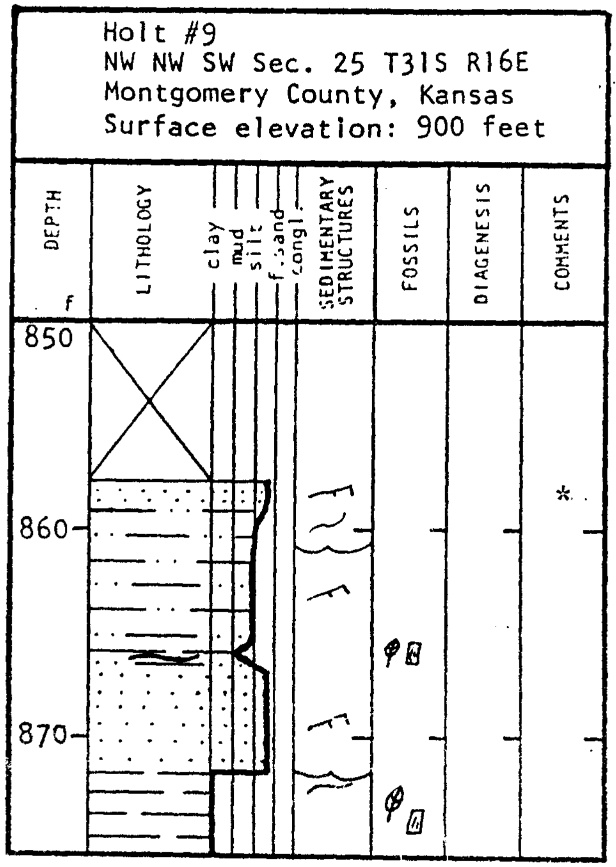
W-36 Knight
NW NW Sec. 26 T28S R19E
Neosho County, Kansas
Surface elevation: 885 feet



Hazel Estes #7
C NE Sec. 30 T29S R17E
Wilson County, Kansas
Surface elevation: 890 feet

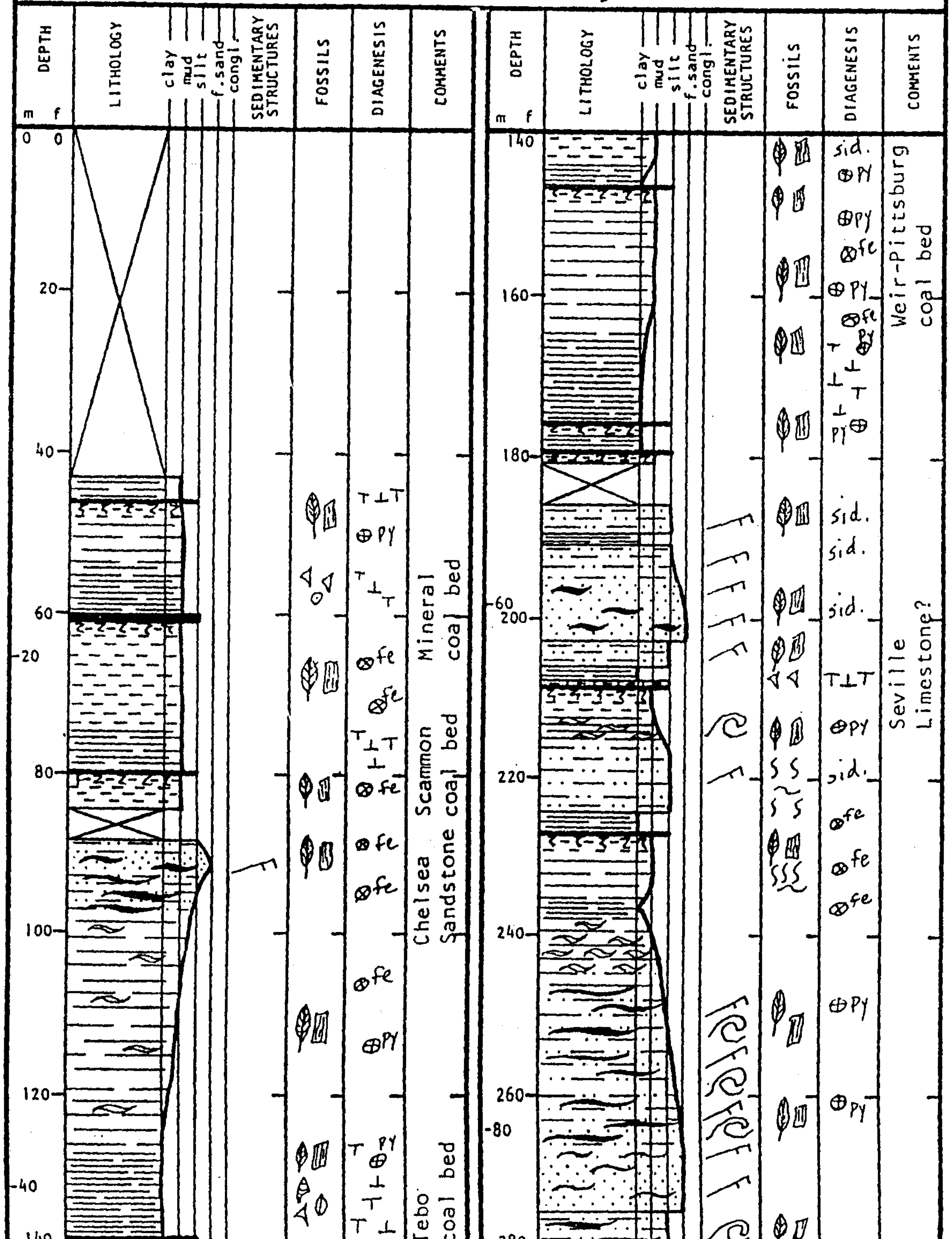



Hadlock #2
SW SE SW Sec. 28 T31S R12E
Elk County, Kansas
Surface elevation: 1006 feet
DEPTH f
LITHOLOGY
clay
mud
silt
f.sand
congl.
SEDIMENTARY STRUCTURES
FOSSILS
DIAGENESIS
COMMENTS
1440
1450
1460
1470
sid.
Chelsea Sandstone

