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STRATIGRAPHY, PETROGRAPHY, AND DEPOSITIONAL ENVIRONMENTS
OF THE BANZET FORMATION (MIDDLE PENNSYLVANIAN) IN
SOUTHEASTERN KANSAS AND NORTHEASTERN OKLAHOMA

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

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ABSTRACT

The Banzet Formation (Pennsylvanian System, Desmoinesian Series) consists of shales, siltstones, thin limestones, thin coals, and lenticular, discontinuous sandstones found in repetitive sequences. Analyses of sedimentary textures and structures of sandstones and of the signatures of 750 gamma-ray well logs indicate that in southeastern Kansas and northeastern Oklahoma, Banzet sedimentation consisted of southward deltaic progradation into the shallow seas that covered the Cherokee Shelf during eustatic transgressions caused by Gondwanan deglaciation.

Interpretation of prodelta and delta plain facies from gamma-ray well log signatures suggest three deltaic cycles. The first two deltaic advances were from the northeast, and covered the eastern half of the shelf. The first advance commenced after deposition of the Ardmore Limestone, and the second after deposition of the Bevier Coal unit. These deltaic cycles are characterized by distributary channel deposits up to 94 feet (21.9 meters) thick, and by widespread crevasse splay sediments. The third deltaic advance occurred after deposition of the Iron Post Coal unit, and is marked by the progradation of two delta lobes from the north. Distributary channel deposits are much

thinner than those of the first two deltaic advances, and are not entrenched deeply into underlying sediments, possibly due in part to a more gentle depositional slope in the north. Subsequent marine transgression displaced the shoreline to the northeast, allowing deposition of a widespread delta-destructive sandstone in the northern half of the study area and formation of the Breezy Hill Limestone in the southern half.

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INTRODUCTION

The lower part of the Desmoinesian Series (Pennsylvanian System) in southeastern Kansas and northeastern Oklahoma consists of shales, siltstones, thin limestones, thin coals, and lenticular, discontinuous sandstones found in repetitive sequences. This study combines both subsurface and surface analyses of rocks and well logs that represent lithologies between the top of the Ardmore Limestone and the base of the Excello Shale. In this report this interval has been designated as the Banzet Formation (Figure 1).

The Banzet Formation is a stratigraphic expansion of the Lagonda Formation as originally illustrated by Searight and others (1953). It has been modified because the coals that were originally used as bounding marker beds are not laterally persistent.

Paleoenvironmental analyses suggest that delta progradation and subsequent marine transgression are responsible for the lithologic sequence within the Banzet.

Purpose of Study

This regional study was initiated at the suggestion of Dr. Robert L. Brenner and was supported financially by both

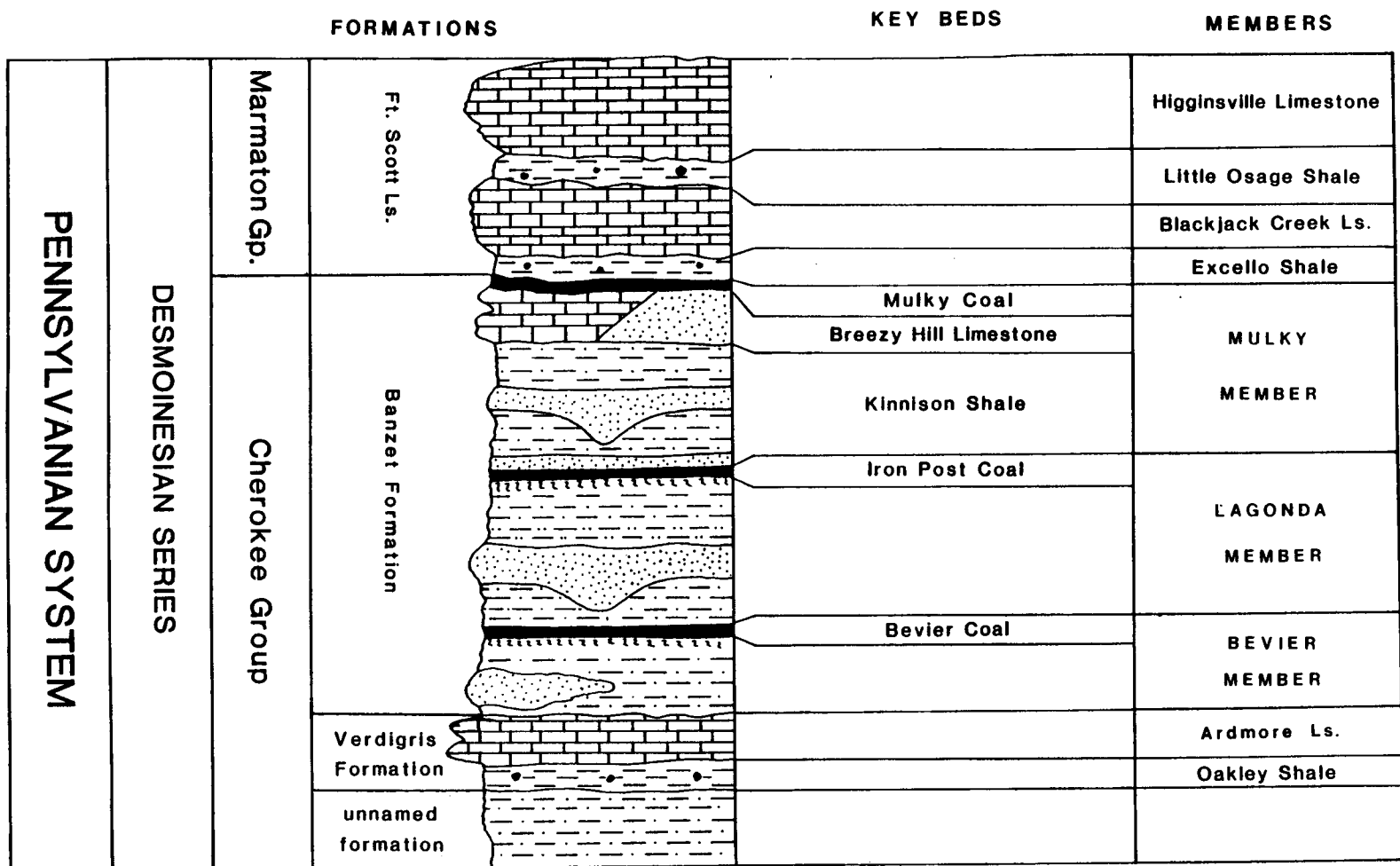


Figure 1. Stratigraphic column of the Banzet Formation in Kansas and Oklahoma.

the Kansas and Oklahoma Geological surveys. Although much has been published about the regional subsurface geologic column in northeastern Oklahoma, little has been written about it in southeastern Kansas. Many workers have suggested depositional models to explain the distribution of lithologies in several portions of the Desmoinesian, but none have developed a detailed model to explain the deposition of rocks within what is here designated as the Banzet Formation. Many previous workers were limited by their use of only electric logs, which have lower bed resolution than do gamma-ray logs.

This study examines the regional geology of the Banzet Formation in southeastern Kansas and northeastern Oklahoma using qualitative and quantitative techniques. Close spacing of 750 gamma-ray logs over a large area (Figure 2) and scattered outcrops provided suitable data to construct isopach and sandstone isolith maps of key beds and intervals. Stratigraphic cross-sections have been constructed to give a representative view of the lateral and vertical lithic variabilities within the formation. Coupled with the examination of well-log signatures, these quantitative maps provide information that allows interpretation of the depositional environments of the rocks within the Banzet.

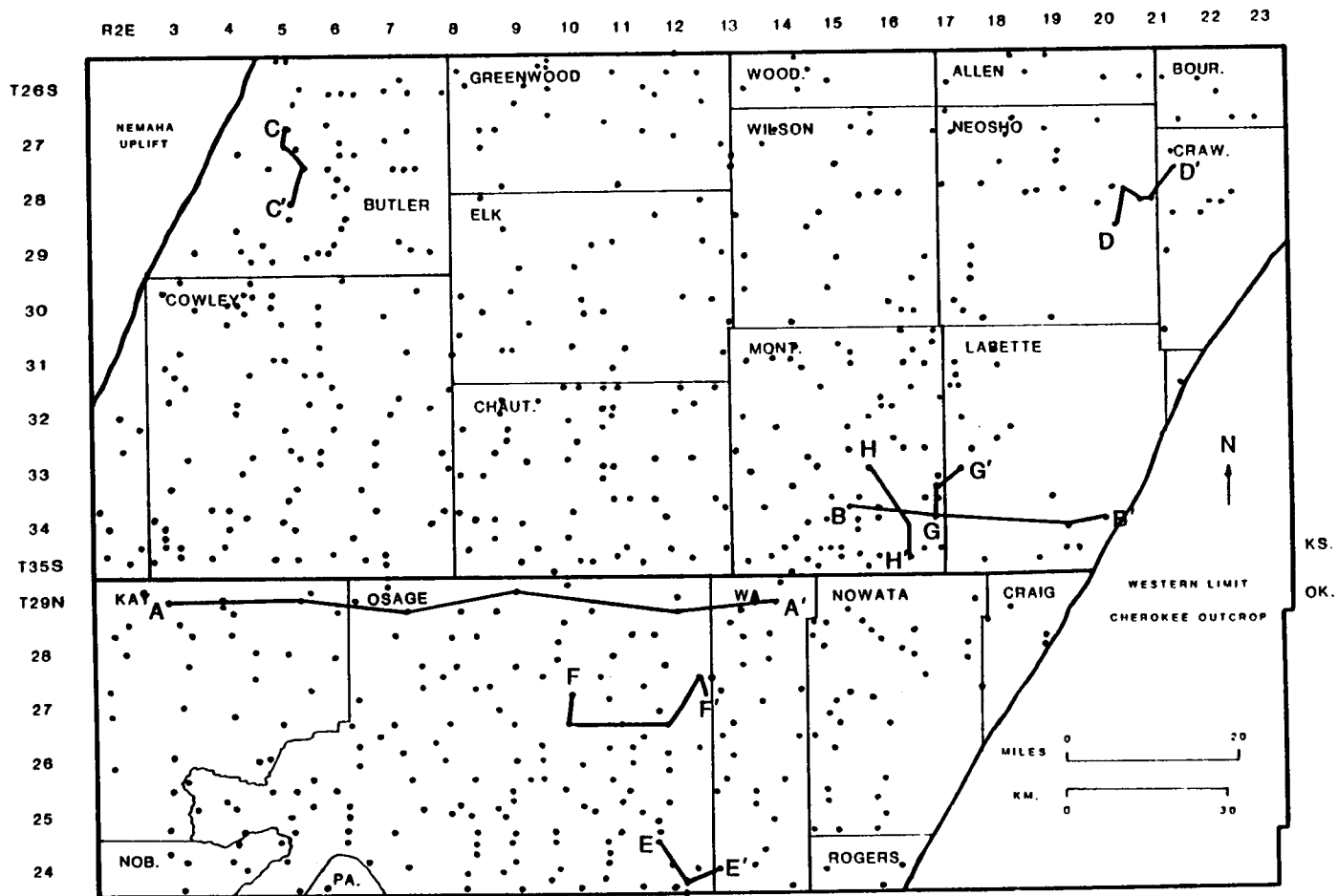


Figure 2. Locations of well logs and cross-sections used in study.

Location

The study area encompasses approximately 11,000 square miles (29,000 square kilometers) within a 19-county area in southeastern Kansas and northeastern Oklahoma (Figure 3). Specifically, the study includes the area between T. 26 S. (Kansas) and T. 24 N. (Oklahoma), and between R. 2 E., and R. 23 E. (both states).

Tectonic Setting and Regional Structure

The strata under consideration were deposited upon the Cherokee Shelf, a tectonically-stable depositional platform, during the Middle and Late Pennsylvanian. The shelf is bounded to the west by the Nemaha Uplift, to the east by the Ozark Uplift, and to the south by the Arkoma Basin (Figure 4). During the Early Pennsylvanian the shelf was a depositional basin, separated from the Forest City Basin by the Bourbon Arch, a low-relief paleotopographic feature, which trends northwest-southeast through east-central Kansas into Missouri (Merriam, 1963), (Figure 4). A north-south well log traverse shows that both the Cherokee and Forest City basins had been filled by the time that Banzet sediments were deposited, so that the Bourbon Arch was not a depositional barrier after the Early Pennsylvanian (Figure 5).

The Nemaha Uplift is a north-south-trending belt of faulted anticlines which extends from Nebraska to central

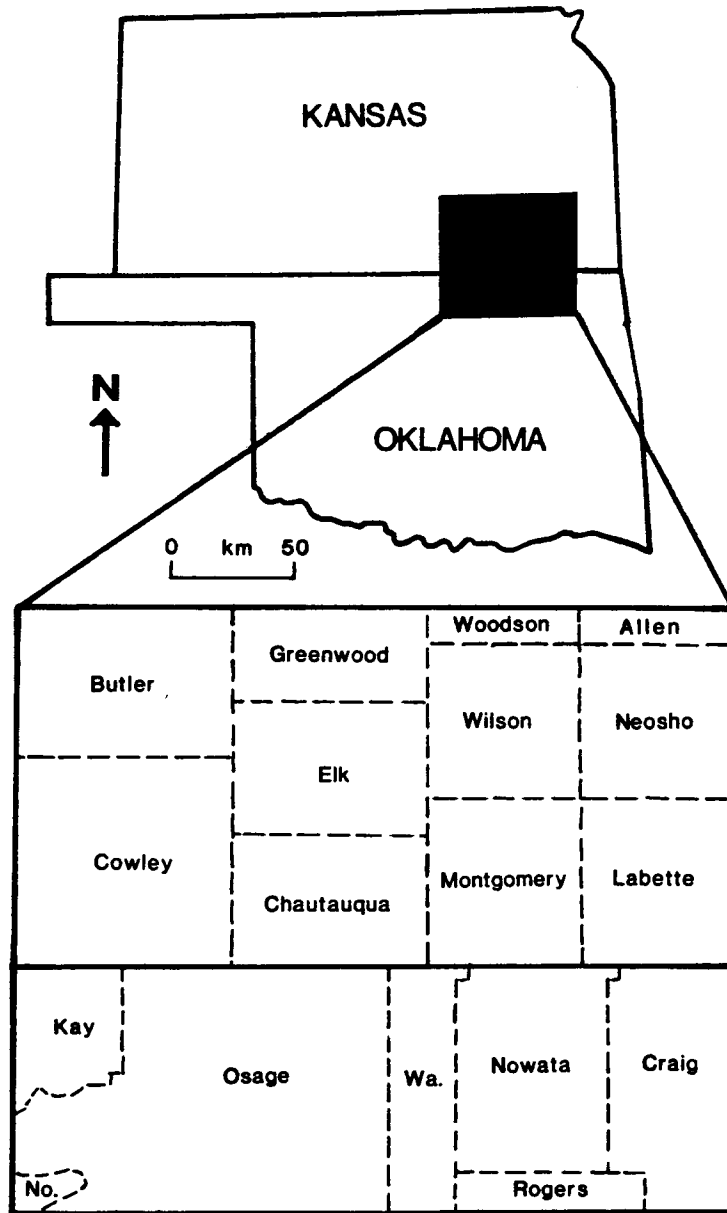


Figure 3. Location of the study area in southeastern Kansas and northeastern Oklahoma.

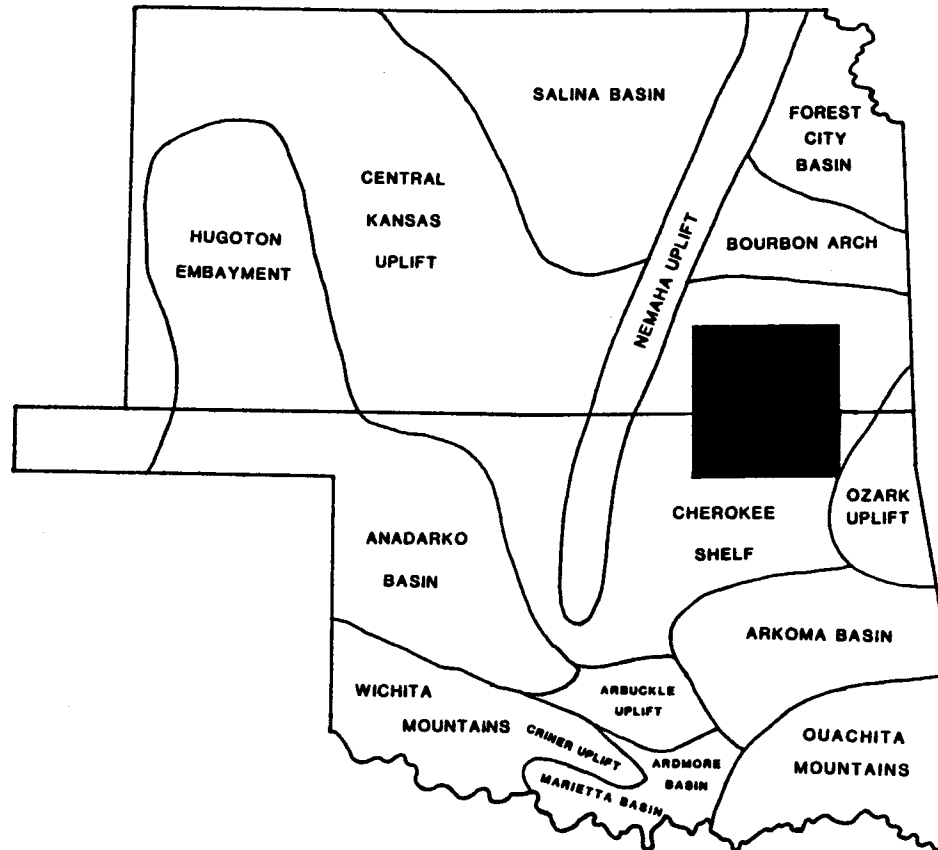


Figure 4. Structural features of Kansas and Oklahoma during the Pennsylvanian. Shaded area = study area. (Modified from Moore (1979) and Krumme (1981)).