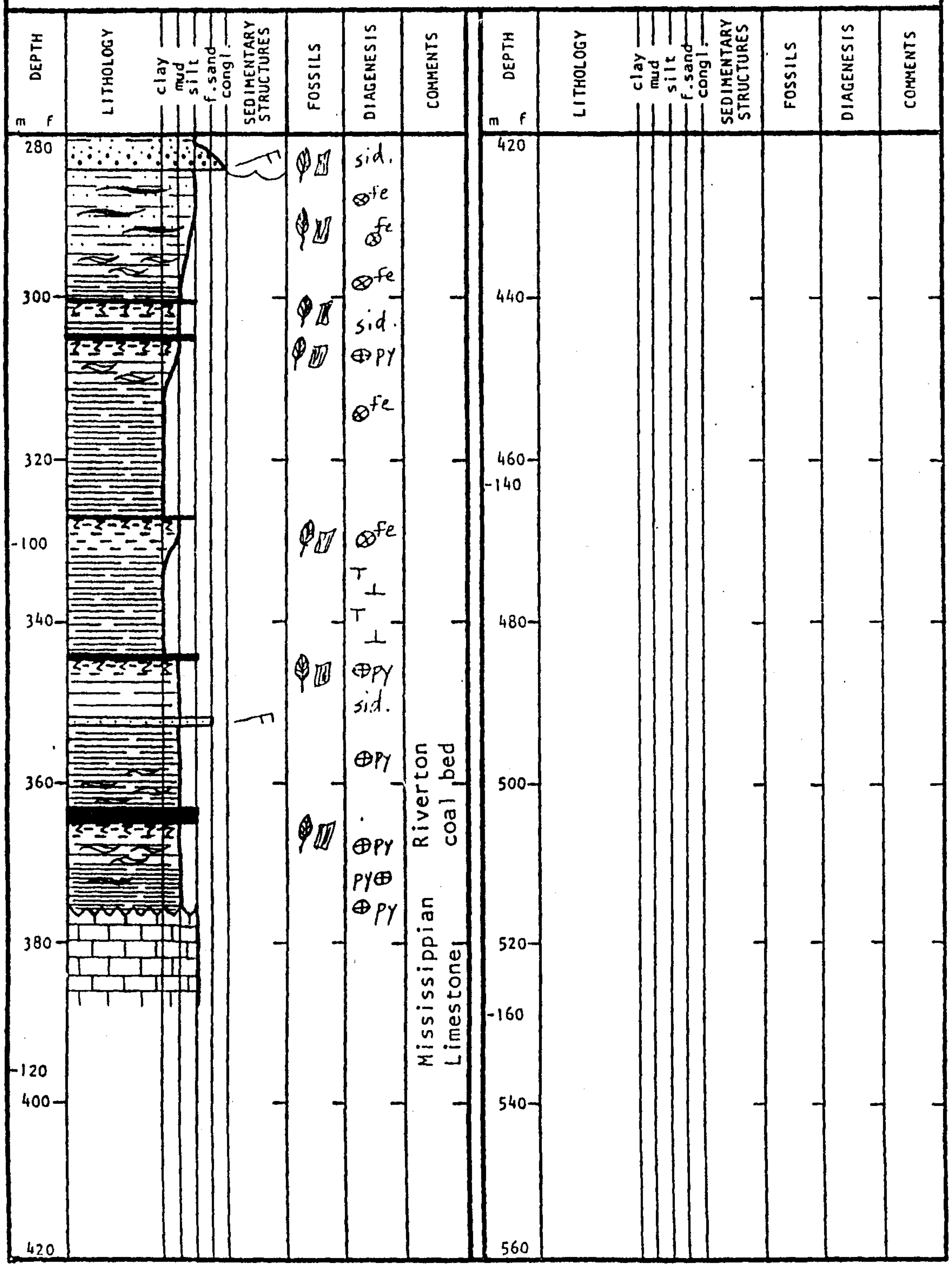


*Cored section correlates with the Weir-Pittsburg interval.

P&M #10*
NW NW SW Sec.22 T31S R22E
Cherokee County, Kansas
Surface Elevation -863

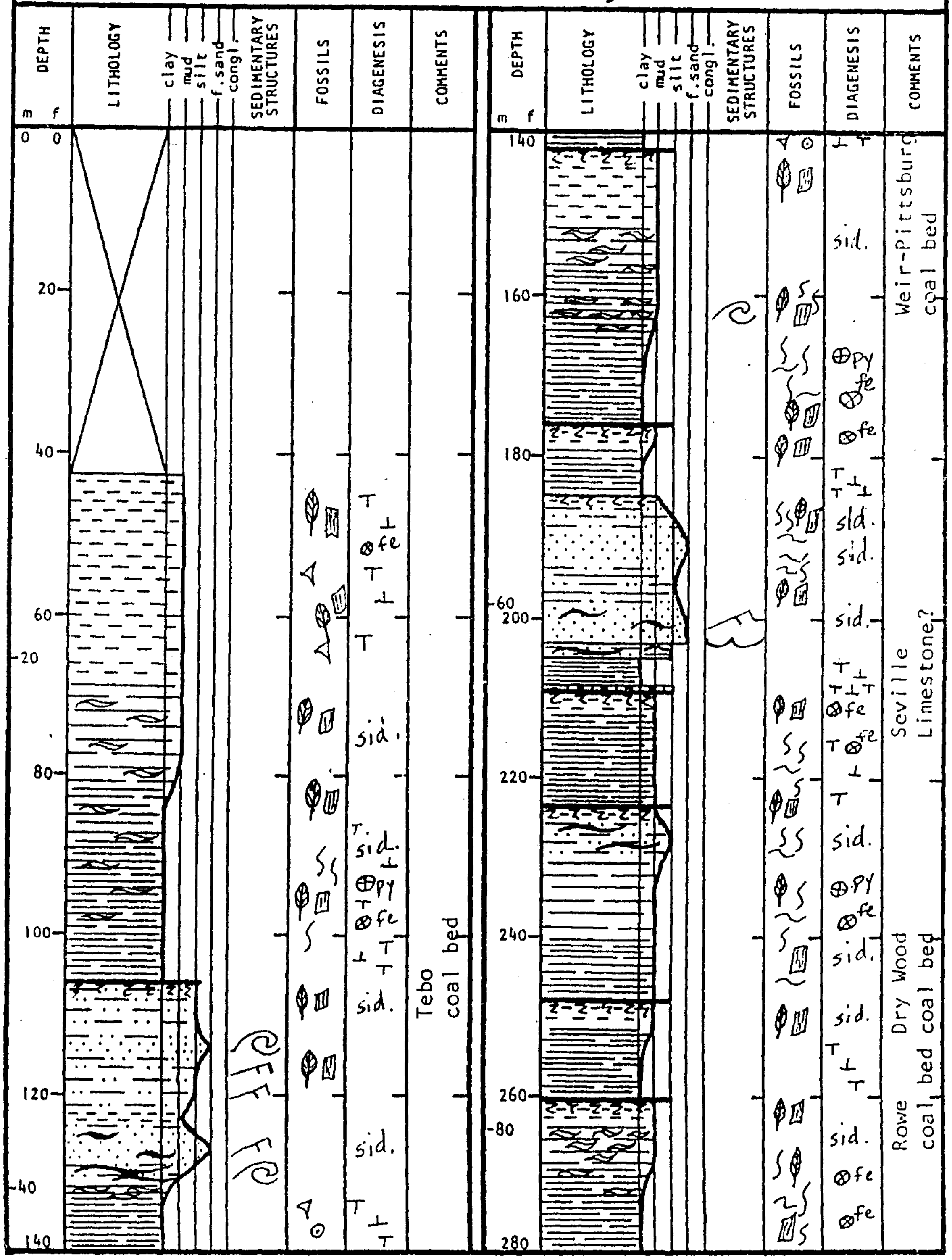


P&M #10
NW NW SW Sec.22 T31S R22E
Cherokee County, Kansas
Surface Elevation -863



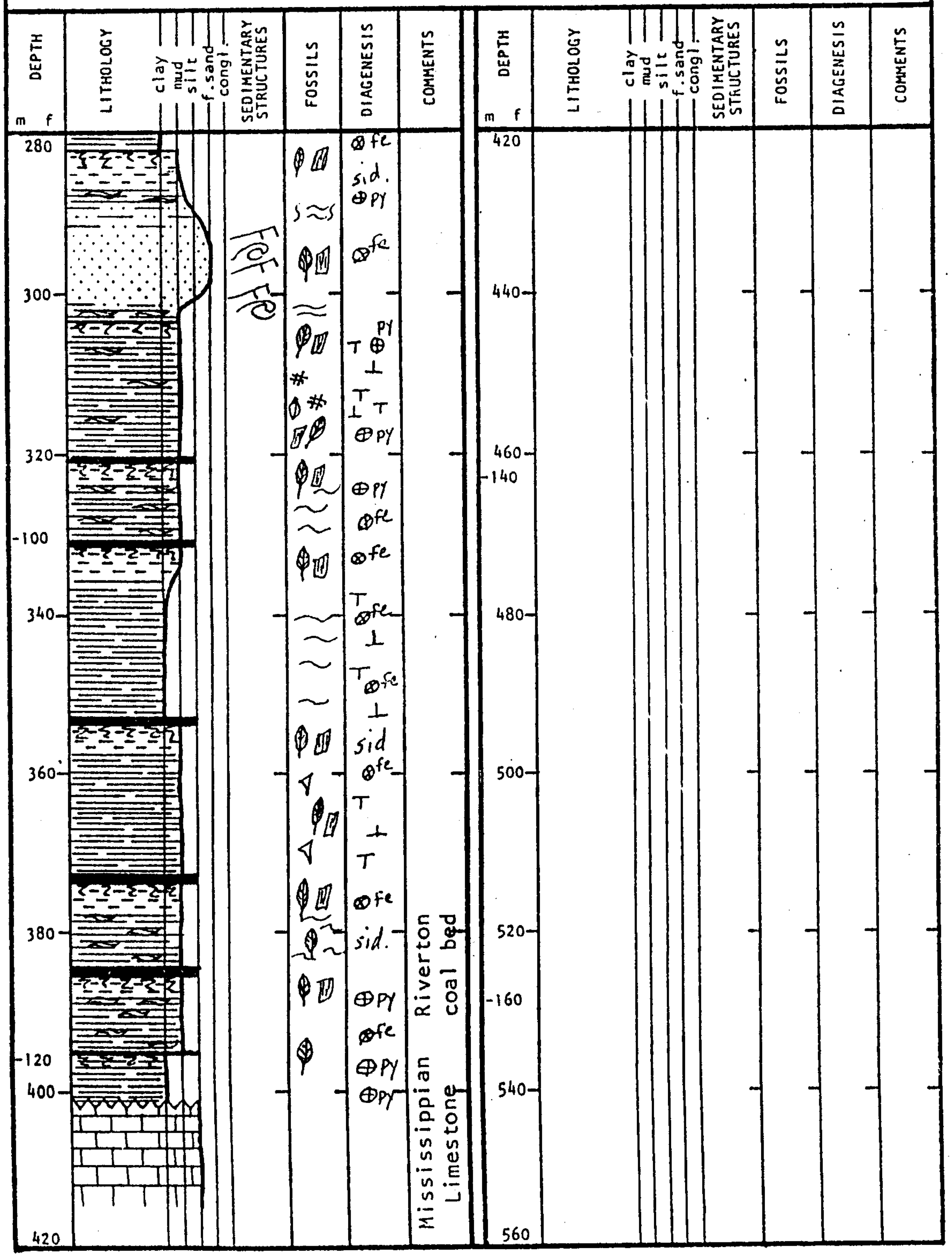
*from Harris, 1984, p. A23-A24.

P&M #11*
NE NE NE Sec.12 T32S R21E
Cherokee County, Kansas
Surface Elevation -825



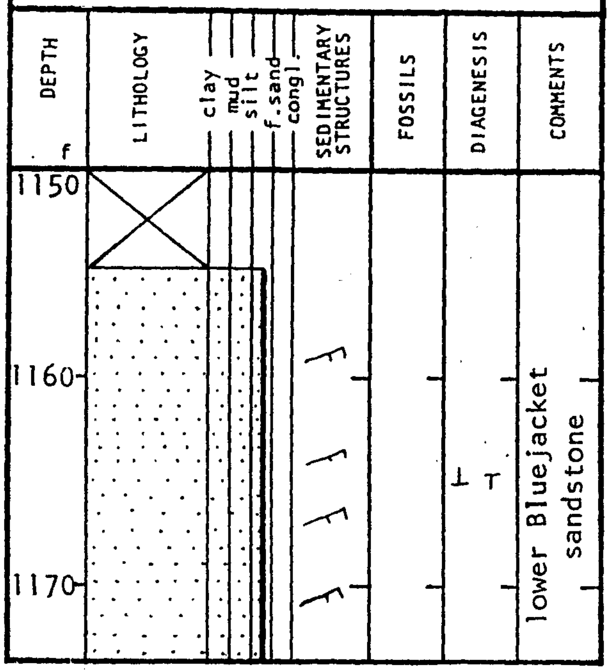
Page 2 of 2

P&M #11
NE NE NE Sec. 12 T32S R21E
Cherokee County, Kansas
Surface Elevation -825

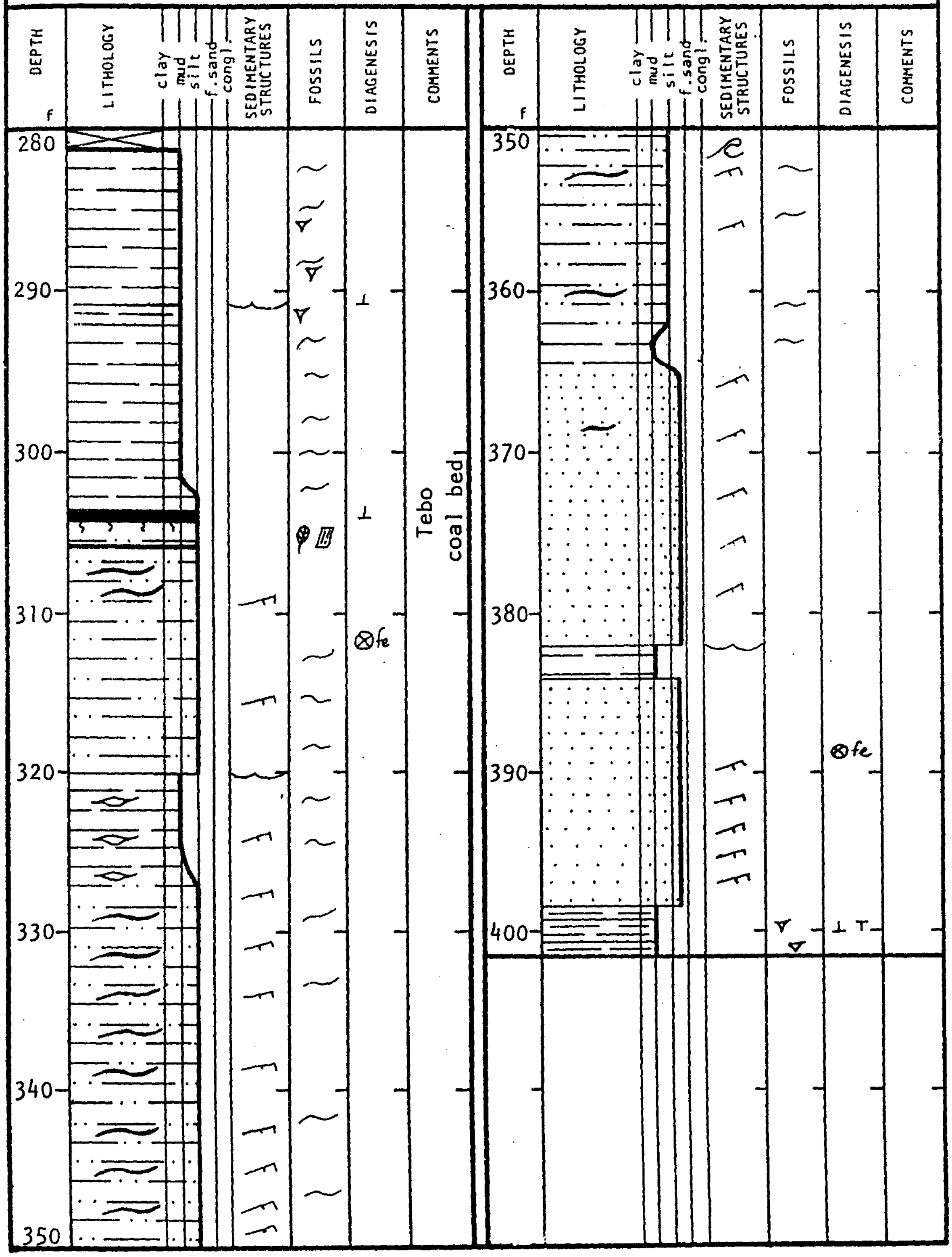


*from Harris, 1984, p. A25-A26.