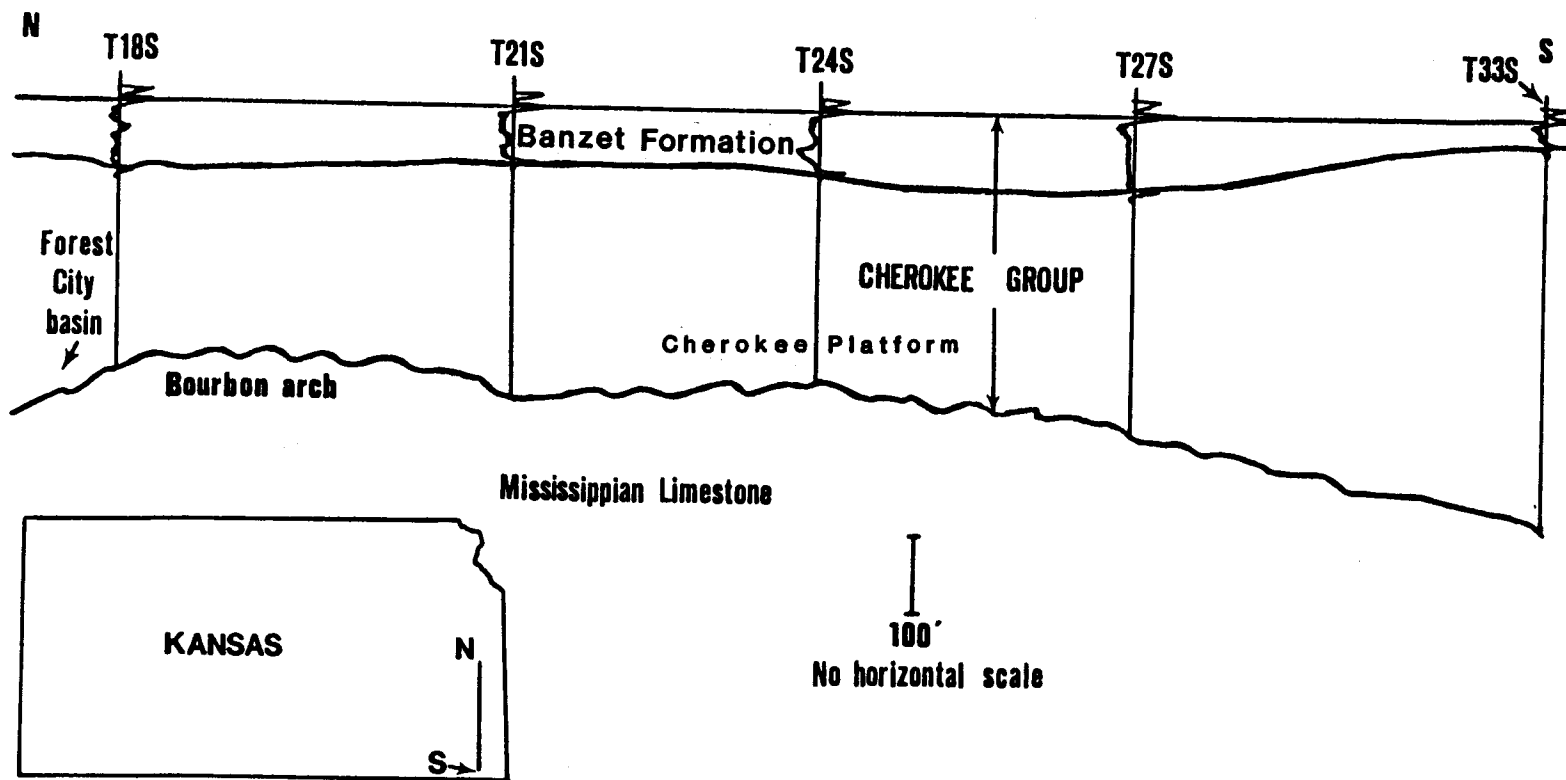


Figure 5. North-south well log traverse across eastern Kansas. Note that Banzet sediments are nearly uniform in thickness across the Bourbon Arch. (Modified from Brenner (1982)).

Oklahoma (McElroy, 1961). Anderson and Wells (1968) reported that movements along the uplift may have begun as early as late Early Ordovician, but major tectonic movements attained a peak in post-Mississippian, pre-Desmoinesian time, or more specifically post-Morrowan, pre-Atokan time (Berryhill, 1960), (Figure 6).

In Oklahoma, complete burial of the Nemaha Uplift was achieved by the beginning of Banzet sedimentation (Krumme, 1981, referring to the Banzet as upper Senora). However, throughout most of its trace in southeastern Kansas the uplift was a positive feature during the Middle Pennsylvanian, as indicated by the onlapping of Banzet beds upon it.

To the east of the Cherokee Shelf lies the Ozark Uplift, which existed as a positive feature during much of the Paleozoic Era. The latest pre-Banzet tectonic movements in the Ozark area appear to have commenced prior to deposition of Cabaniss sediments (Branson and Huffman, 1965), (Figure 6). In this study it could not be discerned if this uplift affected Banzet sedimentation, since outcrops of Banzet strata are eroded between the study area and the uplift.

The regional strike of Desmoinesian strata varies from northeast-southwest along the outcrop belt to north-south through the center, and northwest-southeast in the southwest corner of the study area (Figure 7). This

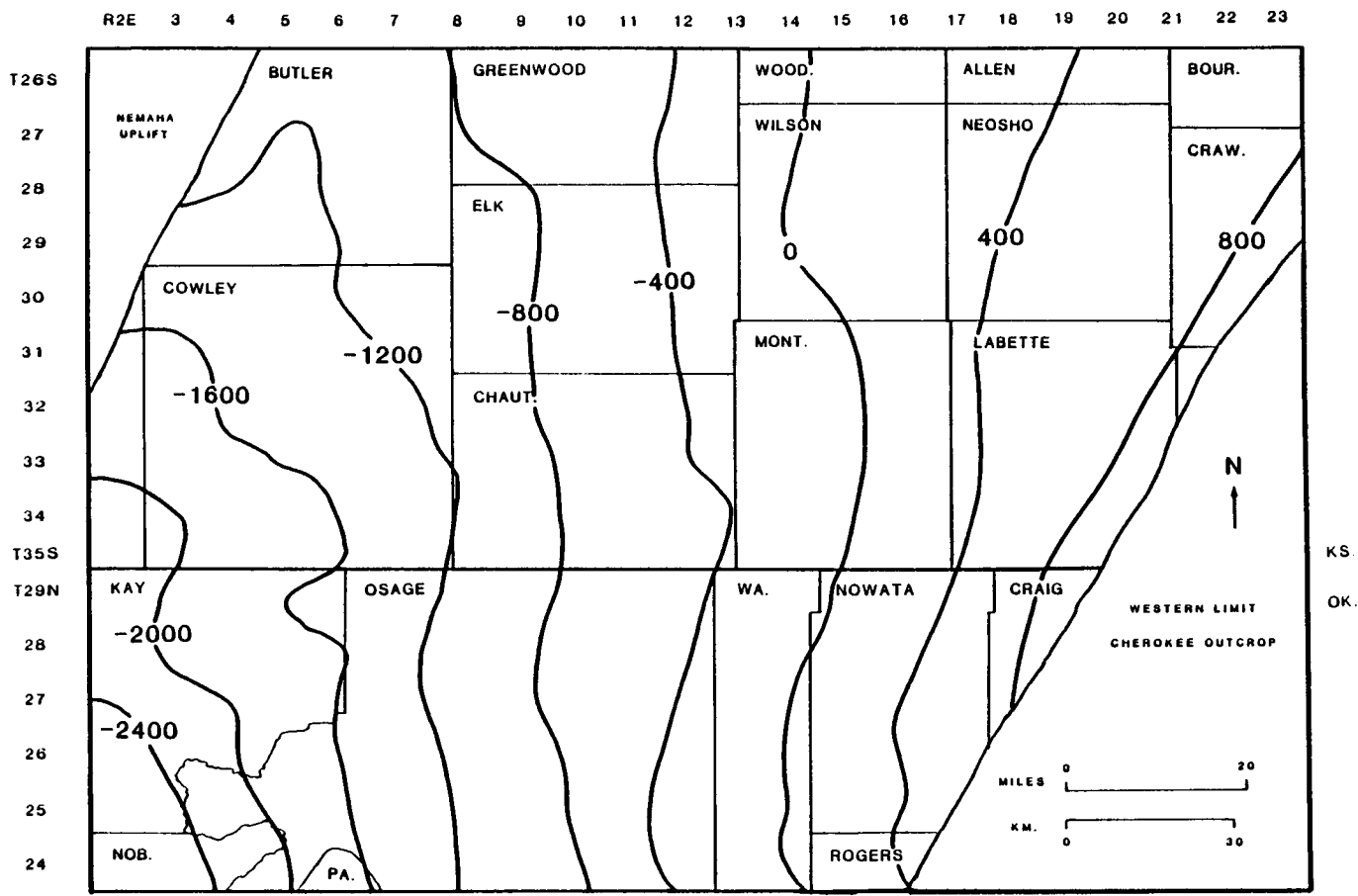


Figure 7. Structural contour map (datum is top of Excello Shale).

variation in strike results from the proximity of the study area to the hinge line of the Anadarko Basin to the southwest.

The region forms part of the Prairie Plains Homocline, a post-Permian structure (Berryhill, 1960). Beds dip westward at about 30 to 50 feet per mile (3 to 9 meters per kilometer). Near the Nemaha Uplift in Butler and Cowley counties, Kansas, the dip changes as beds flatten and then reverse to the east, as a result of post-Banzet depositional tectonic movements along the uplift.

Smith (1955) documented several folds in Cowley County, Kansas, and Kay County, Oklahoma, that trend parallel to the Nemaha Uplift. In the study area there is evidence for tectonic movements involving the Banzet Formation in Butler and Cowley counties, Kansas, and Kay, Osage, and Washington counties, Oklahoma. In this stratigraphic study, these structures have not been analysed, as they appear to have had little influence upon sedimentation during the Middle Pennsylvanian.

Previous Work

Although the Cherokee Shelf has been subjected to oil exploration over the previous 120 years, only during the last 50 years has much been published about the nature of Lower Desmoinesian strata. Investigations of these rocks on the surface have been summarized by Howe (1956) for

Kansas and by Branson and Huffman (1965) for northeastern Oklahoma.

Subsurface studies of Desmoinesian strata in Oklahoma are more numerous than in Kansas due to a large extent to theses and publications from students at the University of Oklahoma. These studies dealt with the nature of lenticular sandstones and persistent marker horizons as they relate to the geologic history of the region. Notable works include those by Ware (1955), Smith (1955), Baker (1958), Graves (1958), Querry (1958), Sartin (1958), Stringer (1958), Berryhill (1960), McElroy (1961), Strong (1961), Hanke (1967), Clayton (1967), Cole (1970), and Scott (1970). In addition, similar studies were done by students from Oklahoma State University and Tulsa University. These authors include Berry (1967), Dogan (1970), Astarita (1975), Candler (1979), and Shipley (1979).

Krumme (1981) examined strata between the base of the Ardmore Limestone and the top of the Checkerboard Limestone (Missourian Series) and interpreted the paleogeography of the shelf by examining the depositional trends and characteristics of limestones, sandstones, and key marker horizons. He also correlated strata from the Arkoma Basin onto the Cherokee Shelf.

Little information about the subsurface stratigraphic nature of the Cherokee Group in southeastern Kansas has

been published. Smith (1955) correlated Kansas and Oklahoma strata by the use of electric log cross-sections from Cowley County, Kansas to Kay County, Oklahoma. Correlations of various prominent Cherokee sandstones were proposed in Bourbon, Cherokee, and Crawford counties by Ebanks and others (1977) and in Greenwood County by Hulse (1978). Woody (1983) examined the sedimentology, diagenesis, and petrophysics of sandstones from various intervals within the Cherokee.

To date, the most comprehensive studies of the stratigraphic relationships and depositional environments of prominent lithologies within the Banzet Formation have come from Master of Science theses at the University of Iowa. Sedimentologic and stratigraphic studies include those by Reinholtz (1982), Lardner (1984), and Nelson (1985). Findings from these as well as those from this study and from Aden (1982) will be summarized in a future Kansas Geological Survey bulletin by R.L. Brenner (in preparation).

Methods of Study

Principles of Correlation

Well logs used in this study were gathered from the files of the well log libraries of the Kansas Geological Survey in Lawrence and the Oklahoma Geological Survey in

Norman. An average density of three well logs per township was used, ensuring reliable representation of strata within the study area. Gamma-ray, neutron, and density well logs were used because of their high resolution, enabling easy differentiation of black shales, coals, and gross geometries of sandstone bodies.

Stratigraphic correlations were based on the identification of persistent marker horizons. These lithologic units are not all considered to be synchronous depositional units but rather some represent facies which are indicative of the local environment of the Cherokee Shelf during brief time intervals.

Within the Banzet there are four key marker beds that are recognizable in both surface and subsurface sections. In ascending order, these are: the Ardmore Limestone, Bevier Coal, Iron Post Coal, and Excello Shale. The Ardmore and Excello persist across the entire study area, while the two coals are often absent due to nondeposition, erosion by overlying channels, or because they are thinner than the spacing between the gamma-ray transmitter and collector.

Lithologic Interpretation

Facies interpretation of strata within the study area was accomplished through the examination of gamma-ray, neutron, and density log signatures. The gamma-ray log can

be used to estimate a continuous grain-size profile in clastic sections because the amount of clay minerals, which contain radioactive potassium -40, decreases with increasing grain size. In turn, grain size can help reflect the energy of various depositional environments.

Ideally, paleoecologic and sedimentologic studies should accompany well-log facies analyses, because although some clastic environments have characteristic grain-size profiles, no environment possesses a unique sequence (Selley, 1976). In the absence of cores, cuttings, and reliable driller's logs, lithologic determinations made from well logs in this study are consistent with those proposed by Reinholtz (1982) and Lardner (1984), which benefitted from the analyses of cored intervals in nearby areas.

Identification of the Banzet Formation from radioactivity logs was enhanced by the presence of phosphatic black shales. Both the Excello Shale, the base of which marks the upper limit of the formation, and the overlying Little Osage Shale contain high concentrations of radioactive elements, producing high gamma-ray counts. On gamma logs these two form a distinct "doublet", or pair of intense deflections to the right of the shale base line (Figure 8). Similarly, the base of the Banzet is marked by the presence of the black phosphatic Oakley Shale, which lies below the Ardmore Limestone.

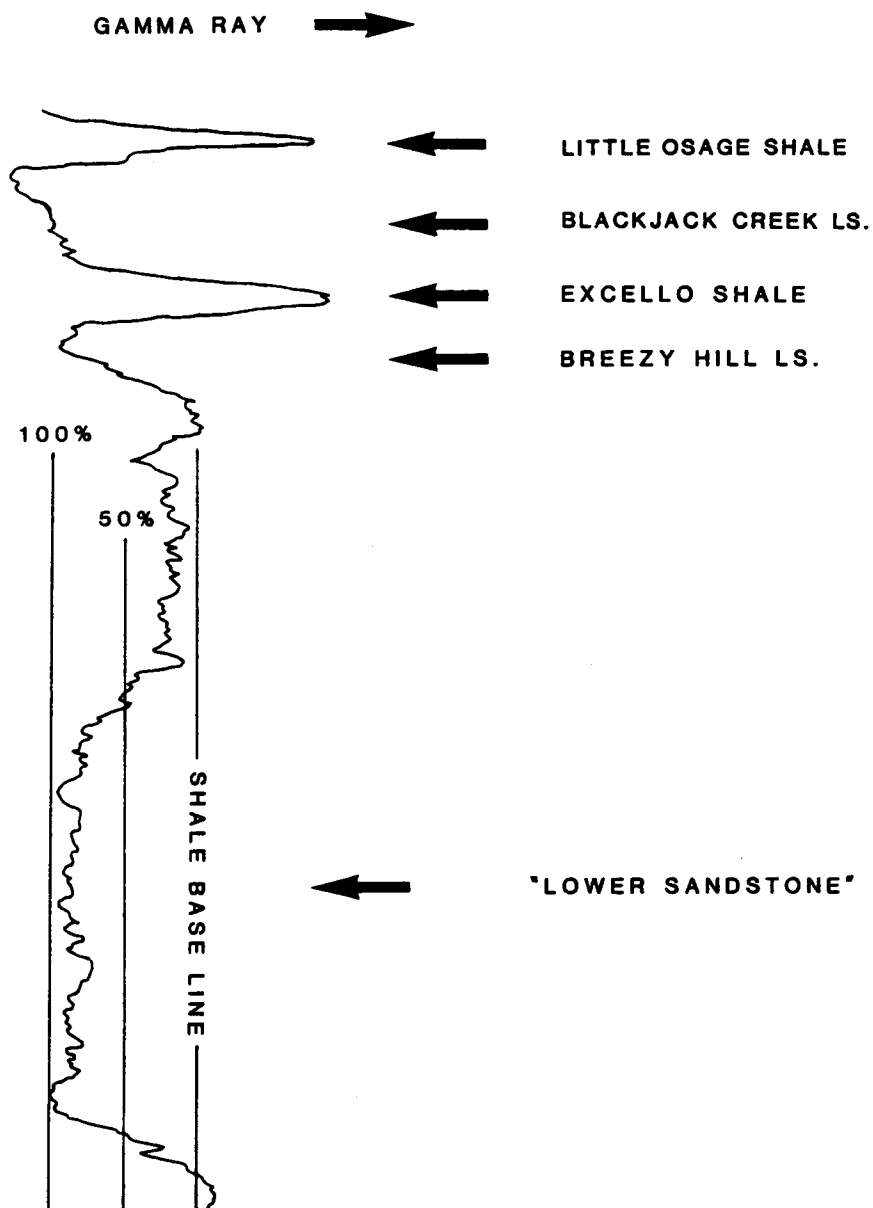


Figure 8. Method of determining sandstone thickness from gamma-ray well logs. Sandstones are defined as areas represented on the gamma-ray curve that lie left of the 50% line as long as limestones are excluded.