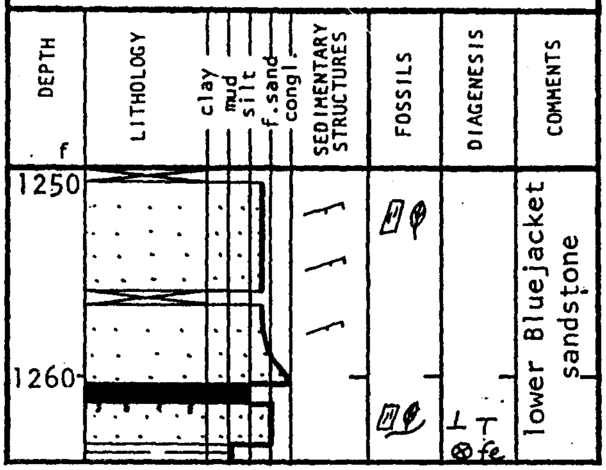
Hoffman #1
C NE NE Sec. 17 T33S R15E
Montgomery County, Kansas
Surface elevation: 860 feet



Murphy #1
NE NE NE Sec. 20 T34S R20E
Labette County, Kansas
Surface elevation: 853 feet



Cannon #1-C
C S2 NW Sec. 3 T35S R15E
Montgomery County, Kansas
Surface elevation: 875 feet



APPENDIX C

List of Well Cuttings

Location	Spot	Well Name	Operator	County
1-27S-6E	NE-NW-NE	Bolin #1	Hawkins Energy	Butler
20-28S-4E	SW-SE-NE	Smith #4	Hammer/MacLean	Butler
5-28S-5E	NW-NW-NE	Patterson 1	Petrol. Manag.	Butler
5-29S-4E	SW-NE-NE	EMC-Harten.	Energy Methods	Butler
15-29S-6E	SE-SW-NW	Mellies #2	Brandt	Butler
36-30S-3E	E2-SE-NE	Walker A-1	Geodessa	Cowley
19-30S-6E	NW-NW-SW	Wakefield A1	TXO	Cowley
5-32S-6E	NW-SE-NE	Lawson #1	American Ener.	Cowley
23-33S-2E	SW-NW-SE	Hill #1	Range	Sumner
1-33S-5E	NE-SE-NE	Chrisler #2	Range	Cowley
17-34S-3E	NW-NE-NE	Baird #2	Range	Cowley

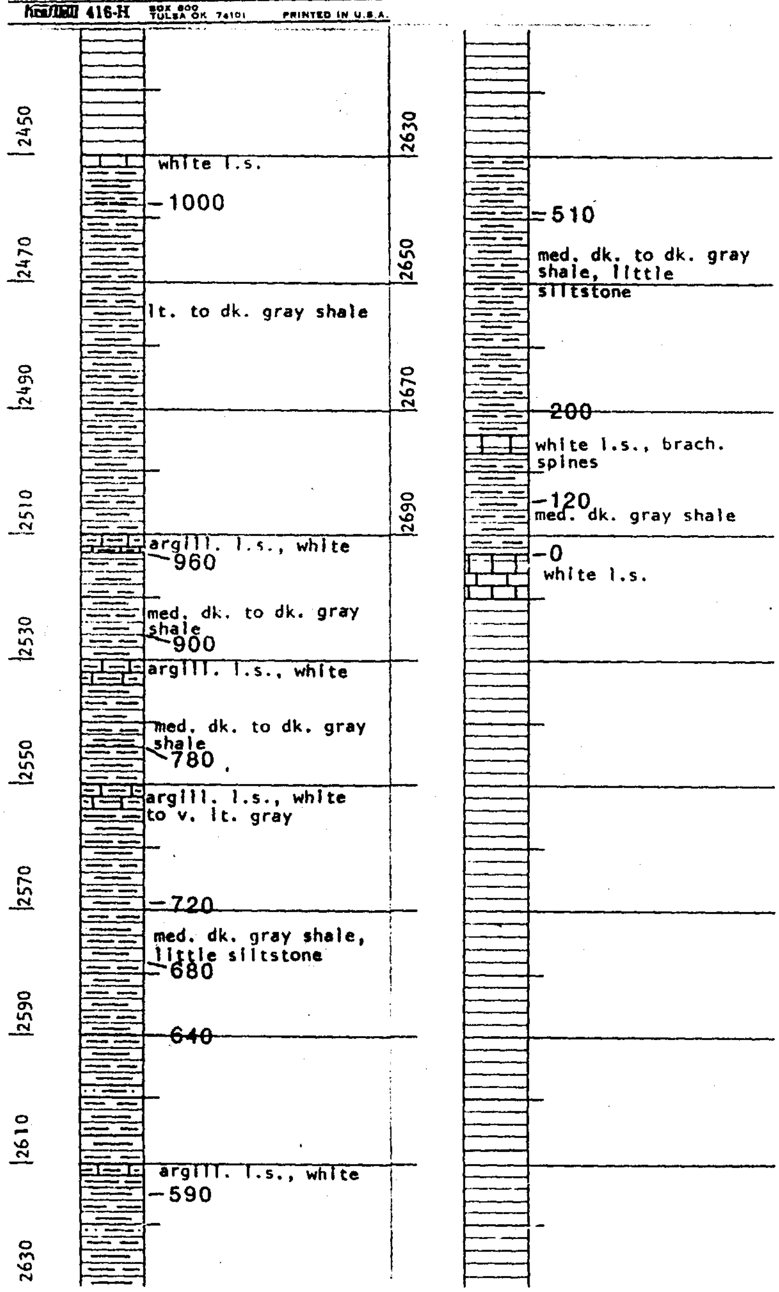
Cuttings obtained from the Kansas Geological Society collection, Wichita, Kansas.

APPENDIX D

Graphic Descriptions of Well Cuttings

sec. 1	
T 27S R. 6E	Hawkins Energy COMPANY
	Bolin NO. 1
	COMMENCED
	COMPLETED
ELEVATION 1388 GL	REMARKS
PRODUCTION	NE-NW-NE

416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 20 | T 28S | R 4E

Hammer & MacLean COMPANY

Smith NO. 4

COMMENCED

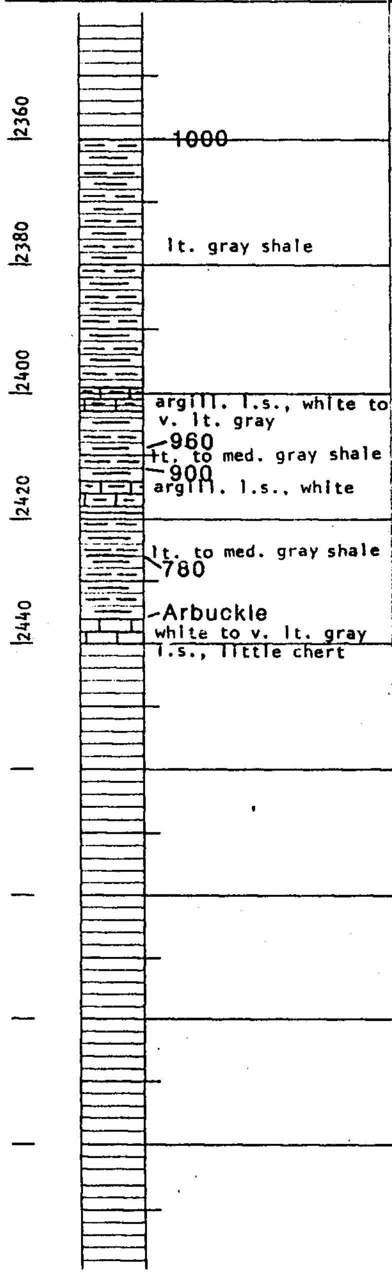
COMPLETED

ELEVATION 1206 GL

REMARKS

PRODUCTION SW-SE-NE

416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 5 | T 28S | R 5E

Petroleum Mngmt. COMPANY

Patterson NO. 1

COMMENCED

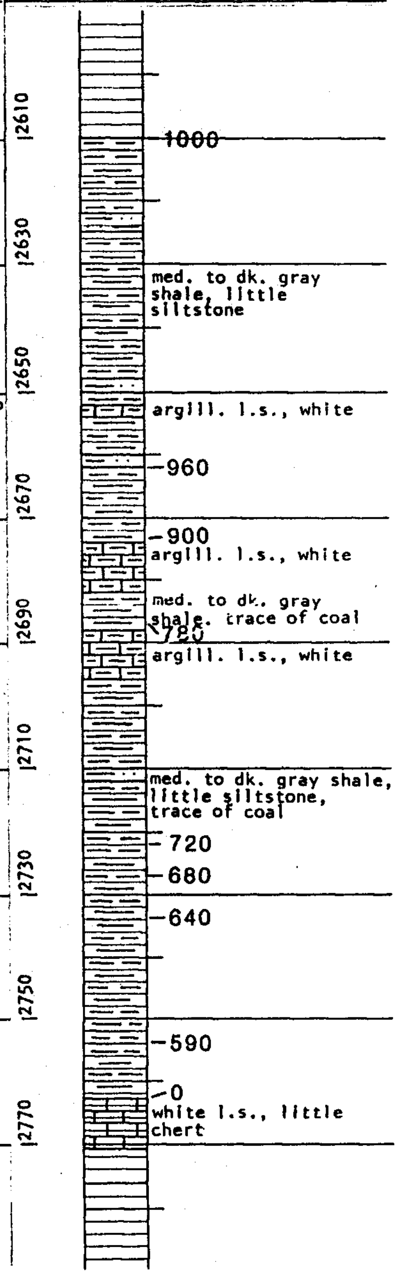
COMPLETED

ELEVATION 1293 GL

REMARKS

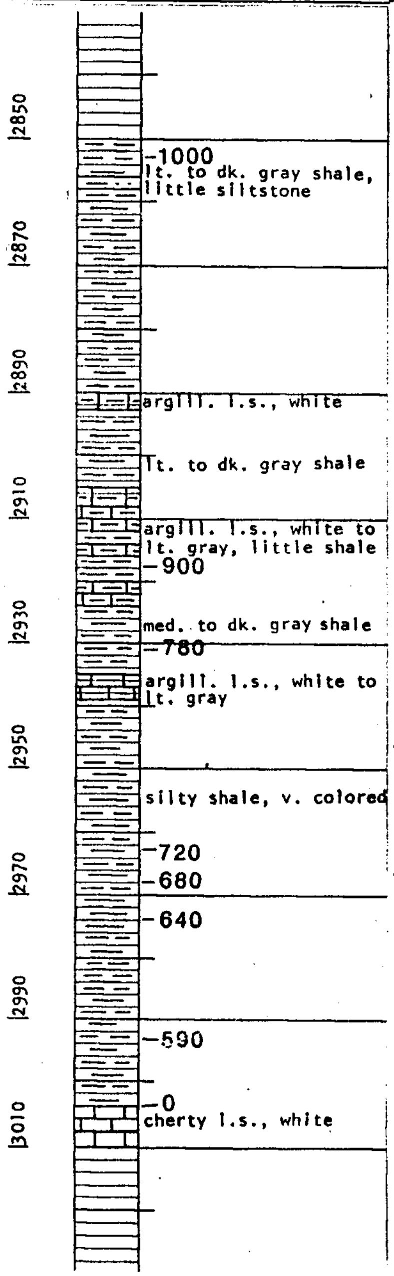
PRODUCTION NW-NW-NE

416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



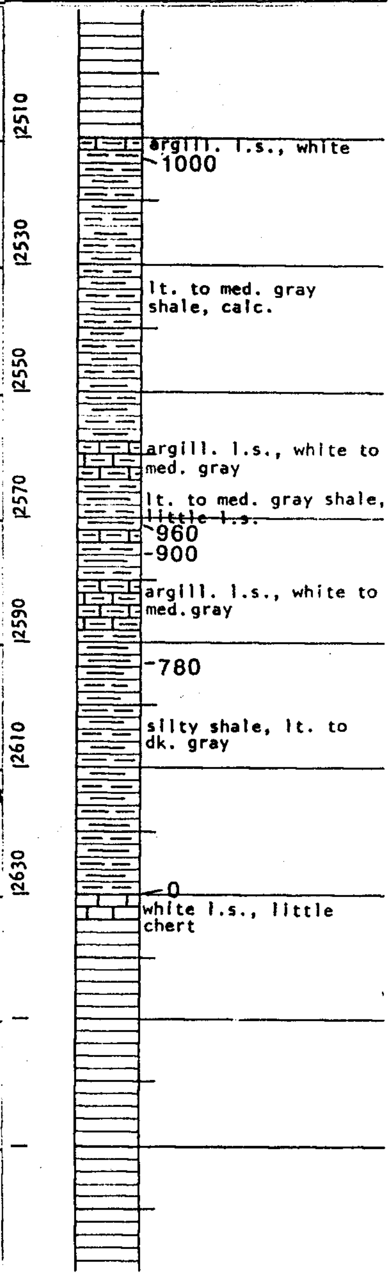
sec. 36
T 30S R 3E
Geodessa Corp. COMPANY
Walker NO. A-1
COMMENCED
COMPLETED
ELEVATION 1209 GL
REMARKS
PRODUCTION E2-SE-NE

Kraftbilt 416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 5
T 29S R 4E
Energy Methods COMPANY
EMC-Hartenbower NO. 1-5
COMMENCED
COMPLETED
ELEVATION 1195 GL
REMARKS
PRODUCTION SW-NE-NE