The Banzet Formation consists of shale, siltstone, sandstone, carbonate, and coal. In this study, siltstone has been included with shale because both have relatively high gamma counts and are often impossible to distinguish on well logs. Coals produce high neutron porosities, low gamma counts, and low density readings. Limestones are usually recognized by their low gamma-ray counts and low neutron porosity readings.

Sandstones were differentiated by using a dividing-line half way between a well-sorted "clean" sandstone and a shale base line. In this method, portions of logs with the lowest gamma-ray counts were interpreted as zones composed of 100% sandstone. If any of these were known to be carbonate, a point was selected slightly to the right of the minimum gamma count, since most sandstones have some clay minerals included, giving them higher gamma counts than carbonates. From this minimum gamma-ray value, a point was picked halfway between this value and the shale base line. Portions of the gamma-ray curve lying to the left of this point were interpreted as zones composed of greater than 50% sand-sized material (Figure 8).

Stratigraphic sections were measured from outcrops in Labette County, Kansas, and Craig, Rogers, and Wagoner counties, Oklahoma (Figure 9). Samples of sandstone oriented perpendicular to stratification were collected from various sections. These were impregnated with blue

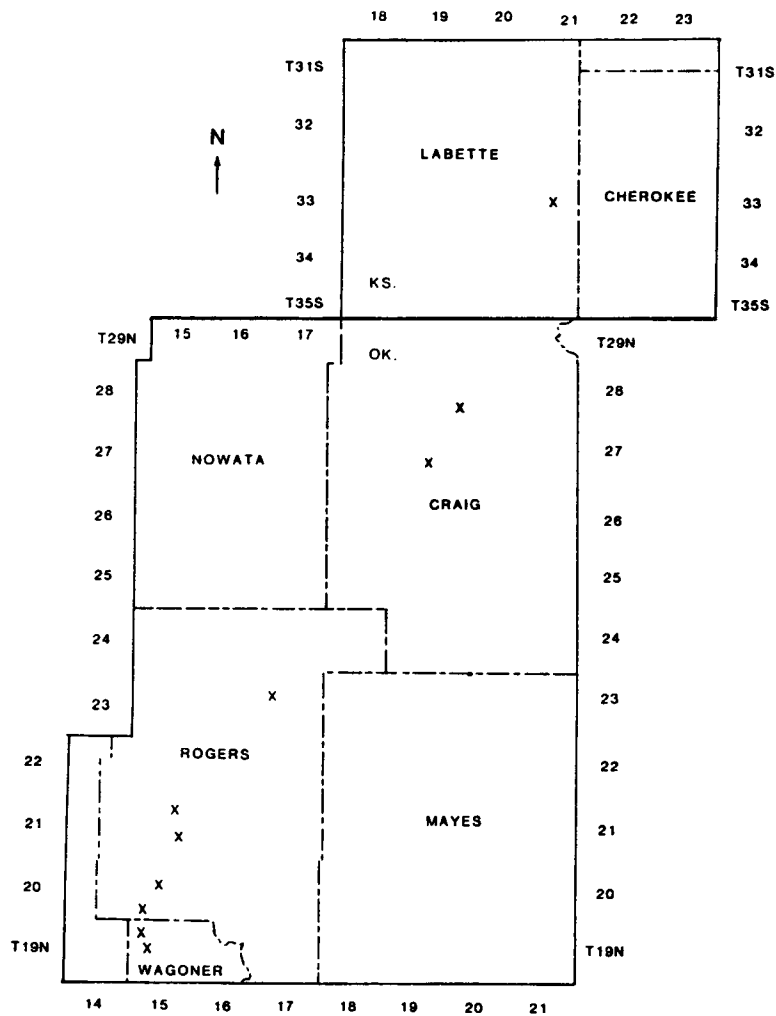


Figure 9. Locations of measured sections (X, listed in Appendix A).

epoxy to distinguish pore space. Compositions of these sandstones were determined by modal analyses of 9 thin sections from 5 outcrops. The sandstones were classified using Folk's (1974) classification scheme. These analyses were compared to those of cored sandstones studied by Reinholtz (1982) and Lardner (1984) to gain a clearer understanding of the provenance of siliciclastic grains.

STRATIGRAPHIC OVERVIEW

Historical Overview

The Pennsylvanian System in the Midcontinent is divided into five series based on biostratigraphic zones. In ascending order these are the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian Series. Morrowan and Atokan rocks are restricted to the Arkoma Basin of Oklahoma; therefore, only rocks belonging to the latter three series are found on the Cherokee Shelf (Krumme, 1981). The Desmoinesian Series, which contains the Banzet Formation, unconformably overlies rocks of the Mississippian System and conformably underlies rocks of the Missourian Series upon the Cherokee Shelf.

The Desmoinesian Series was originally defined as a group by the U.S. Geological Survey to include the interval between the Hertha Limestone and the top of the Mississippian System in northwest Missouri and southeast Iowa (Condra, 1949). Included within the Desmoines Group were the "Cherokee shales", a term coined by Haworth and Kirk (1894) to designate shale, sandstone, coal, and thin limestone in Cherokee County, Kansas. Moore (1932, 1936) redefined the Desmoines Group as a series to include the Marmaton and Cherokee Groups.

At a conference held on March 31-April 1, 1953, in Nevada, Missouri, representatives from Iowa, Kansas, Missouri, Nebraska, and Oklahoma reached an agreement on the division, classification, and nomenclature of Desmoinesian beds in these states. Older established names were retained with some redefinition and new names were introduced to complete the classification.

Due to paleontological discordance at the Seville Limestone (Kansas) or Inola Limestone (Oklahoma), two substages, the Ventran and Cygnian, were adopted as time-stratigraphic divisions of the Desmoinesian Series. Two group names, Krebs and Cabaniss, were later proposed to replace Cherokee (Oakes, 1953). However, the term Cherokee was reaffirmed by the Kansas Geological Survey in 1955 (Howe, 1956), with the Krebs and Cabaniss being reclassified as subgroups. Because of the cyclic nature of Pennsylvanian rocks in that region, the representatives of the Nevada conference decided to subdivide the two new subgroups into formations composed of beds from the top of a coal bed to the top of the next higher coal bed with four exceptions. These were named after the unit judged to be the most distinctive within the formation, regardless of the lithology. Usage of these formational units was restricted to areas where shelf conditions prevailed. However, at the present time, Missouri is the only state of the five that still subdivides the Desmoinesian Series by

the guidelines set up at the Nevada Conference.

Current Stratigraphic Nomenclature

Oklahoma

The term Cherokee is not used in formal nomenclature in Oklahoma. Soon after the Nevada conference, the Oklahoma Geological Survey replaced it with the terms Krebs and Cabaniss, which were elevated from subgroup to group status. The boundary between the two was originally defined in the Arkoma Basin, where there is a distinct paleontological break, change in character of sediments, and discordance in structure at the Krebs-Cabaniss boundary (Oakes, 1953). This paleontological break was placed at the Inola Limestone on the shelf, but because of the discontinuous nature of this limestone the boundary is often placed at the top of the Weir-Pittsburg Coal, which overlies the Inola Limestone (Branson, 1957).

The Krebs Group is the lowest group in the Desmoinesian Series, and includes all rocks between the top of the Atoka Formation and top of the Boggy Formation (Figure 6). It contains the following formations in ascending order: Hartshorne, McAlester, Savanna, and Boggy formations. Atokan and Morrowan rocks are sporadic in distribution north of the Arkoma Basin, so throughout much of the shelf the base of the Krebs rests directly upon

rocks of the Mississippian System.

Krebs Group thickness varies from 8000 feet (2438 meters) in the basin to 340 feet (104 meters) near the Kansas-Oklahoma border (Oakes, 1953). On the shelf the Krebs contains many prominent sandstones and continuous limestones and coals. These include the Warner, Bluejacket, and Taft sandstones (Warner, Bartlesville, and Red Fork sandstones of the subsurface), Sam Creek and Spaniard limestones (Brown Limestones of the subsurface), Inola Limestone, and the Riverton, Rowe, Drywood, and Weir-Pittsburg coals (Figure 10).

The Cabaniss Group contains all rocks between the top of the Krebs Group and base of the Marmaton Group. Its boundaries are marked by the top of the Weir-Pittsburg Coal, below, and the top of the Excello Shale, above. In the Arkoma Basin, the Cabaniss is approximately 1000 feet (305 meters) thick, but thins to about 160 feet (49 meters) near the Kansas-Oklahoma border (Oakes, 1953). The Cabaniss contains the following formations in ascending order: Thurman Sandstone, Stuart Shale, and Senora Formation (Figure 10). From the basin northward, the Thurman Sandstone is overlapped by the Stuart Shale at a point near the South Canadian River. In turn, the Stuart Shale is overlapped by the Senora Formation in the vicinity of T. 13 N., R. 16 E. From this point the Senora Formation rests unconformably upon the Boggy Formation of the Krebs

OKLAHOMA KANSAS

SENOIRA FORMATION	Breezy Hill Limestone	Mulky Coal	CABANISS FORMATION
	Kinnison Shale	Breezy Hill Limestone	
	Iron Post Coal		
	Lagonda Sandstone	Lagonda Sandstone	
	Bevier Coal	Bevier Coal	
	Ardmore Limestone	Ardmore Limestone	
	black shale	black shale	
	Croweburg Coal	Croweburg Coal	
	Goldenrod Sandstone	Fleming Coal	
	Russell Creek Ls.	Mineral Coal	
Mineral Coal	Scammon Coal	KREBS FORMATION	
Chelsea Sandstone	Chelsea Sandstone		
Tiawah Limestone	Tiawah Limestone		
black shale	black shale		
Tebo Coal	Tebo Coal		
Weir-Pittsburg Coal	Weir-Pittsburg Coal		
Taft Sandstone			
Inola Limestone	Seville Limestone		
Bluejacket Coal	Bluejacket Coal		
Bluejacket Sandstone	Bluejacket Sandstone		
SAYANNA FORMATION	Drywood Coal	Drywood Coal	
	Doneley Limestone		
	Rowe Coal	Rowe Coal	
	Sam Creek Limestone		
MCALESTER FM.	Spaniard Limestone		
	Stigler Coal	Neutral Coal	
HART-SHORE FM.	Warner Sandstone	Warner Sandstone	
	Riverton Coal	Riverton Coal	

Figure 10. Correlations between persistent marker beds within the Cherokee Group of Kansas and the Cabaniss and Krebs Groups of Oklahoma (modified from Branson, 1957).

Group northward into Kansas (Ware, 1955).

Lithologically the Senora Formation resembles the ~~Krebs~~ Group in that it contains shale, discontinuous lenticular sandstones, and several thin, persistent limestones and economically important coals. Prominent beds include the Chelsea, Goldenrod, and Lagonda sandstones (Lower Skinner, Upper Skinner, and Prue or Squirrel sandstones of the subsurface), Tiawah Limestone (Pink lime of subsurface), Ardmore and Breezy Hill limestones, Tebo, Mineral, Croweburg, and Iron Post coals, and the black shales beneath the Tiawah and Ardmore limestones (Figure 10).

Kansas

The term Cherokee Group is currently recognized by the Kansas Geological Survey. The type locality of the Cherokee Group is in Cherokee County, Kansas (Howe, 1956). The Krebs and Cabaniss Subgroups were changed to formations by Jewett (1959), with only the previously named coals, limestones, and sandstones retained as members of the two formations (Zeller, 1968).

The Krebs Formation comprises rocks lying above the top of the Atoka Formation and below the top of the Seville Limestone (Figure 10). Since Atokan rocks are generally absent and the Seville has an erratic distribution over southeastern Kansas, the lower Krebs boundary is generally

regarded as the top of the Mississippian System, while its upper boundary is often placed at the top of the Bluejacket Coal, which underlies the Seville. Krebs thickness on outcrops varies from 200 to 250 feet (61 to 74 meters), (Zeller, 1968).

Listed in ascending order, prominent members of this formation include the Riverton Coal, Warner Sandstone, Rowe Coal, Drywood Coal, Bluejacket Sandstone, and Seville Limestone.

Rocks lying above the Seville and below the Excello Shale belong to the Cabaniss Formation. On outcrops the formation thickness averages 220 feet (67 meters), (Zeller, 1968). Prominent members include the Weir-Pittsburg, Tebo, Scammon, Mineral, Croweburg, and Bevier coals, Chelsea and Lagonda sandstones, and the Ardmore and Breezy Hill Limestones (Figure 10).

Revisions in Stratigraphic Nomenclature

Until late in the Pennsylvanian, sediments deposited in the Arkoma Basin were significantly different from those of the Cherokee Shelf, and two geologic columns with complementary names have come into usage (Krumme, 1981), (Figure 6). Attempts to merge the two columns into a single classification have been frustrated by the lateral facies variations of beds traced from the basin to the shelf. Because the character of sediments on the shelf is

genetically similar to that of northern Midcontinent Pennsylvanian sediments, it stands to reason that Cherokee Shelf terminology in Kansas and Oklahoma should relate to the nomenclature of Desmoinesian strata of other Midcontinent states where shelf conditions prevailed during the Pennsylvanian. Therefore, the writer believes that unless beds can be traced with confidence from the basin to the shelf, stratigraphic nomenclature of shelf strata should relate to that of other shelf areas, and not the Arkoma Basin.

For example, as stated earlier, the placement of the Krebs-Cabaniss boundary was based on paleontological, structural, and lithic variance in the Arkoma Basin. However, the placement of this contact upon the shelf has always been inexact and genetically meaningless. Its position has ranged from the top of the Seville Limestone (Howe, 1956) to the top of the Bluejacket Sandstone (Zeller, 1968) to the top of the Weir-Pittsburg Coal (Branson, 1957), and to the base of the Tiawah Limestone (Berryhill, 1960). For this reason the Krebs-Cabaniss division is impractical for extension beyond the Arkoma Basin, and its use on the shelf has always been artificial (Krumme, 1981).

In Kansas, Nebraska, Missouri, and Iowa, the term Cherokee Group is still formally accepted, while in Oklahoma the term is used informally on the Cherokee Shelf. Since the definition of the Cherokee strata precedes that

of either Krebs or Cabaniss, the term Cherokee has precedence. Therefore, this writer believes that the terms Krebs and Cabaniss should be abandoned on the shelf, with the term Cherokee being restored to formal usage in northeastern Oklahoma when describing shelf stratigraphy. Current nomenclature should be retained for use in the Arkoma Basin.

Parts of four formations as originally defined by Howe (1956, 1961) after being proposed at the Nevada conference (Searight and others, 1953) compose the interval between the top of the Ardmore Limestone and the base of the Excello Shale. In ascending order these are the: 1) Verdigris Formation, defined as the beds between the top of the Croweburg Coal and top of the Wheeler Coal, 2) Bevier Formation, consisting of beds between the top of the Wheeler Coal and top of the Bevier Coal, 3) Lagonda Formation, representing the beds between the top of the Bevier Coal and the top of the Iron Post Coal, and 4) Mulky Formation, defined as the beds between the top of the Iron Post Coal and the top of the Mulky Coal.