Kraftbilt 416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 15

T	R.
29S	6E

Brandt Drilling COMPANY

Mellies NO. 2

COMMENCED

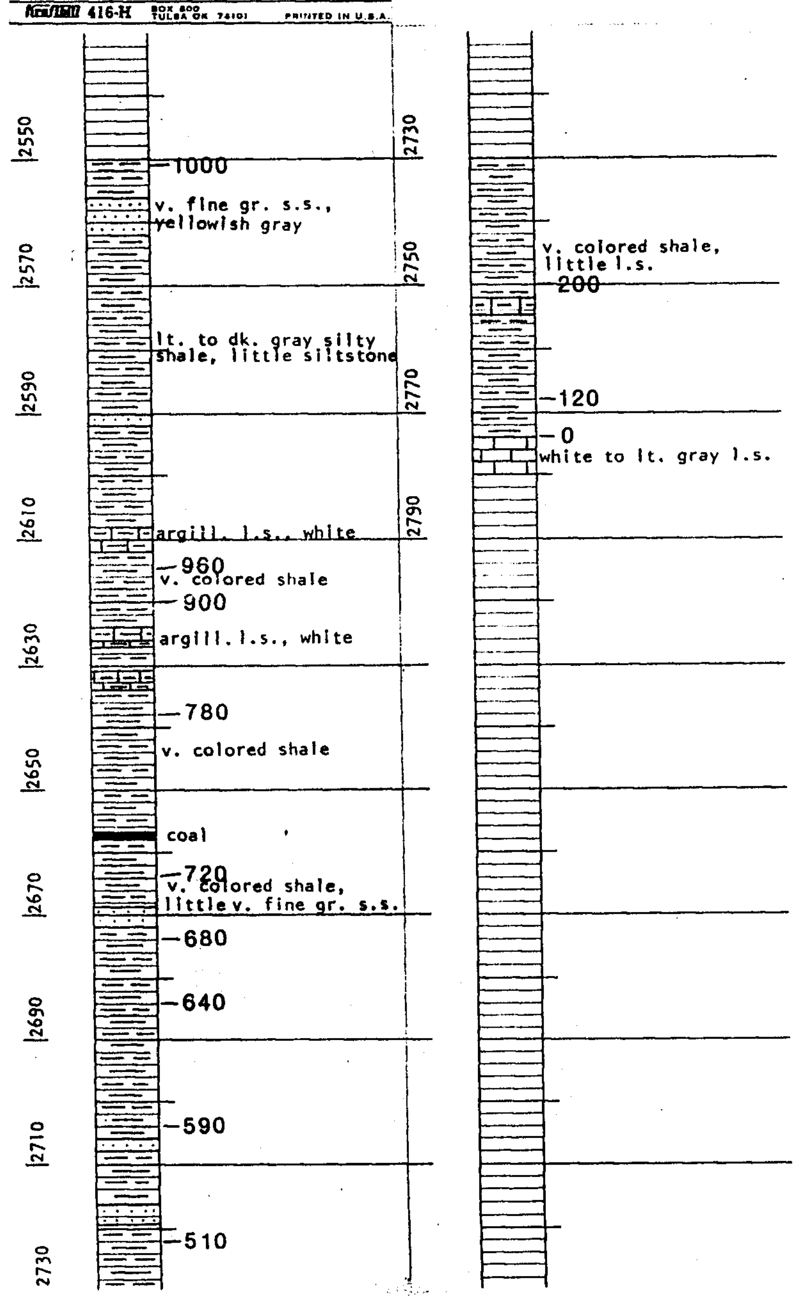
COMPLETED

ELEVATION 1388 GL

REMARKS

PRODUCTION SE-SW-NW

416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 19

T. 30S R. 6E

TXO Prod. COMPANY

Wakefield NO. A1

COMMENCED

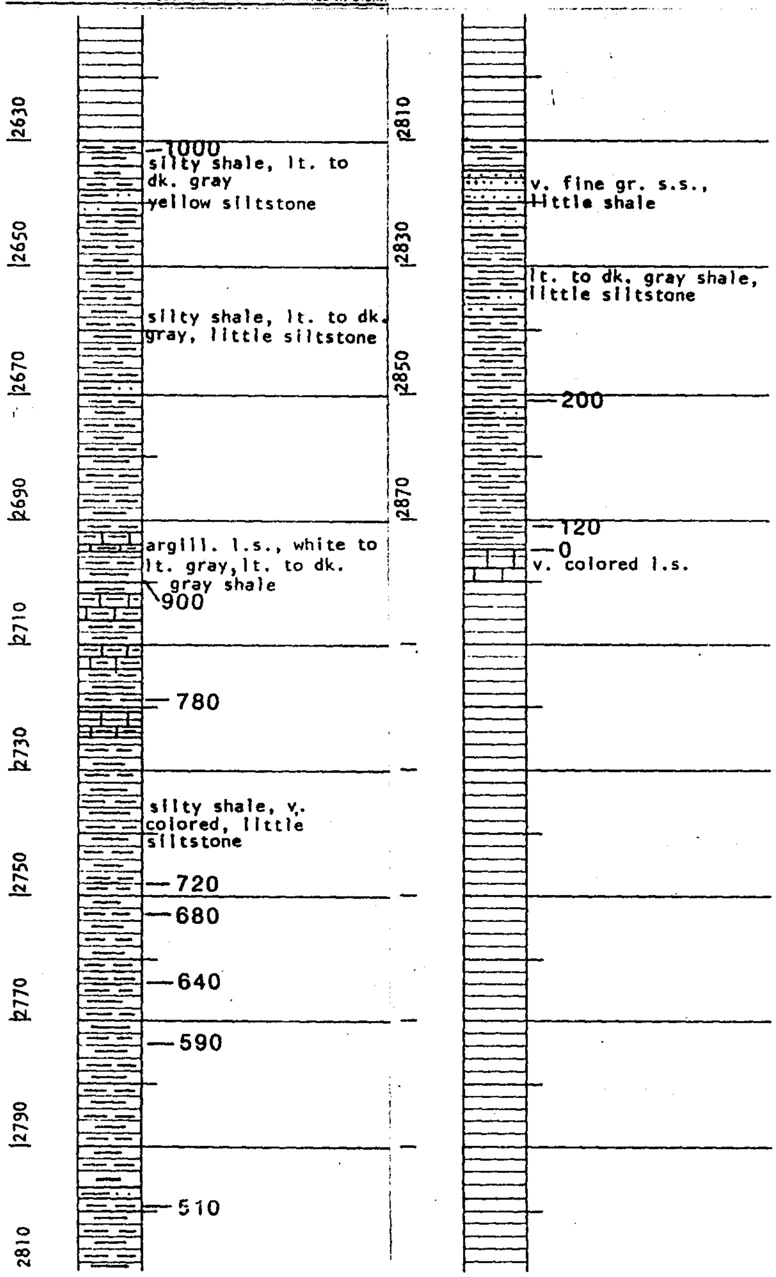
COMPLETED

ELEVATION 1349 GL

REMARKS NW-NW-SW

PRODUCTION

Kewanee 416-H BOX 600 TULSA OK 74101 PRINTED IN U.S.A.



sec. 5

T.	R.
32S	6E

American Energies COMPANY

Lawson NO. 1

COMMENCED

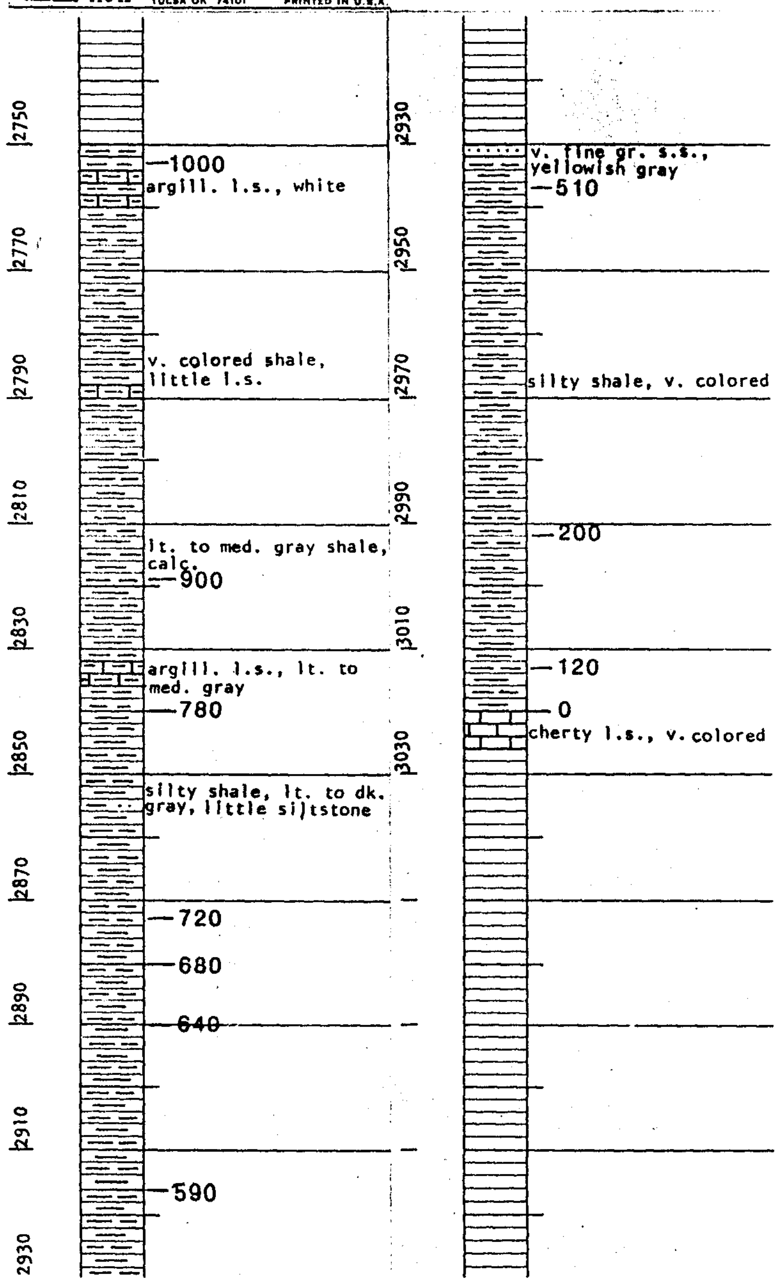
COMPLETED

ELEVATION 1343 GL

REMARKS

PRODUCTION NW-SE-NE

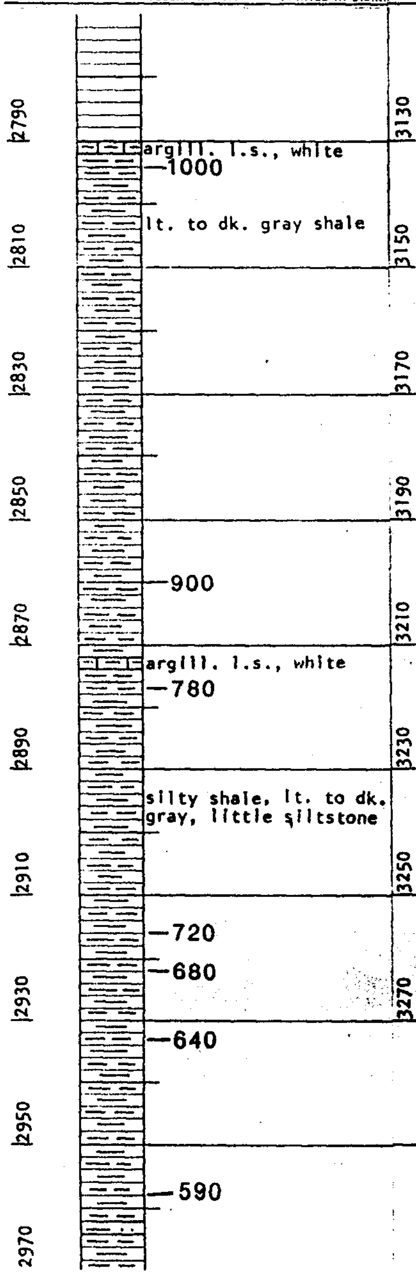
416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 1 T. 33S R. 5E

Range Oil COMPANY
Chrisler NO. 2
COMMENCED
COMPLETED
REMARKS
ELEVATION 1309 GL
PRODUCTION NE-SE-NE

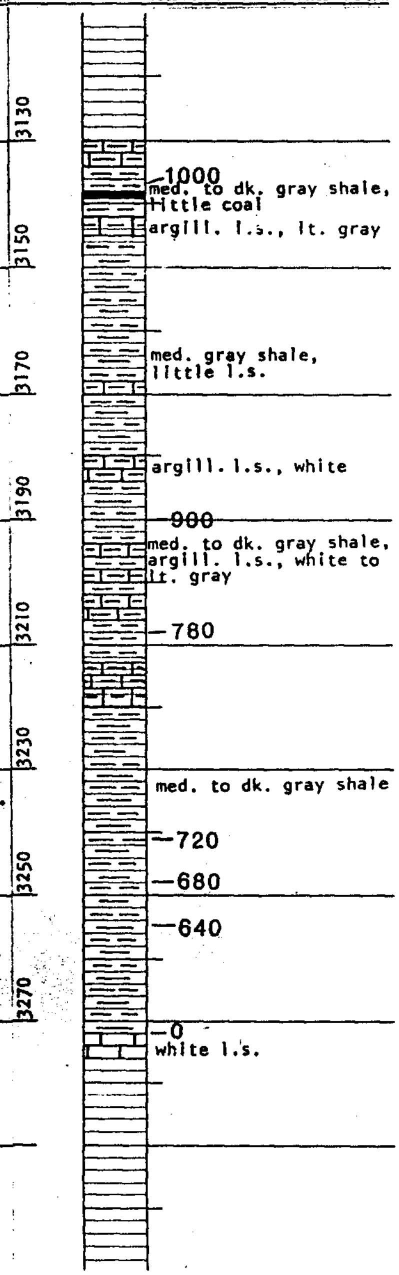
416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 23 T. 33S R. 2E