At the Nevada conference, coals were designated as formational boundaries because at the time it was thought that these represented the most laterally persistent beds in the Desmoinesian Series. However, the use of these formational boundaries caused confusion among stratigraphers because each of the coals within the Ardmore-Excello

interval was either erratically distributed or was absent in adjoining states. For example, exposures of Iron Post Coal occur throughout northeastern Oklahoma, but are absent in Kansas. The Mulky and Bevier coals are widespread in the outcrop belt of Kansas, but the former is absent and the latter is sporadically distributed in Oklahoma. Workers in Oklahoma recognized this and compensated by expanding certain formational boundaries. Schell (1955) regarded all strata between the top of the Ardmore and base of the Breezy Hill limestones as the Lagonda Formation, while Gruman (1954) denoted the Lagonda as comprising beds below the base of the Kinnison Shale and above the base of the Lagonda sandstone. In Kansas, Jewett (1959) circumvented this problem by redefining the Krebs and Cabaniss subgroups as formations, thus effectively terminating the usage of coals as formational boundaries.

In recent years both subsurface and surface stratigraphic correlations have shown that both limestones and black shales are more laterally continuous than are the coals. For example, both the Ardmore Limestone and Excello Shale persist across the Midcontinent as far east as Kentucky (Wright, 1975), while the Oakley Shale can be correlated with the Mecca Quarry Shale of Indiana (Ravn and others, 1984). Hence, in this study, the interval between the top of the Ardmore Limestone and the base of the Excello Shale is incorporated into one formation, thus simplifying

correlations between adjoining states.

The proposed name of this formation is the Banzet Formation, named for exposures along state highway 10 south-southeast of the hamlet of Banzet, in Craig County, Oklahoma. Its designated type locality is in SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ of section 30, T. 28 N., R. 20 E., Craig County, Oklahoma, where a section between the base of the Oakley Shale and the base of the Fort Scott Limestone is well exposed in a roadcut (Section 2, Appendix A). Based on examination of other outcrops, the Banzet Formation in southeastern Kansas and northeastern Oklahoma can further be subdivided into three members, listed in ascending order: 1) Bevier Member, representing beds between the top of the Ardmore Limestone and top of the Bevier Coal, 2) Lagonda Member, comprising beds between the top of the Bevier Coal and top of the Iron Post Coal, and 3) Mulky Member, which ranges from the top of the Iron Post Coal to the top of the Mulky Coal, or where not present, the base of the Excello Shale. This member breakdown is essentially the same as the current formational subdivision in use in Missouri (Howe and others, 1961), except that the base of the Bevier Member is at the top of the limestone within Missouri's Verdigris Formation.

Because both the Ardmore Limestone and Oakley Shale persist laterally from northeastern Oklahoma to at least Indiana and are easily identifiable in both surface and subsurface sections, this author proposes that these two

lithologic units be incorporated into one formation, called the Verdigris Formation.

The type section of the Verdigris Limestone, which is the term for the Ardmore Limestone in current Kansas and Oklahoma stratigraphic nomenclature, is currently located 3 miles (4.8 kilometers) southwest of Verdigris, Oklahoma, in the south bank of the Verdigris River at the location of the old U.S. Highway 66 bridge, SE $\frac{1}{4}$ of section 17, T. 20 N., R. 15 E., Rogers County (Tillman, 1952). However, inspection of this outcrop in 1984 revealed that it had been covered during riverbank modification. Therefore, the author proposes that a new principal reference section of the Verdigris Formation be located at the type section of the Banzet Formation (see section 2, Appendix A).

Kansas and Oklahoma stratigraphic nomenclature must be altered in order to accommodate the naming of both the Banzet and Verdigris Formations. The author recommends that the terms Krebs and Cabaniss formations of Kansas and the Senora Formation of Oklahoma be abandoned, with the sub-Verdigris-Formation Desmoinesian rocks grouped into formations bounded by similarly geographically extensive lithologies, whether they be black shales or limestones. The Cherokee Group forms a genetic sequence of strata that does not lend itself easily to subdivision. However, it is believed that enough laterally persistent units occur in the Cherokee to enable widespread formational boundaries to

be delineated in Kansas and northeastern Oklahoma (P.H. Heckel, personal communication), as Iowa has already done (Ravn and others, 1984). It appears that more detailed subsurface stratigraphic studies of sub-Verdigris Formation rocks must be completed before revision of stratigraphic terms in the lower portion of the Cherokee is attempted.

OUTCROP STRATIGRAPHY

Strata belonging to the Banzet Formation crop out in a northeast-southwest band across the southeastern corner of Kansas and into Oklahoma, terminating in northeastern Pontotoc County in southcentral Oklahoma (Figure 11). Because the Iron Post Coal is absent in Kansas and the Bevier Coal is sporadically distributed in Oklahoma, descriptions of exposures between the top of the Ardmore Limestone and the base of the Breezy Hill Limestone are presented first for southeastern Kansas, then northeastern Oklahoma.

Oakley Shale

The Oakley Shale is defined as the black phosphatic shale that directly underlies the Ardmore Limestone. This shale is not officially named in Kansas and Oklahoma, but a correlative shale has been named the Mecca Quarry Shale Member of the Linton Formation in Indiana (Wright, 1975) and the Oakley Shale Member of the Swede Hollow Formation in Iowa (Ravn and others, 1984). Because Iowa is located closer to the study area than is Indiana, the term Oakley was used for this shale in this study.

The Oakley Shale is a dark gray to black, fissile

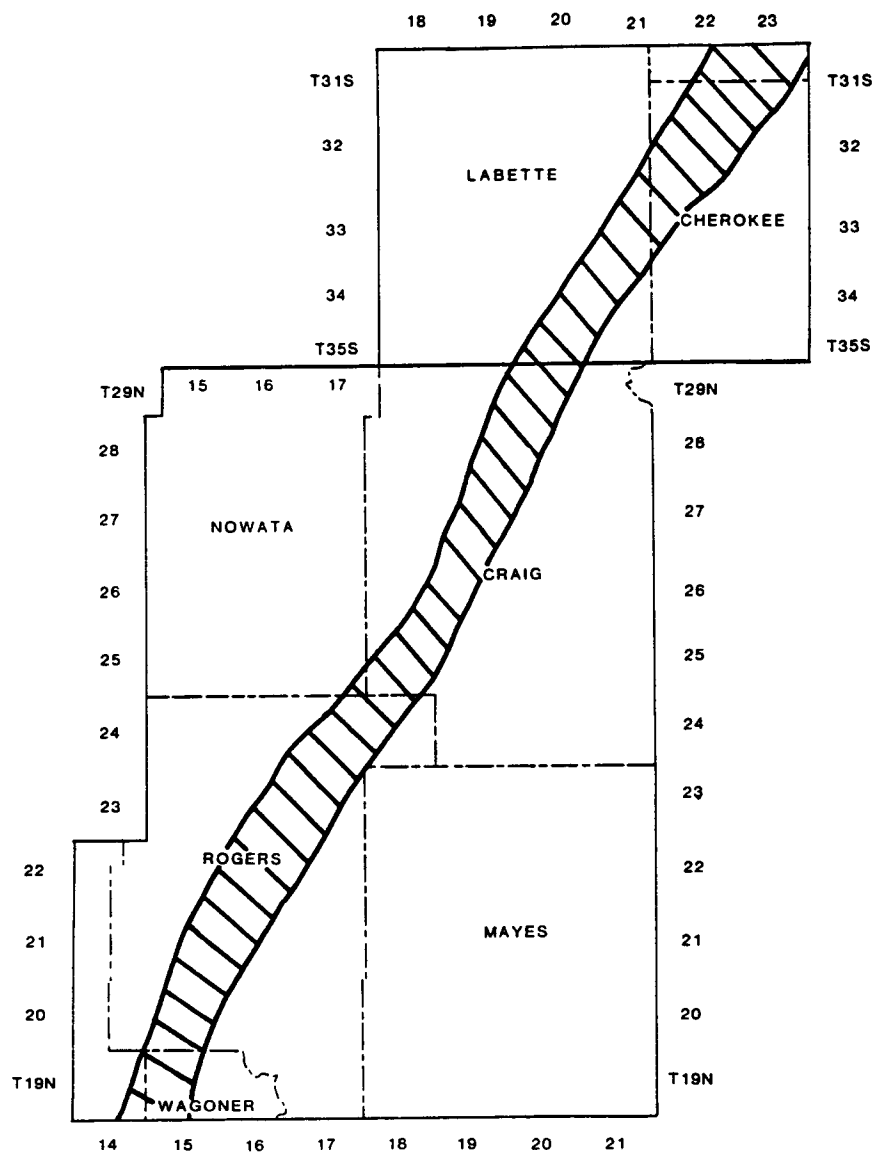


Figure 11. Approximate boundaries of outcropping Banzet sediments in the study area.

clayshale containing abundant phosphatic concretionary nodules. In places the shale is separated from the overlying Ardmore Limestone by a thin, medium gray, fossiliferous clayshale (Howe, 1956). The Oakley has remarkable lateral persistence, being continuous across southeastern Kansas and northeastern Oklahoma both on outcrop and in the subsurface. Because of its extensive distribution it forms an important stratigraphic datum within the Cherokee Group. Its thickness ranges from 1.5 to 5 feet (0.5-1.8 meters), and averages between 2 and 3 feet (0.6-1.0 meters). Lateral trends in thickness variation have not been noticed.

Ardmore Limestone

Due to the implementation of the Verdigris Formation, the author recommends that the Verdigris Limestone of Kansas and Oklahoma be renamed Ardmore. The Ardmore is traceable through Missouri and Iowa, while eastward it is referred to as the Oak Grove in Illinois, Velpen in Indiana, and Hamden in Ohio, and represents the most laterally persistent limestone in the Cherokee Group.

The Ardmore is a gray to dark gray, finely crystalline, fossiliferous limestone containing brachiopods, bryozoans, echinoderms, corals, and algal debris (Schell, 1955). Its thickness varies between 0 and 14 feet (0 and 4.3 meters), averaging 2 to 5 feet (0.6-1.5 meters). In

southeastern Kansas the Ardmore consists of three limestones with interstratified shale units (Howe, 1956), with the uppermost limestone being the thickest. In Craig County the Ardmore grades into a single bed, while in Rogers County this single bed splits into two limestone beds that are each 5 feet (1.5 meters) thick, and are separated by 1.5 (0.5 meters) of shale and thin limestone (Tillman, 1952).

The most southern Ardmore exposure visited is located in the spillway of the dam at Lake Bixhoma, section 2, T. 16 N., R. 14 E., Wagoner County, where it exists as two 1 foot (0.2 meter) limestone beds separated by 1 foot of dark gray shale.

Top of Ardmore Limestone to base of
Breezy Hill Limestone--southeastern Kansas

Bevier Member

Outcrops of the Bevier Member in southeastern Kansas can be traced from the Kansas-Missouri state line in Bourbon County southwestward to the Kansas-Oklahoma state line in Labette County.

The Bevier Coal, named by McGee (1888) for coal mined near Bevier, Macon County, Missouri, varies in thickness from 0 to 2 feet (0 to 0.6 meters). In Bourbon and Crawford counties the coal and its underclay rest directly upon the Ardmore Limestone, but to the southwest the Bevier Member

thickens with the introduction of siliciclastics. The member is at least 8.3 feet (2.5 meters) thick in section 24, T. 34 S., R. 20 E., Labette County, where it consists of massive to thin-bedded sandstone.

Top of Bevier Coal to base of Breezy Hill Limestone

Because the Iron Post Coal is not exposed in southeastern Kansas, the Lagonda and Mulky members were not differentiated.

Throughout most of southeastern Kansas a succession of dark gray to black clayshale and thin limestone beds directly overlie the Bevier Coal. Many of the lower shales are extremely fossiliferous, containing pelecypods, brachiopods, crinoids, and fusulinids (Howe, 1956). Individual shale units are extremely variable in thickness, ranging from 0 to 7 feet (0 to 2.1 meters). Separating these shale beds are thin, impure, dark gray to black, fossiliferous limestones containing brachiopods, corals, pelecypods, and gastropods (Howe, 1956). Locally this shale-limestone succession is interrupted by lenticular beds of micritic limestone that are often more than 1 foot (0.3 meters) thick. This succession grades upward into a coarsening-upward progression of gray clayshale and siltshale, thin-bedded, rippled siltstone, and fine to medium-grained, thin-bedded to massive sandstone. The sequence between the top of the Bevier Coal and base of the Breezy Hill Limestone thins from north to south, ranging from 31 feet (9.5 meters) in section 16, T.

31 S., R. 23 E., Crawford County, to 77 feet (23 meters) in section 32, T. 27 S., R. 25 E., Crawford County. Along the Neosho River east of Oswego, the Bevier-Breezy Hill interval consists primarily of medium gray clayshale and siltshale interstratified locally with rippled, fine-grained sandstone having load structures at its base.

Top of Ardmore Limestone to base of
Iron Post Coal--northeastern Oklahoma

Bevier Member

The Bevier Coal is exposed southward of the Kansas-Oklahoma state line to points within T. 25 N., R. 18 E., Craig County, where southward the Bevier is absent. The Bevier Coal is erratically distributed in northeastern Oklahoma, and where present the section below it most often comprises a coarsening-upward progression from clayshale or siltshale to massive or fissile, fine-grained sandstone. Thickness of the massive sandstone rarely exceeds 3 feet (1 meter) while the thicknesses of fissile sandstone zones average 5.5 feet (1.7 meters). Most contacts between the sandstone and siltshale are irregular and abrupt.

The Bevier Coal seatrock is a medium to dark gray claystone with coalified plant material and root impressions. It is poorly exposed in Oklahoma but becomes well developed in the southeastern Kansas outcrop belt.

The Bevier Member thickens southward, reaching its maximum thickness of 26 feet (8 meters) in sections 25 and 36, T. 26 N., R. 18 E., Craig County, reflecting an increase in siltshale content. Because the Bevier Member thickens and the Lagonda Member thins southward in northeastern Oklahoma, it is assumed that in areas south of the southernmost Bevier Coal exposure, the sediments within the Ardmore Limestone-Iron Post Coal interval are more related to those of the Bevier Member.

In areas south of T. 25 N., the interval between the top of the Ardmore Limestone and the base of the Iron Post Coal increases in thickness to the south, varying from 26 feet (7.9 meters) in section 36, T. 24 N., R. 16 E., Rogers County, to at least 45 feet (13.7 meters) in section 7, T. 19 N., R. 15 E., Wagoner County.

Two types of sandstone occur within this interval. Sandstone type A is a light gray to medium brown, fine-grained, ripple-stratified sandstone. Often these sandstones are interstratified with fissile siltstone. Lower contacts are generally abrupt, with load structures often present. Individual sandstone thicknesses range from 0.5 to 5 feet (0.2 to 1.7 meters). Type A sandstones are bounded by unfossiliferous, micaceous, medium gray siltshale and rippled, fissile, light gray to medium brown siltstone. The thickness of siltshale and siltstone that lie between the top of these sandstones and the base of the Iron Post

Coal varies from 1.3 feet (0.4 meters) in section 17, T. 19 N., R. 15 E., Wagoner County, to 23 feet (7 meters) in section 2, T. 21 N., R. 15 E., Rogers County.

Type B sandstones are tan to buff, medium-grained sandstones characterized by high-angle (15-20 degrees) southwest-southeast-trending cross-strata that are locally interrupted by siltshale partings. Irregular, erosional contacts with underlying siltshale are commonly observed. These sandstones are overlain by light brown, interbedded rippled siltstone and fine-grained sandstone. A maximum sandstone thickness of 25 feet (7.6 meters) occurs in section 16, T. 20 N., R. 15 E., Rogers County.

Lagonda Member

The Lagonda Member in northeastern Oklahoma consists of a fining-upward sequence of sandstone, siltstone, and siltshale. The member thins from north to south, varying from 20 feet (6.2 meters) in section 29, T. 27 N., R. 19 E., to 3.5 feet (1.1 meters) in section 28, T. 25 N., R. 18 E., Craig County.

In most outcrops the Bevier Coal is directly overlain by fine to medium-grained, thick-bedded, rippled sandstone that is 2 to 7 feet (0.6 to 2.1 meters) thick. At various places the thickness of this sandstone is variable due to load structures at its base. This sandstone grades upward into fine-grained, micaceous, fissile, rippled sandstone

and medium gray siltshale. Contacts are generally sharp between the thick-bedded and fissile sandstone but are gradational between the fissile sandstone and siltshale.

Mulky Member

Iron Post Coal and Kinnison Shale

The Kinnison Shale and the underlying Iron Post Coal were named by Howe (1951). Both units pinch out northward just south of the Kansas-Oklahoma border, while to the south both can be traced into the Concharty Mountain area, section 7, T. 16 N., R. 14 S., Wagoner County.

Outcrops of the Iron Post Coal have been mined for local consumption. A cap rock composed of skeletal limestone containing abundant brachiopods overlies the coal in areas where the Kinnison is thickest.

The Kinnison Shale is composed of clayshale, and is highly to poorly fissile, rarely fossiliferous, and highly variable in color and thickness. Where the Kinnison is thicker than 2.6 feet (0.8 meters) its color is always dark gray or black at its base to light gray or yellow at its top. Where it is thinner than 2.6 feet (0.8 meters), its color is black and yellow, with no consistent upward color trend noticed within vertical sections.

North of T. 23 N. the Kinnison Shale is erratic in thickness, ranging between 2 and 7 feet (0.6 and 2.1 meters)

while to the south it is consistently thinner than 2 feet (0.6 meters). It appears that the Kinnison is thinner in outcrops that have thick Ardmore-Iron Post sections. For example, in section 3, T. 25 N., R. 18 E., the Ardmore-Iron Post sequence is 25 feet (7.6 meters) thick, and the Kinnison is 4 feet (1.2 meters) thick, while 3.5 miles away the Ardmore-Iron Post sequence is 32 feet (9.8 meters) thick and the Kinnison is 2 feet (0.6 meters) thick.

Breezy Hill Limestone

The Breezy Hill Limestone was named by Pierce and Courtier (1937) from exposures near Mulberry, eastern Crawford County, Kansas (Howe, 1956). In Kansas the Breezy Hill overlies sandstone but in Oklahoma it overlies the Kinnison Shale.

Throughout northeastern Oklahoma north of Concharty Mountain the Breezy Hill is a skeletal calcilutite sporting a highly diverse fauna, implying open marine facies (Knight, 1983). Its thickness is highly variable, ranging from 4.6 feet (1.4 meters) in section 12, T. 24 N., R. 16 E., Rogers County, to over 10 feet (3 meters) in section 14, T. 21 N., R. 15 E., Rogers County and section 25, T. 26 N., R. 18 E., Craig County.

North of the Kansas-Oklahoma border the Breezy Hill becomes a silty skeletal calcilutite, which grades upward into a silty skeletal calcarenite, with its biota still

reflecting deposition in open marine waters. Throughout Labette and southern Crawford counties its thickness averages 4 feet (1.2 meters).

In a section along U.S. Highway 69, 6 miles (9.6 km) north of Arma, Crawford County, the Breezy Hill loses its marine characteristics, becoming a caliche or rhizolite (Knight, 1984). This facies persists throughout northern Crawford County into Bourbon County, where it varies between 1 and 2 feet (0.3 and 0.6 meters) in thickness.

Mulky Coal

The Mulky Coal is the uppermost coal of the Cherokee Group. Where it is mined in northeastern Crawford and eastern Bourbon counties it attains a thickness of 1.6 feet (0.5 meters) (Howe, 1956). It is absent in most surface exposures in and adjacent to the study area, and therefore it could not be described in detail.

Excello Shale

The Excello Shale is underlain by the Mulky Coal in much of southeastern Kansas and by the Breezy Hill Limestone throughout northeastern Oklahoma. Where it is exposed, the Excello is overlain by the Blackjack Creek Member of the Fort Scott Formation. The base of the Excello marks the division between the Cherokee and Marmaton Groups (Ravn and others, 1984).

The Excello is a highly fissile, phosphatic black shale that grades upward into a gray shale. It consistently averages 5 to 6 feet (1.5 to 2.0 meters) in thickness throughout northeastern Oklahoma, but has a more variable thickness in southeastern Kansas, ranging between 2 and 8 feet (0.6 and 2.5 meters).

SUBSURFACE FACIES ANALYSIS

In the subsurface the Banzet Formation thins from north to south, varying in thickness from 125 feet (38 meters) in section 28, T. 27 S., R. 23 E., Crawford County, Kansas, to 32 feet (9.8 meters) in section 32, T. 27 N., R. 5 E., Kay County, Oklahoma (Figure 12). The thickness of the Mulky Member thickens rapidly upon passage northward across a line that trends northeastward from Kay County to the southwest corner of Neosho County, Kansas, and then south to Craig County, Oklahoma. Therefore, within the subsurface the study area has been divided into two domains (Figure 13). Well logs representative of domain 1 north of this line and domain 2 south of this line are listed in figures 14 and 15, respectively. Marker beds in each of the two domains are listed in figure 16. Descriptions of the lithologies within the Banzet Formation have been listed in ascending stratigraphic order first for domain 1, then domain 2.

Stratigraphic Relationships of the Bevier Coal and Iron Post Coal

The lithic characteristics of the intervals between various marker horizons cannot be adequately discussed

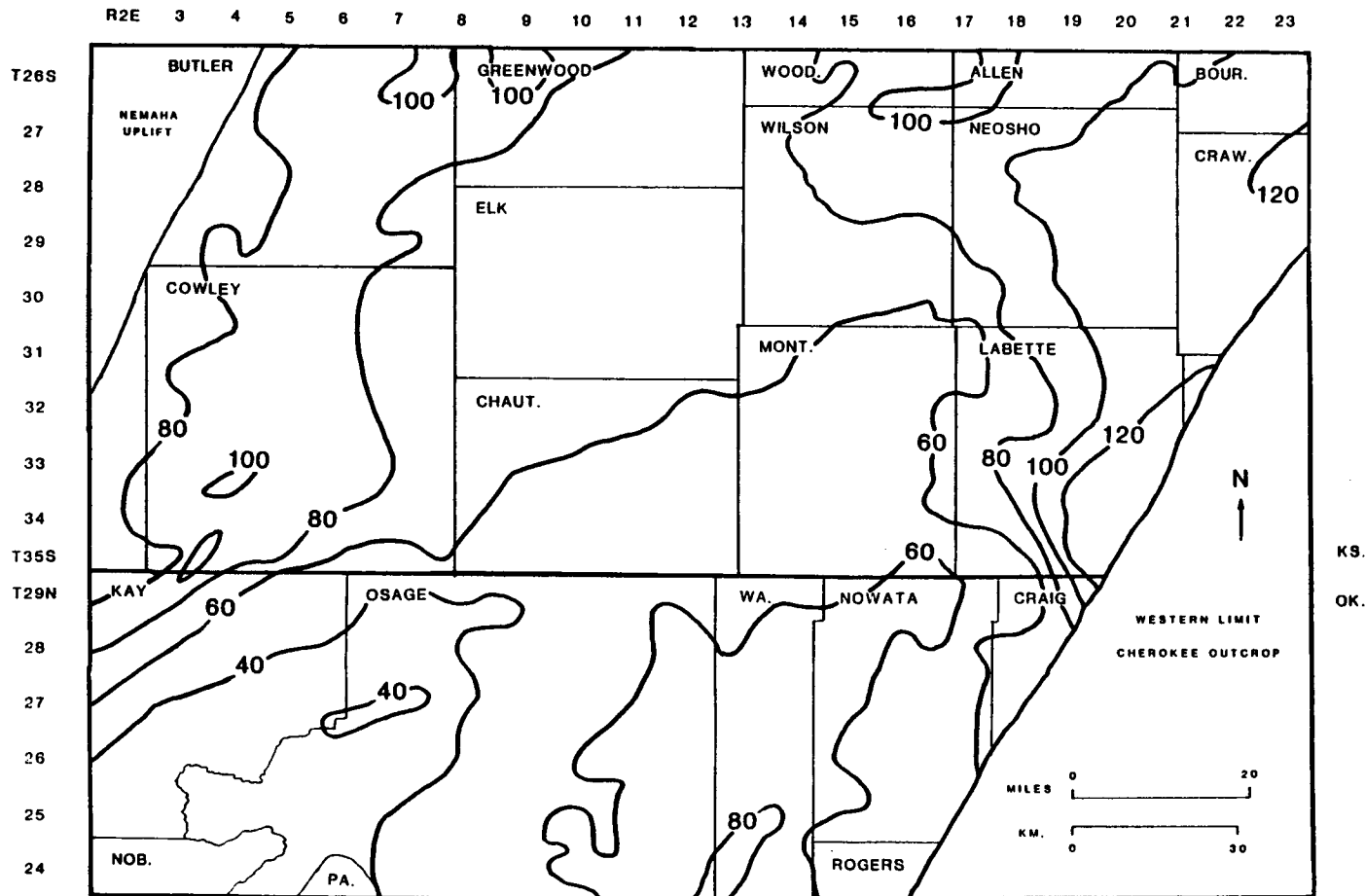


Figure 12. Isopach map of the Banzet Formation (contour interval = 20 feet).

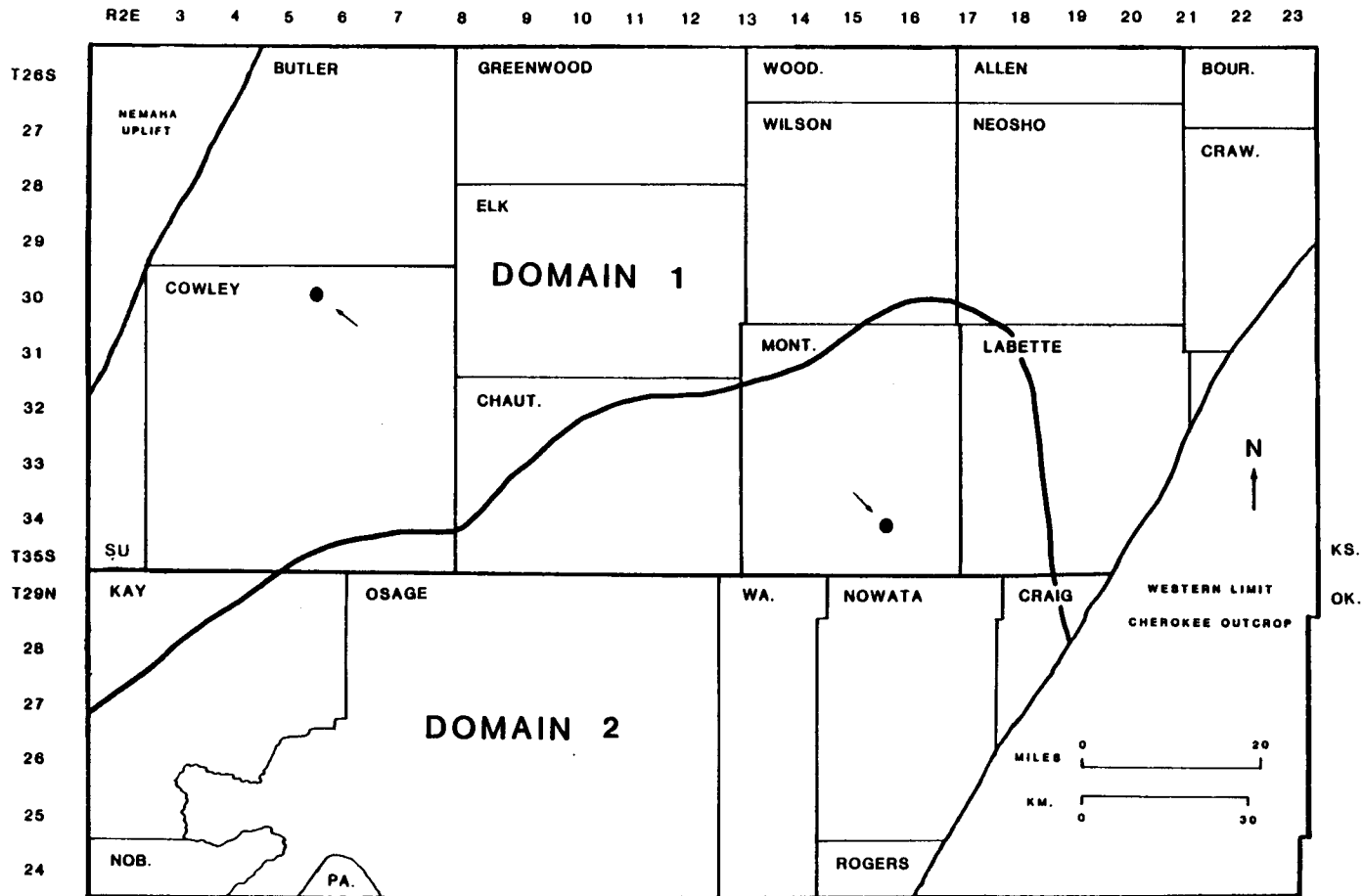


Figure 13. Domains of Banzet strata within the subsurface. Dots mark locations of well logs used in figures 14 and 15.

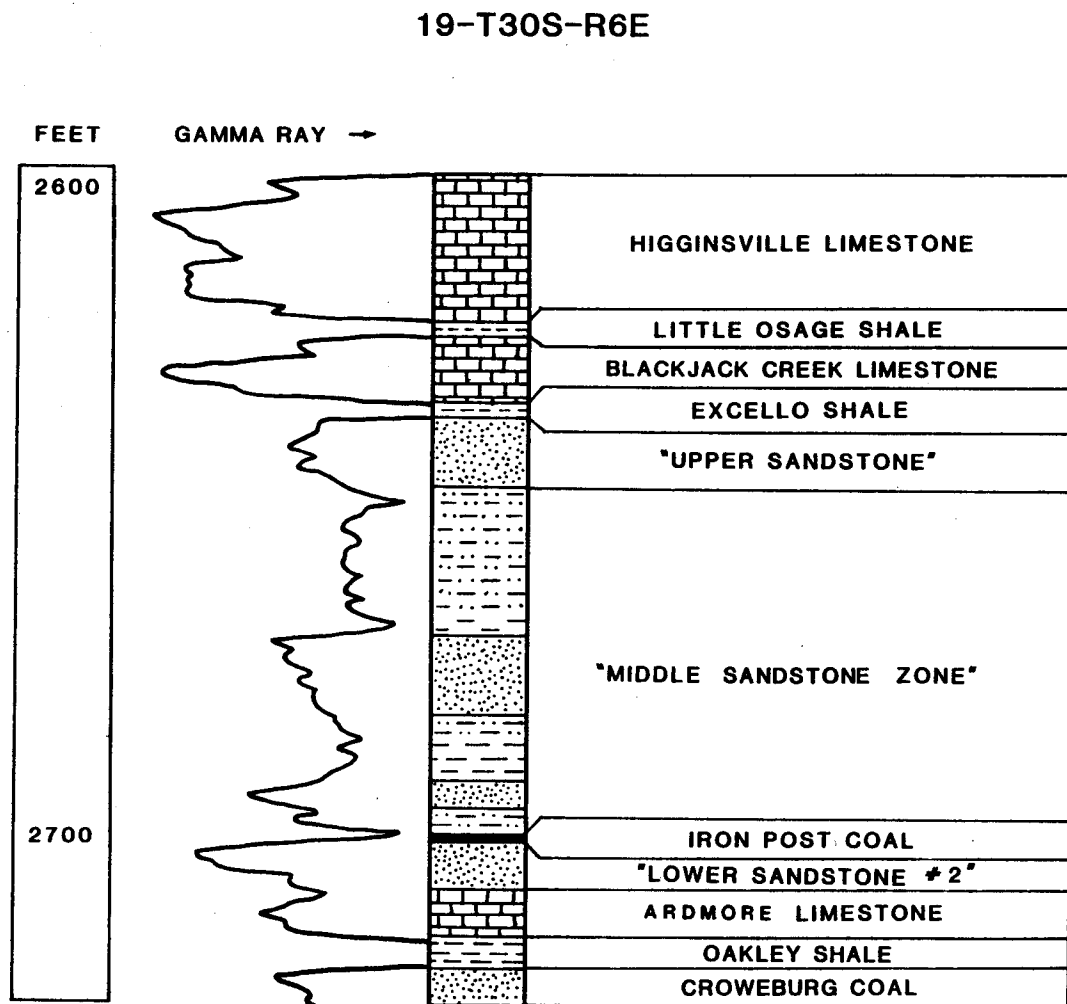


Figure 14. Type well log and corresponding lithologic interpretations from domain 1. See figure 13 for location and page 115 for lithologic key.

17-T34S-R16E

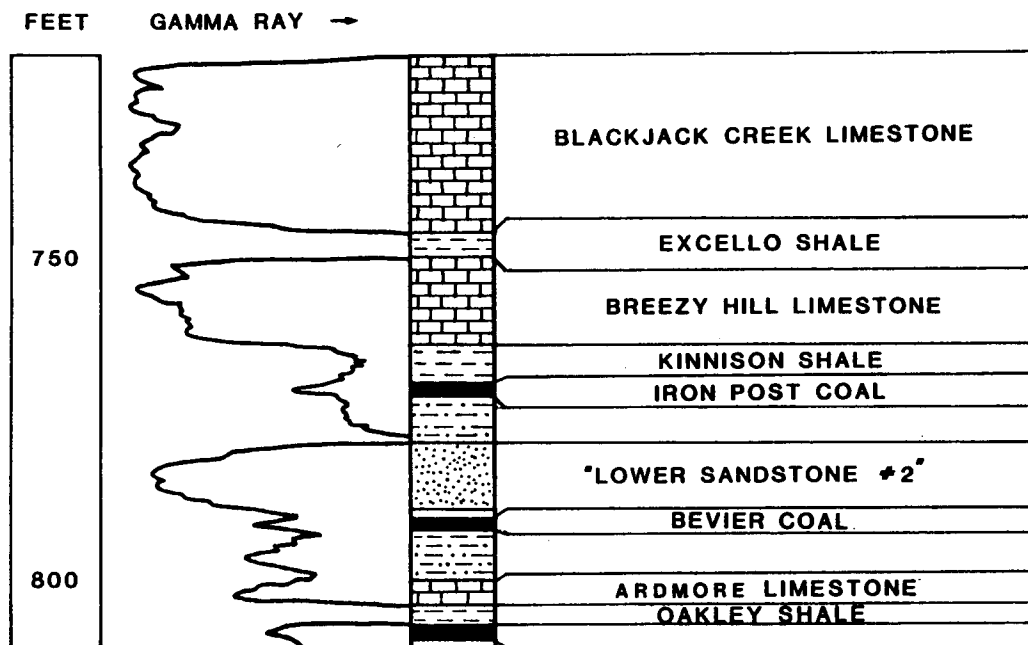


Figure 15. Type well log and corresponding lithologic interpretations from domain 2. Note that the Ardmore-Iron Post interval is thicker and the Mulky Member is thinner than in the type well log from domain 1. See figure 13 for location and page 115 for lithologic key.