Range Oil COMPANY
Hill NO. 1
COMMENCED
COMPLETED
REMARKS
ELEVATION 1109 GL
PRODUCTION SW-NW-SE

416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



sec. 17

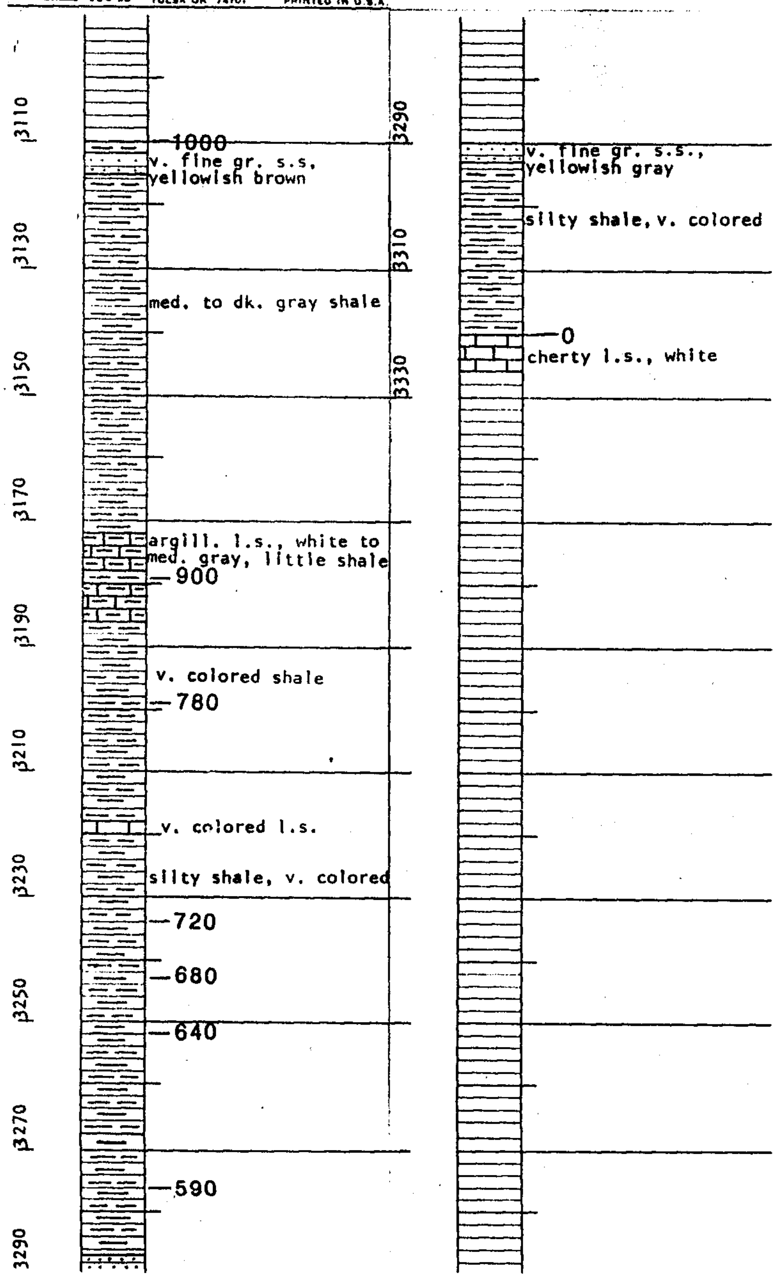
T	R
34S	3E

ELEVATION 1093 GL

PRODUCTION

Range Oil	COMPANY
Baird	NO. 2
COMMENCED	
COMPLETED	
REMARKS	
NW-NE-NE	

New Well 416-H BOX 800 TULSA OK 74101 PRINTED IN U.S.A.



APPENDIX E

List of Geophysical Well Logs Used in This Study

Location	Spot	Well Name	Operator	County
1-27S-3E	NW-SW-SW	Ballew #1	Chapman	Butler
21-27S-3E	SW-SW-SE	Myler #1	Shawver	Butler
35-27S-3E	NE-NW-SW	Young #1	Oil Mngmt.	Butler
10-27S-4E	N2-N2-SW	Razook A19	Razook	Butler
16-27S-4E	N2-NE-NE	Scully #28	Sinclair	Butler
1-27S-5E	SE-NW-NW	Leon 41-523	Kennedy	Butler
15-27S-5E	NE-SE-NE	Chinn #1	Range	Butler
18-27S-5E	NE-SW-NW	Hoefgen #1	Black Gold	Butler
1-27S-6E	NE-NW-NE	Bolin #1	Hawkins	Butler
17-27S-6E	N2-SE-NW	Lickteig #1	Range	Butler
1-27S-7E	NW-SW-NW	Lucas #1	Allison	Butler
20-27S-7E	SW-NW-SW	Hummel #1	Range	Butler
36-27S-7E	SE-SW-SW	Kanady B-1	TXO	Butler
7-27S-8E	NW-NW-NW	Smith #1	Dunne	Butler
12-27S-8E	C-N2-SE	Wiedeman 2	Teichgrabr.	Greenwood
25-27S-8E	SW-NE-SW	Lewis A35	Beaumont	Greenwood
35-27S-8E	NW-NW-NW	Lewis A39	Beaumont	Greenwood
7-27S-9E	SE-NE-NW	Payne C-2	Teichgrabr.	Greenwood
18-27S-9E	SE-NW-NW	Gould #1	Morris	Greenwood
5-27S-10E	NE-NE-SE	Pike B-1	Purkeypile	Greenwood
12-27S-10E	SE-SW-NE	Cross #2	McCarthy	Greenwood
31-27S-11E	none	French #2	Shira	Greenwood

Location	Spot	Well Name	Operator	County
33-27S-11E	SW-NW-SW	Cuninhm. 4	Midwest	Greenwood
1-27S-12E	NW-NE-SE	Manwarren 3	Sterling	Greenwood
7-27S-13E	NW-SW-NW	Latham #2	Osage	Greenwood
9-27S-13E	N2-NW-NE	Shinkle #7	B & L	Greenwood
33-27S-13E	NE-SW	Fee #1-33	Lauck	Greenwood
17-27S-14E	NE-NE-SE	Trimmell 33	Modeer	Wilson
29-27S-14E	NW-NW-NE	Pryor #1	Kristlin	Wilson
4-27S-15E	C-NW-NE	Clinsmth. 1	Argonaut	Wilson
6-27S-15E	C-NE-NW	Braman #1	Oil Reserve	Wilson
18-27S-15E	C-NE	Sndy Creek 1	Mecca	Wilson
19-27S-16E	C-SE-NE	Benjgrdes 16	Ridge	Wilson
20-27S-16E	NW-NW-NW	Benjgrdes 10	Ridge	Wilson
3-27S-17E	S2-NW-NW	Carlson #1	Markan	Wilson
26-27S-17E	C-W2-SE	Dick SWD #1	Consldatd.	Neosho
32-27S-17E	W2-NW-NW	Anderson #3	Mitchell	Neosho
14-27S-18E	SW-SW-NW	Beach #A-1	Ross-Keas	Neosho
22-27S-18E	SE-NE-SW	Kaney #A-4	Ross-Keas	Neosho
25-27S-18E	none	Penintn. B20	Burroughs	Neosho
34-27S-18E	N2-NW-NW	D.J. #103-D	D.J.	Neosho
27-27S-19E	N2-SE-SW	DeWeese #10	Z & B	Neosho
32-27S-19E	none	Watts #4-F	Indepndnce.	Neosho
14-27S-20E	N2-NE-NE	Gericke #1	Coran	Neosho
7-27S-21E	SW-SW-SW	Dye #1	Backman	Neosho
12-27S-21E	NW-NW-NE	Johnson #1	Mitidete	Bourbon

Location	Spot	Well Name	Operator	County
22-28S-3E	SE-SW-SE	McCall #3	Petro Amer.	Butler
29-28S-3E	C-W2-NE	Blood #1	Eckland	Butler
35-28S-3E	NW-SW-SE	Jones #1-35	First Ntnl.	Butler
2-28S-4E	SE-NE-SW	Augusta 1-58	Cities	Butler
14-28S-4E	NW-SE-NW	Augusta 54-5	Cities	Butler
20-28S-4E	SW-SE-NE	Smith #4	Hammer	Butler
5-28S-5E	NW-NW-NE	Patterson 1	Petr. Mgmt.	Butler
23-28S-5E	SW-SW-SE	Fox-Bush 3-A	Magnolia	Butler
32-28S-5E	NW-SE-SW	Harvey 1-831	Kennedy	Butler
5-28S-6E	W2-W2-SE	Tabing #2	Sun Range	Butler
10-28S-6E	NE-SE-SE	Lucas D #4	Rex-Morris	Butler
29-28S-6E	SW-SW-SW	Beard #1	Mallard	Butler
6-28S-7E	SE-NW-NW	Houston #6	Dunne	Butler
23-28S-7E	SE-NE-SW	Brewer #7	Morris	Butler
6-28S-8E	SW-NW	Lewis #4	General	Butler
28-28S-8E	SW-SW-NE	Ferrell #3	Beaumont	Butler
33-28S-8E	NE-SW-SE	Ferrell #17	Morris	Butler
23-28S-9E	C-SE-NW	Knox #22-23	Masek	Elk
15-28S-10E	C-SE	Drumond 1-15	Rho-Lambda	Greenwood
13-28S-11E	S2-SE-SW	Bateson #1	Tulsa	Greenwood
16-28S-11E	NW-NW-NW	Johnson #1	Tulsa	Greenwood
2-28S-12E	SW-NE-SW	Oakes #1	M & B	Greenwood
26-28S-12E	NW-SE-NE	Hughes #1	Br. Spines	Elk
2-28S-13E	SW-SE-SW	Wilson #2N	Oklahoma	Wilson
28-28S-14E	C-NW	New Albany 1	Mecca	Wilson