DOMAIN 1	DOMAIN 2
EXCELLO SHALE	EXCELLO SHALE
"UPPER SANDSTONE"	BREEZY HILL LS.
"MIDDLE SANDSTONE ZONE"	
KINNISON SHALE	KINNISON SHALE
IRON POST COAL	IRON POST COAL
"LOWER SANDSTONE #2"	"LOWER SANDSTONE #2"
BEVIER COAL	BEVIER COAL
	"LOWER SANDSTONE #1"
ARDMORE LS.	ARDMORE LS.
OAKLEY SHALE	OAKLEY SHALE

Figure 16. Prominent marker beds within domains 1 and 2.

without mention of the correlations regarding the Bevier Coal and the overlying Iron Post Coal. In the subsurface, it is difficult to distinguish between the two coals when only one coal is present in Ardmore-Breezy Hill sections. Stratigraphic correlations of the coals within the Banzet Formation was accomplished through the construction of cross-sections that utilize well logs in which both coals are present and the examination of the thicknesses and lithic characteristics of overlying and underlying sediments in wells where only one coal is present.

Cross-section A-A' is an example that shows the lateral variations of the two coals (Figure 17). Within this well-log traverse, the thickness of the Bevier Member decreases westward until the Bevier Coal vanishes in T. 29 N., R. 9 E., while the overlying Iron Post Coal continues westward across the study area. It can be argued that it is the Iron Post rather than the Bevier which terminates at this point, but that interpretation is unlikely because, 1) the thickness of the Kinnison Shale remains fairly uniform westward to R. 3 E., and 2) there is no evidence elsewhere to support a sudden thickening of the Bevier Member west of this point.

From this interpretation, it is inferred that the Iron Post Coal is more laterally extensive than is the Bevier Coal. The Iron Post Coal persists across the entire study area while the Bevier Coal is restricted to the extreme

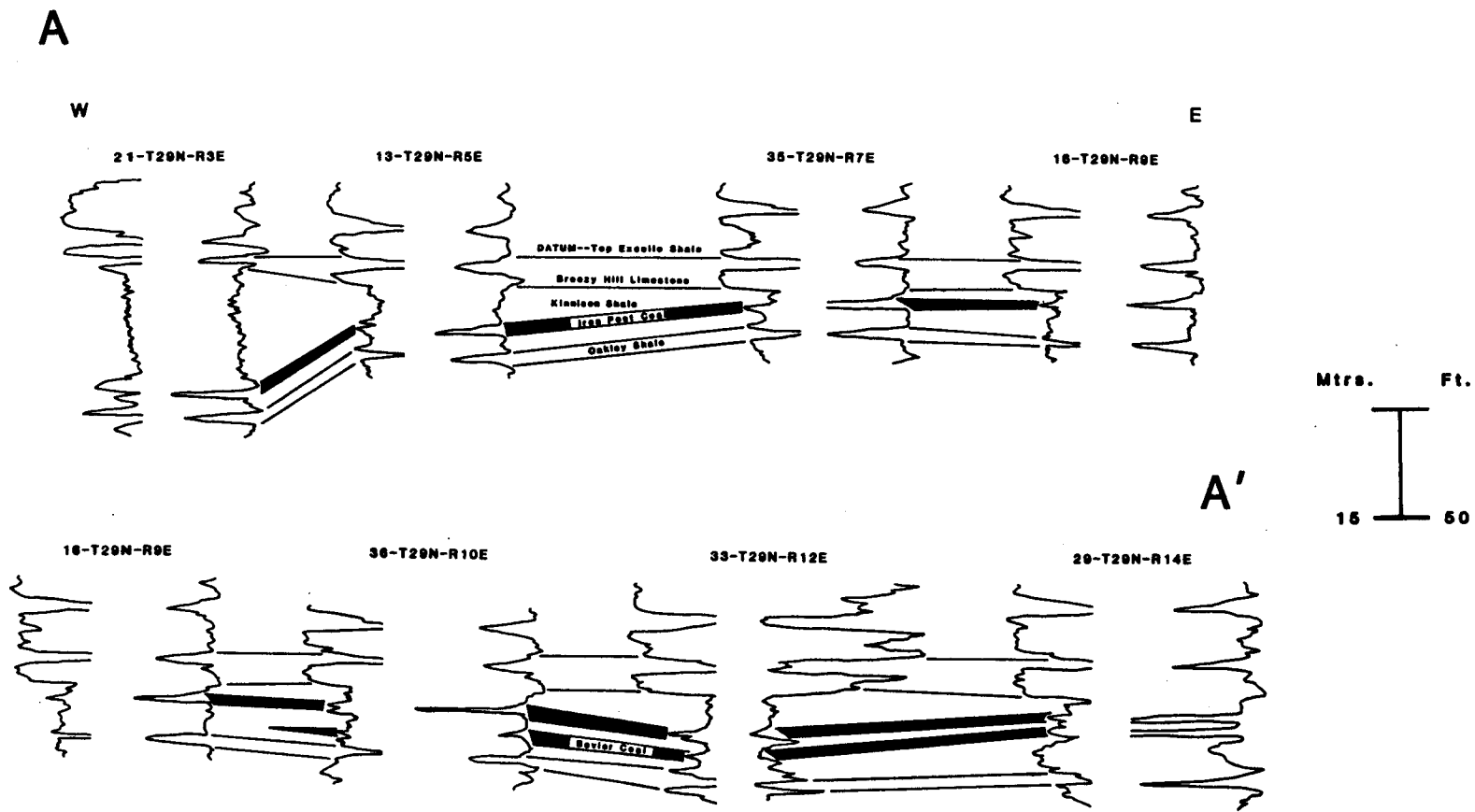


Figure 17. Cross-section A-A' shows that the Bevier Member thins to the west. Note that the Bevier Coal disappears between R. 9 E. and R. 10 E., while the Iron Post Coal persists through the entire cross-section. See figure 2 for location.

southeastern corner of domain 1 and the eastern half of domain 2.

Key Beds Within Both Domains 1 and 2

Oakley Shale and Ardmore Limestone

Both the Oakley Shale and Ardmore Limestone, which underlie the Banzet Formation, persist across the entire study area. On gamma-ray logs, the Oakley is characterized by a sharp increase of gamma-ray values, which is indicative of a highly radioactive black shale, while the gamma-ray signature of the overlying Ardmore shows a sharp deflection to the left (Figure 15). In scattered wells in the northern part of the study area, the Ardmore cannot be distinguished, probably because the limestone is too thin to be detected by the gamma-ray instrument.

The Oakley Shale has a constant thickness of 5 to 6 feet (1.5-1.8 meters) throughout the study area, while the Ardmore is generally thicker to the south, and ranges in thickness from less than 2 feet (0.6 meters) to about 6 feet (1.8 meters).

Key Intervals Within Domain 1

Top of Ardmore Limestone to top of Iron Post Coal

In domain 1, Banzet sediments cannot be divided into Bevier and Lagonda members because the Bevier Coal is

absent over most of the domain. The Ardmore-Iron Post interval averages 11 feet (3.4 meters) in the western part of the domain but thickens eastward to average 17 feet (5.2 meters) in southern Neosho County, Kansas, achieving a maximum thickness of 23 feet (7.0 meters) in section 7, T. 30 S., R. 19 E., Neosho County.

Throughout most of the southern half of domain 1 this interval consists of shale, which, in most localities, is interbedded with siltstone. However, to the northwest this interval forms a regressive sequence, grading upward from shale and siltstone to coarsening-upward sandstone. This sandstone has a gradational contact with underlying siltstone and an abrupt upper contact with the overlying Iron Post Coal (Figure 18). Within domain 1 this sandstone, called "lower sandstone #2", has an average thickness of 6 feet (2.0 meters) in northern Cowley and eastern Butler counties, and thins to the south and east (Figure 19). It has a maximum thickness of 9 feet (2.7 meters) in section 7, T. 31 S., R. 6 E., Cowley County, where it consists of two 4 foot (1.2 meter) upward-coarsening sandstones separated by shale.

Mulky Member

Kinnison Shale

The Kinnison Shale is considerably thicker in the subsurface than on outcrop. Within domain 1 it rapidly

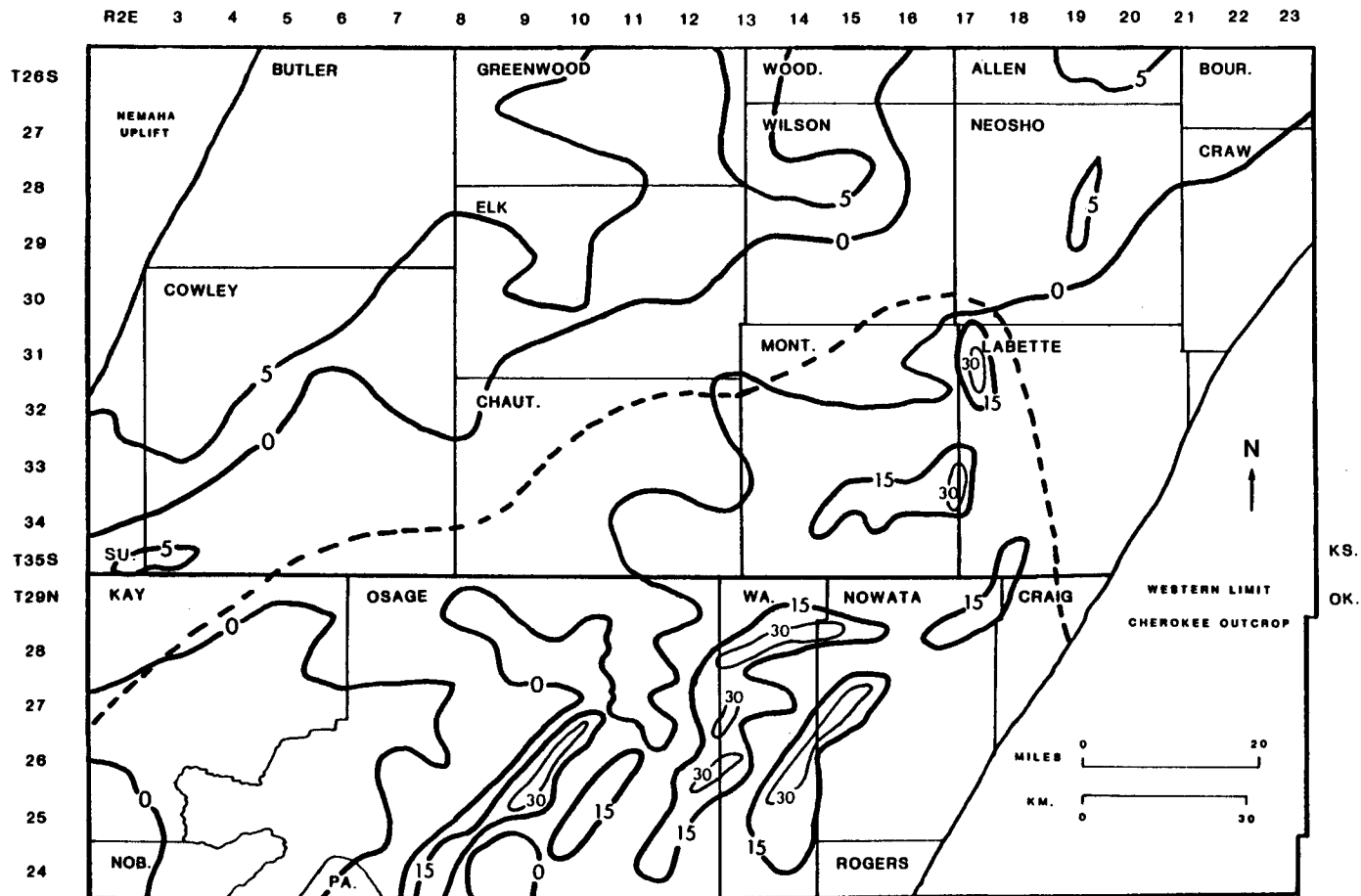


Figure 19. Sandstone isolith map of the Ardmore-Iron Post interval. Domain 1-2 border is outlined by the dashed line. Contour interval = 5 feet in domain 1, and 15 feet in domain 2.

thickens northward, reflecting an increase of sandstone in the northwest, and shale to the east and northeast. The Kinnison averages 20 feet (6.1 meters) in thickness along the domain border and reaches a maximum thickness of 97 feet (30 meters) in northern Crawford County (Figure 20).

Figure 21 is a west to east cross-section that cuts across the domain 1-2 border, and reflects the increase in shale content within the Kinnison. Interpretation of the Iron Post Coal in the two easternmost wells of the cross-section is tenuous since the Iron Post is absent in nearby outcrops. However, its placement is substantiated in part by the fact that the interval between the Iron Post and Bevier coals remains constant throughout southern Labette County, and there is no evidence from outcrops to support the occurrence of another coal (such as the Wheeler Coal of Missouri) in this stratigraphic position in southeastern Kansas.

Two sandstone bodies can be mapped within the Kinnison Shale in domain 1. These bodies are referred to as the "middle sandstone zone" and the "upper sandstone" (Figure 14). The "upper sandstone" is a persistent unit that directly underlies the Excello Shale, while the "middle sandstone zone" consists of sandstones between either the base of the "upper sandstone" or, where not present, the base of the Excello Shale, and the top of the Iron Post Coal.

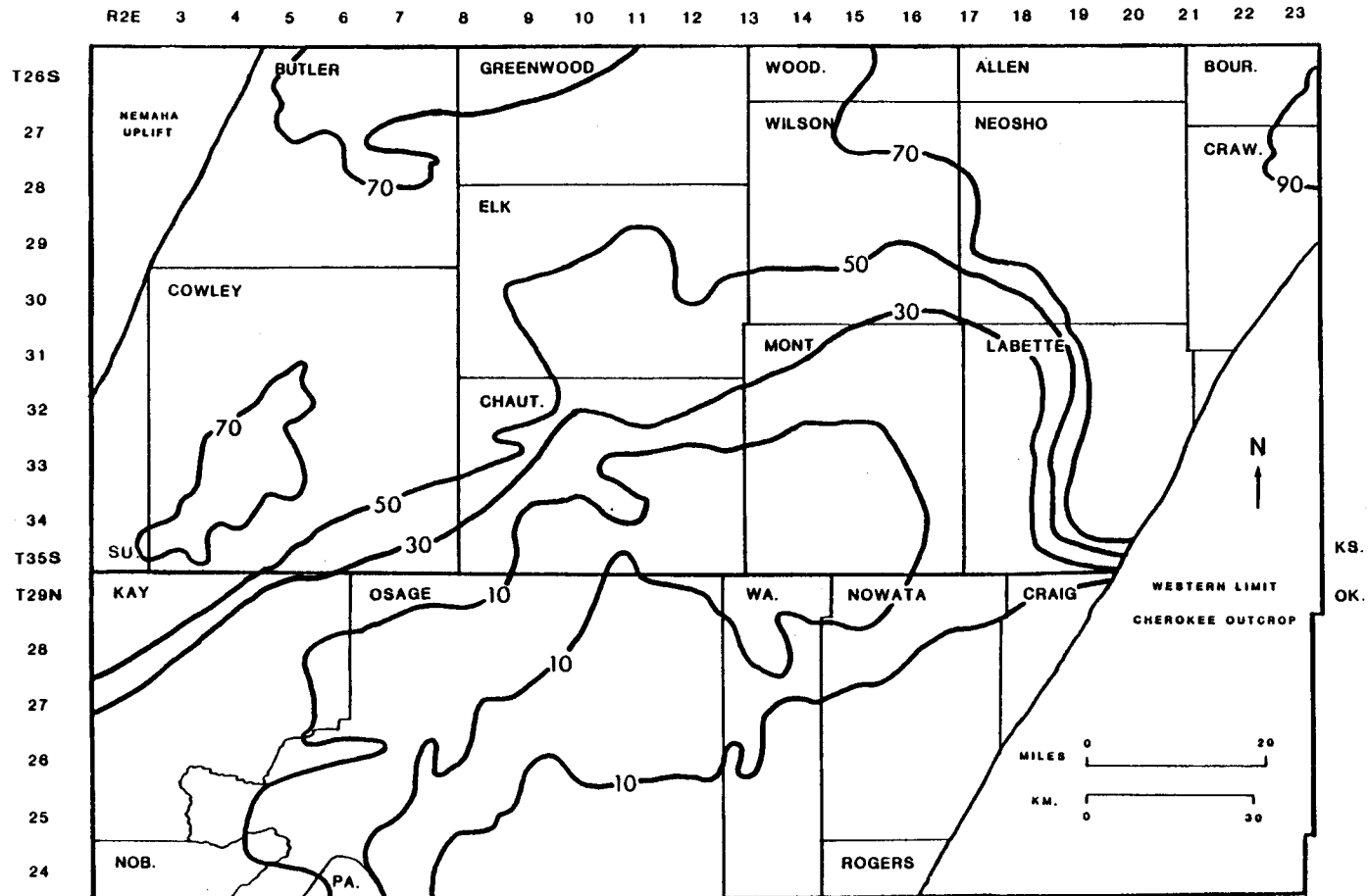


Figure 20. Isopach map of the Kinnison Shale. Note that the Kinnison is much thicker in domain 1. Domain 1-2 border parallels the 30 foot contour. Contour interval = 20 feet.

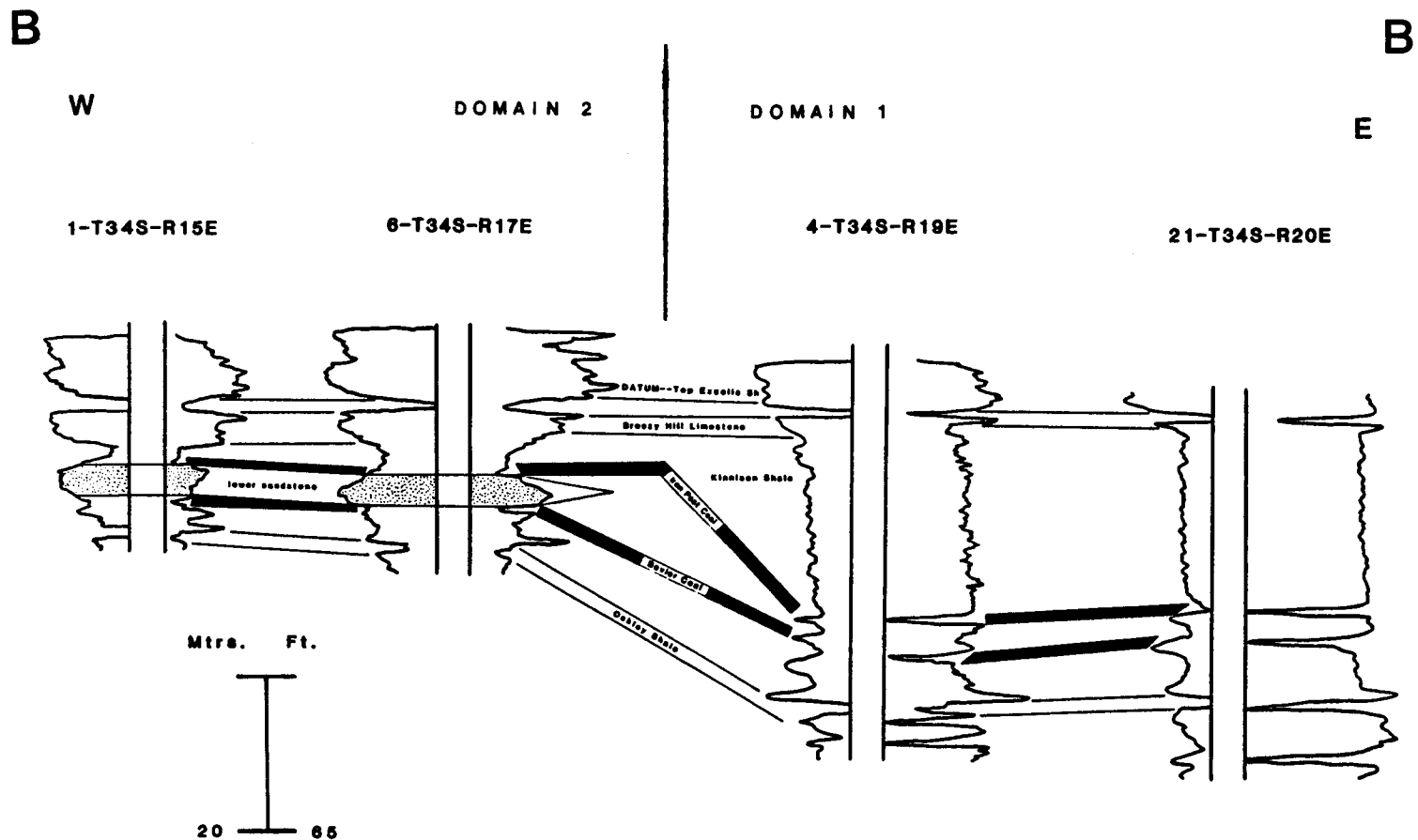


Figure 21. Cross-section B-B' shows the eastward thickening of the Kinnison Shale and the thinning of the Breezy Hill Limestone toward the outcrop belt. Domain 1-2 border occurs between the central two wells. See figure 2 for location.

"Middle Sandstone Zone"

The "middle sandstone zone" consists of thin, laterally discontinuous sandstone horizons. These sandstones are informally called the "squirrel" sandstones by drillers because of the manner in which the interval varies or "jumps" between the sandstone and either the overlying Breezy Hill Limestone or Excello Shale (Chrisman, 1951).

The variance in gross sandstone thickness permitted the delineation of two major sandstone trends. The thickest accumulations of sandstone within the "middle sandstone zone" lie parallel to the Nemaha Uplift and extend from western Greenwood and eastern Butler counties southward to southeastern Sumner County (Figure 22). Sandstones reach a maximum thickness of 24 feet (7.3 meters) in section 26, T. 28 S., R. 5 E., Butler County. The "middle sandstone zone" is also highly developed within Woodson, Wilson, northwest Montgomery, and northeast Chautauqua counties (Figure 22).

A north-south cross-section oriented perpendicular to a "middle sandstone zone" isopach "thick" in Butler County shows a well developed sandstone directly above "lower sandstone #2" (Figure 23). A thinner, more variable sandstone is found in two of the wells in the cross-section. In other areas within the domain, the stratigraphic positions of sandstones are highly erratic, with the

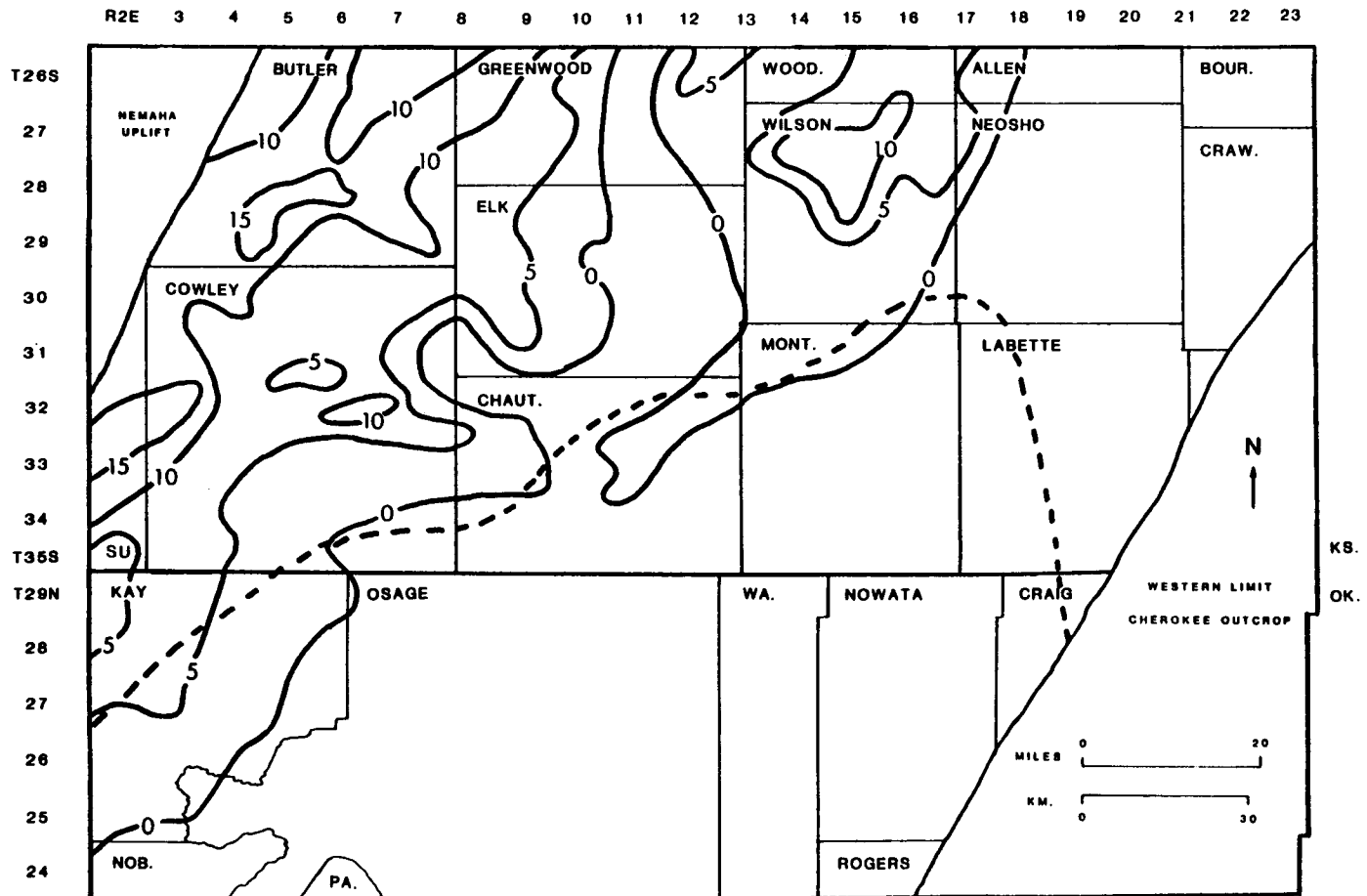


Figure 22. Sandstone isolith map of the "middle sandstone zone". Two northeast-southwest-oriented sandstone systems can be delineated. (Contour interval = 5 feet).

C
N

C'
S

15-T27S-R5E

27-T27S-R5E

1-T28S-R5E

26-T28S-R5E

35-T28S-R5E

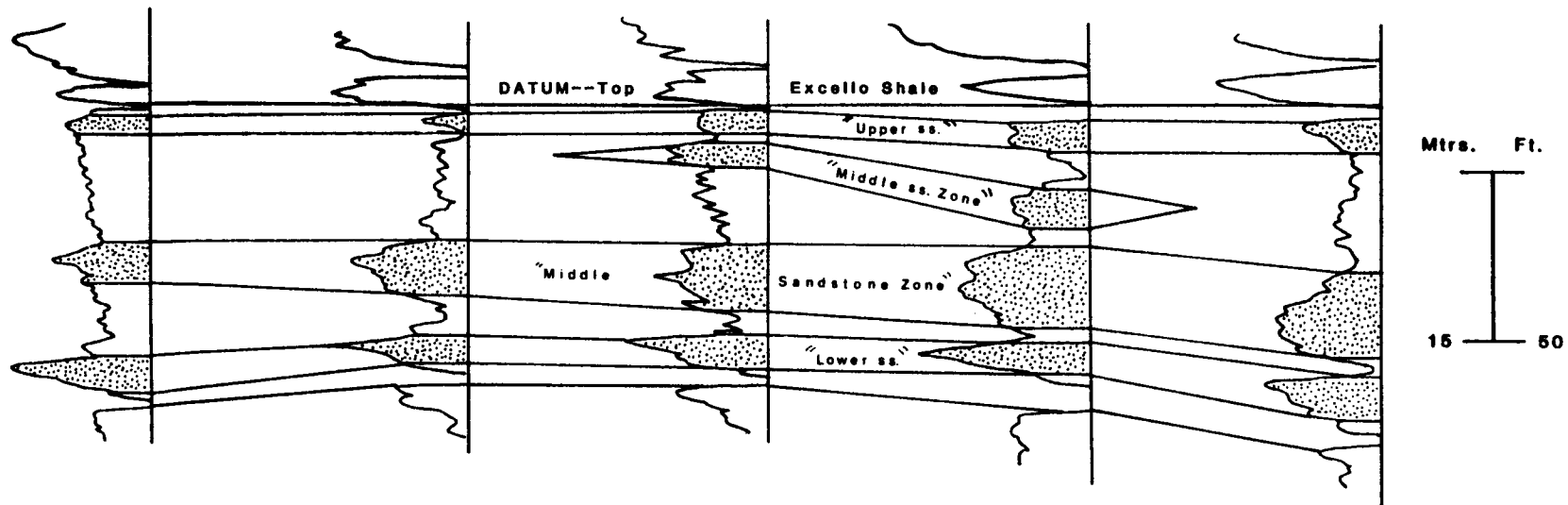


Figure 23. Cross-section C-C' is oriented perpendicular to the northeast-southwest-trending thick "middle sandstone zone" deposit in Butler County, Kansas. The lowest sandstone within the "middle sandstone zone" is well developed, while the stratigraphic position of the sandstone above it is more variable. See figure 2 for location.

thicknesses of shale and siltstone intervals between them highly variable. Most of the thicker accumulations are upward-fining, and have sharp basal contacts and gradational upper contacts (Figure 23). However, many of the thinner sandstones that are positioned some distance away from the thicker sandstones are upward-coarsening, with gradational basal contacts and sharp upper contacts (Figure 14). Where sandstone within the "middle sandstone zone" is present, the number of individual sandstone units varies from 1 to 4, with the greatest numbers of these in areas adjacent to the thickest sandstones.

"Upper Sandstone"

The "upper sandstone", often referred to as the "upper squirrel" sandstone by drillers, is found in two distinct systems within domain 1, one extending to the southwest through Greenwood, northern and western Elk, central Cowley, and northeastern Chautauqua counties, Kansas, and the other extending through Bourbon, northwestern Crawford, and east-central Neosho counties (Figure 24). The "upper sandstone" in the northwest part of the study area is generally thickest in areas where the "middle sandstone zone" is poorly developed, and is upward-coarsening, with a gradational lower contact with underlying shales and siltstones (easternmost well, figure 23) and an abrupt contact with the overlying Excello Shale.

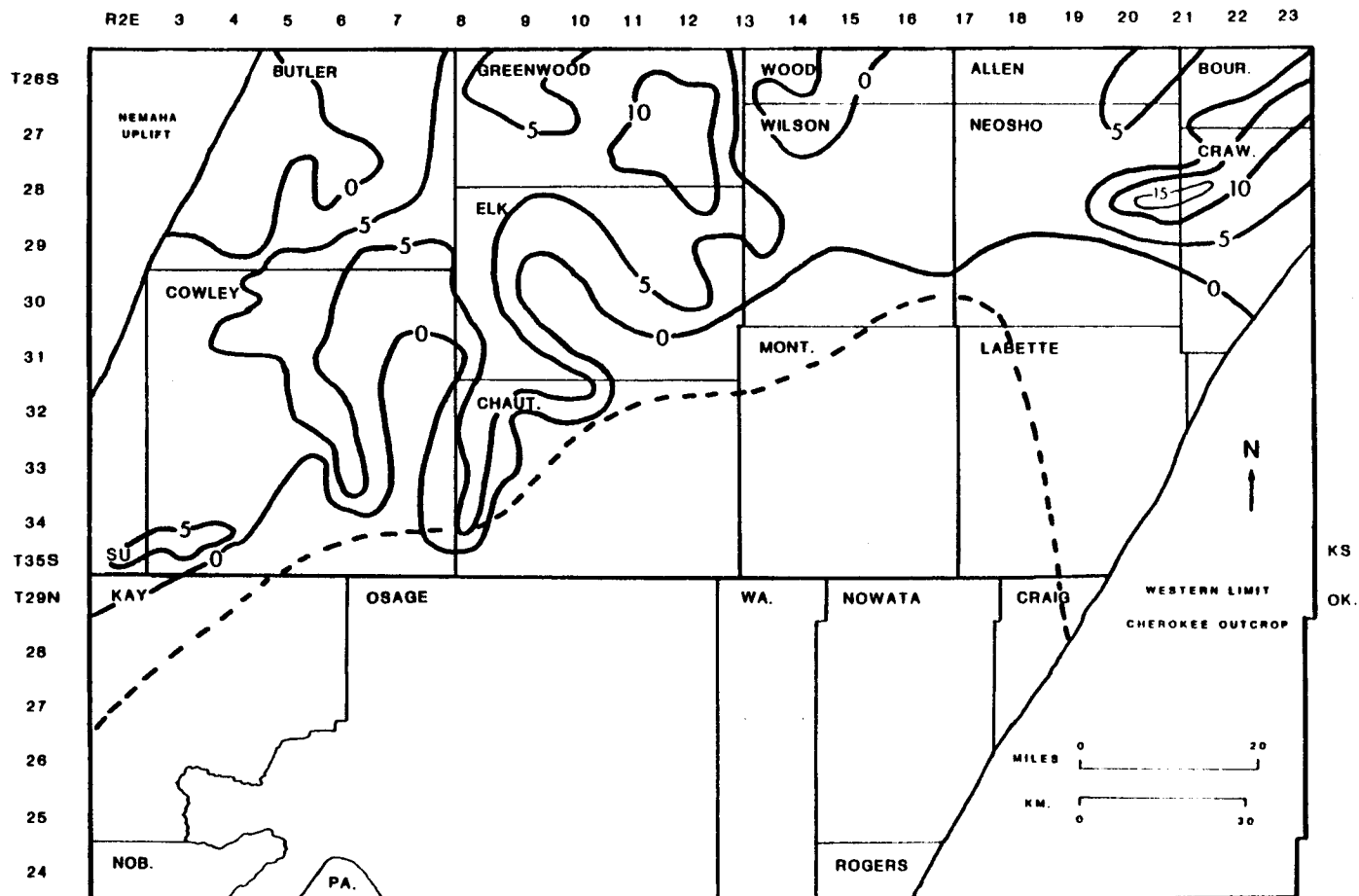


Figure 24. Sandstone isolith map of the "upper sandstone". Domain 1-2 border is outlined by the dashed line. Contour interval = 5 feet.

In the northwest part of the study area the "upper sandstone" caps a regressive sequence of shale, siltstone, and sandstone between the Iron Post Coal and Excello Shale (Figure 25). In this area the sandstone has a maximum thickness of 11 feet (3.4 meters) in section 24, T. 26 S., R. 11 E., Greenwood County.

The extent of the "upper sandstone" in the northeast part of the study area is not well delineated due to poor well control in the area. These sandstones appear to have sharp basal contacts and are upward-fining (Figure 26). Maximum sandstone thickness occurs in section 22, T. 28 S., R. 20 E., Neosho County, where it is 22 feet (6.7 meters) thick.

Key Intervals Within Domain 2

Bevier Member

The Bevier Coal is present in the subsurface within Labette, Montgomery, and Chautauqua counties, Kansas, and Washington, eastern Osage, and northern Nowata and Craig counties, Oklahoma. Within domain 2 the Bevier Member thickens from north to south, and averages between 12 and 25 feet (3.7 and 7.6 meters) in thickness (Figure 27). The member is thickest in southeastern Osage and southern Washington counties, where it achieves a maximum thickness of 132 feet (40.2 meters) in section 13, T. 27 N., R. 15 E., Nowata County.

16-T28S-R11E

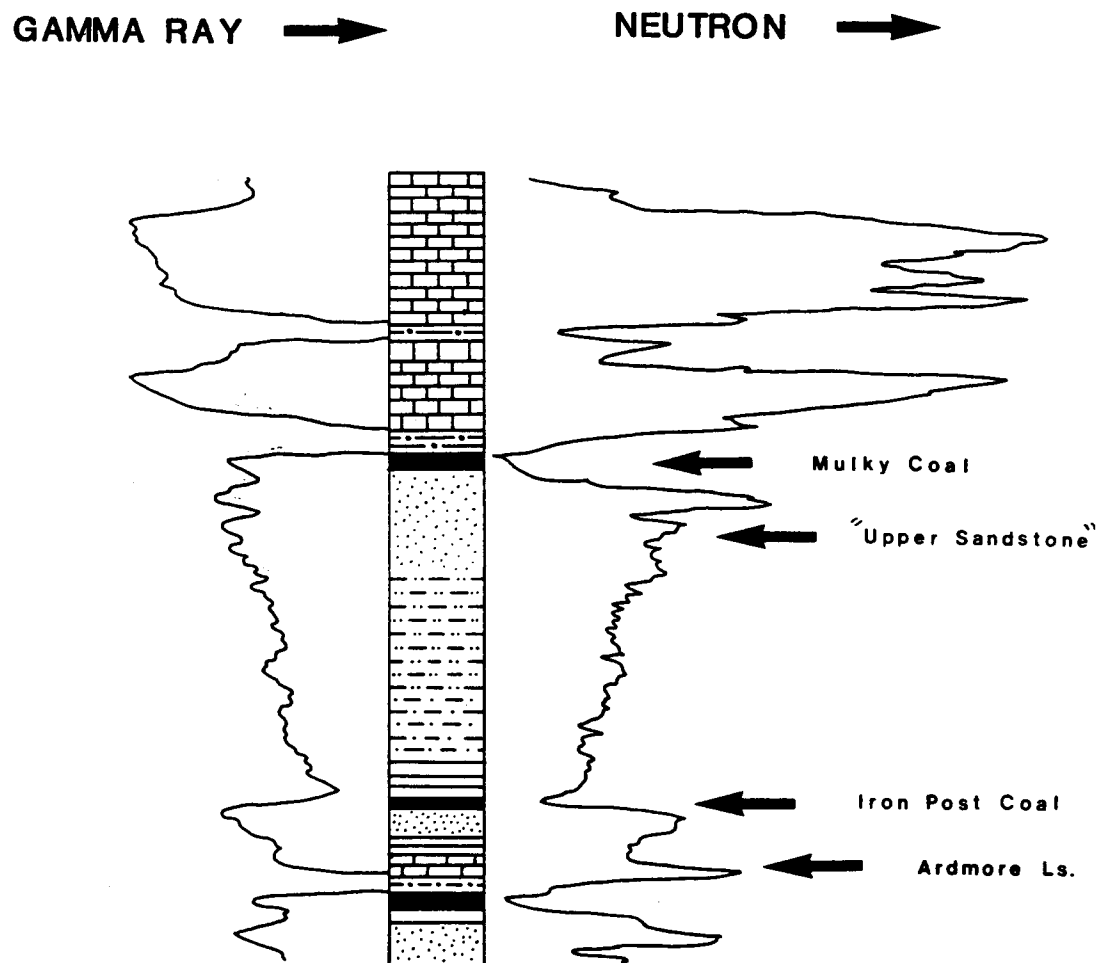


Figure 25. Gamma-ray neutron well log and corresponding lithologies from the "upper sandstone" in the Greenwood-Elk county area. The Mulky Member comprises a progression of shale, siltstone, and sandstone. The "middle sandstone zone" is not developed in this well.

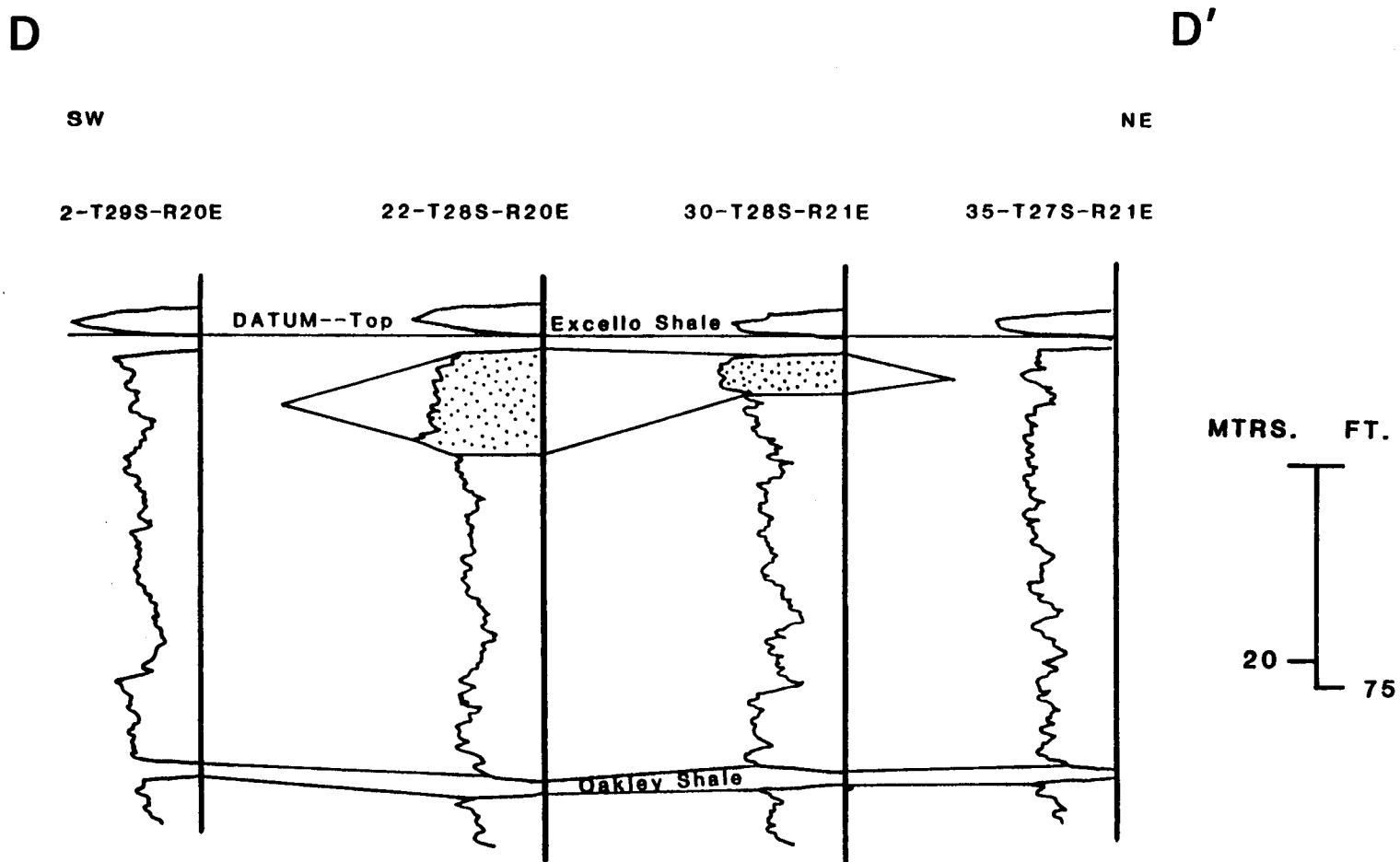


Figure 26. Cross-section D-D', which is oriented perpendicular to the outline of "upper sandstone" in the northeast part of the study area. The sandstones appear to show sharp basal and gradational upper contacts, and are upward-fining. See figure 2 for location.

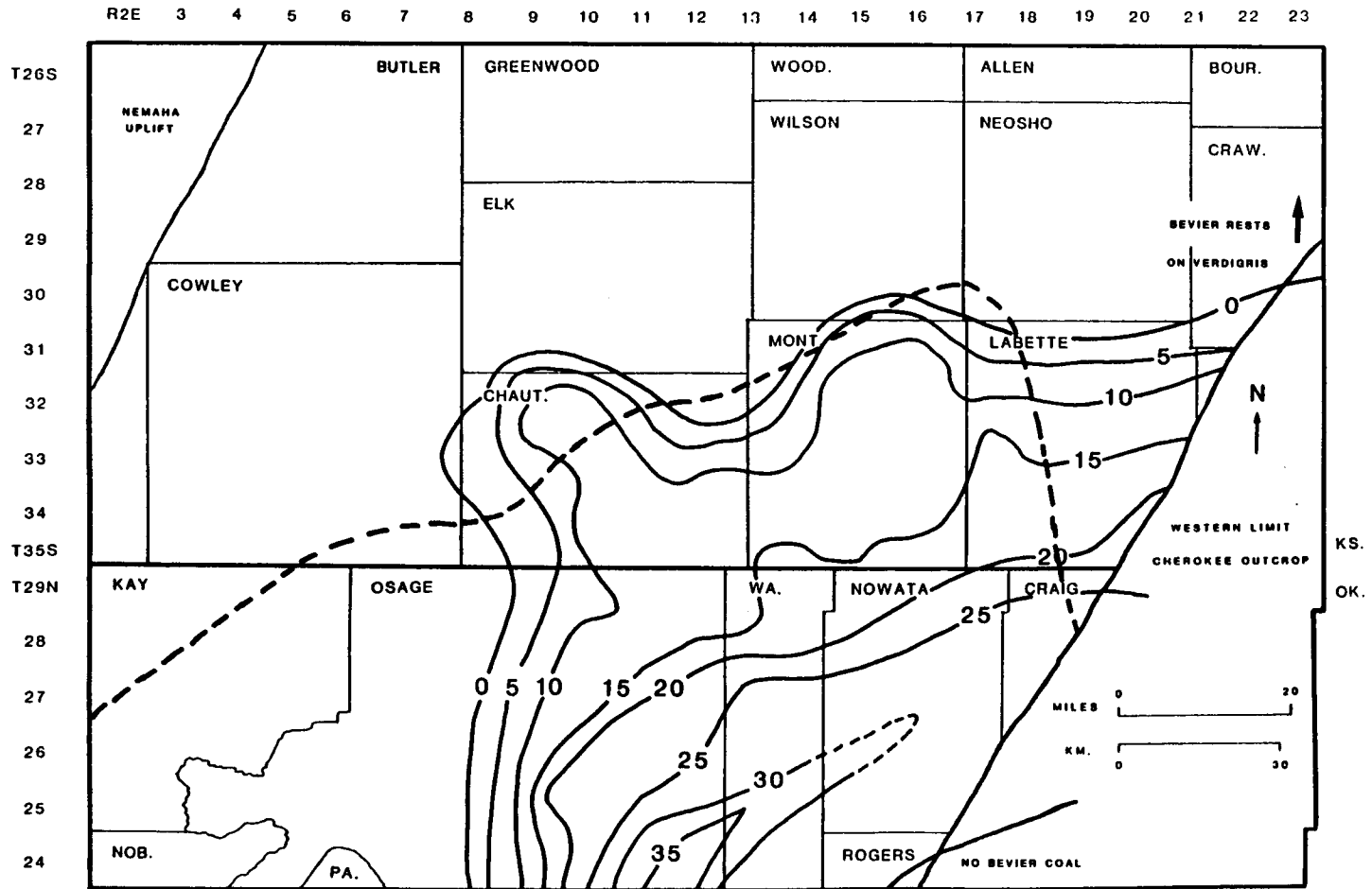


Figure 27. Isopach map of the Bevier Member. Domain 1-2 border is outlined by the dashed line. Contour interval = 5 feet.

Conspicuous within the Bevier Member are highly lenticular and laterally discontinuous sandstones. The gamma-ray signatures of these sandstones are characterized by sharp, convex-downward basal contacts as indicated by sharp gamma-ray deflections, and show gradational, fining-upward upper contacts, forming a bell-shaped curve (Figure 28). These sandstones range in thickness from 10 to 88 feet (3.0 to 26.8 meters). Three northeast-southwest-oriented sandstone bodies cross Nowata, Washington, and extreme eastern Osage counties, Oklahoma (Figure 29). The longest sandstone body crosses northern Washington County, and is at least 41 miles (68.3 kilometers) long.

In areas laterally adjacent to these sandstone bodies the Bevier Member comprises shale, siltstone, and thin sandstones. The sandstones are generally less than 6 feet (1.8 meters) thick, and generally show abrupt basal contacts. The Bevier Coal often caps these sandstones. As many as three sandstones, separated by siltstone, are present. With increasing lateral distance from sandstone bodies the Bevier Member thins, and becomes dominated by shale and siltstone, often found interbedded (Figure 30). Thin (under 2 feet) sandstones are rarely found within shale-siltstone-dominated areas.

Lagonda Member

The Lagonda Member is thickest along a

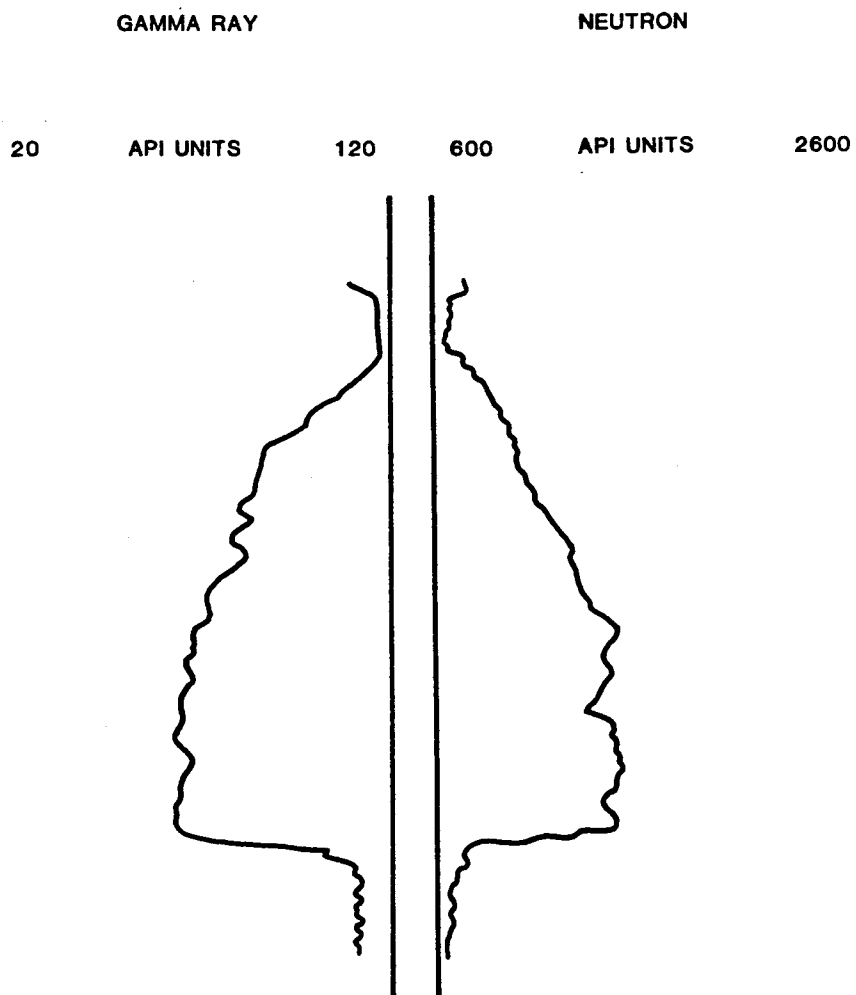


Figure 28. Characteristic gamma-ray well log signature of a channel sandstone (modified from Selley, 1978).

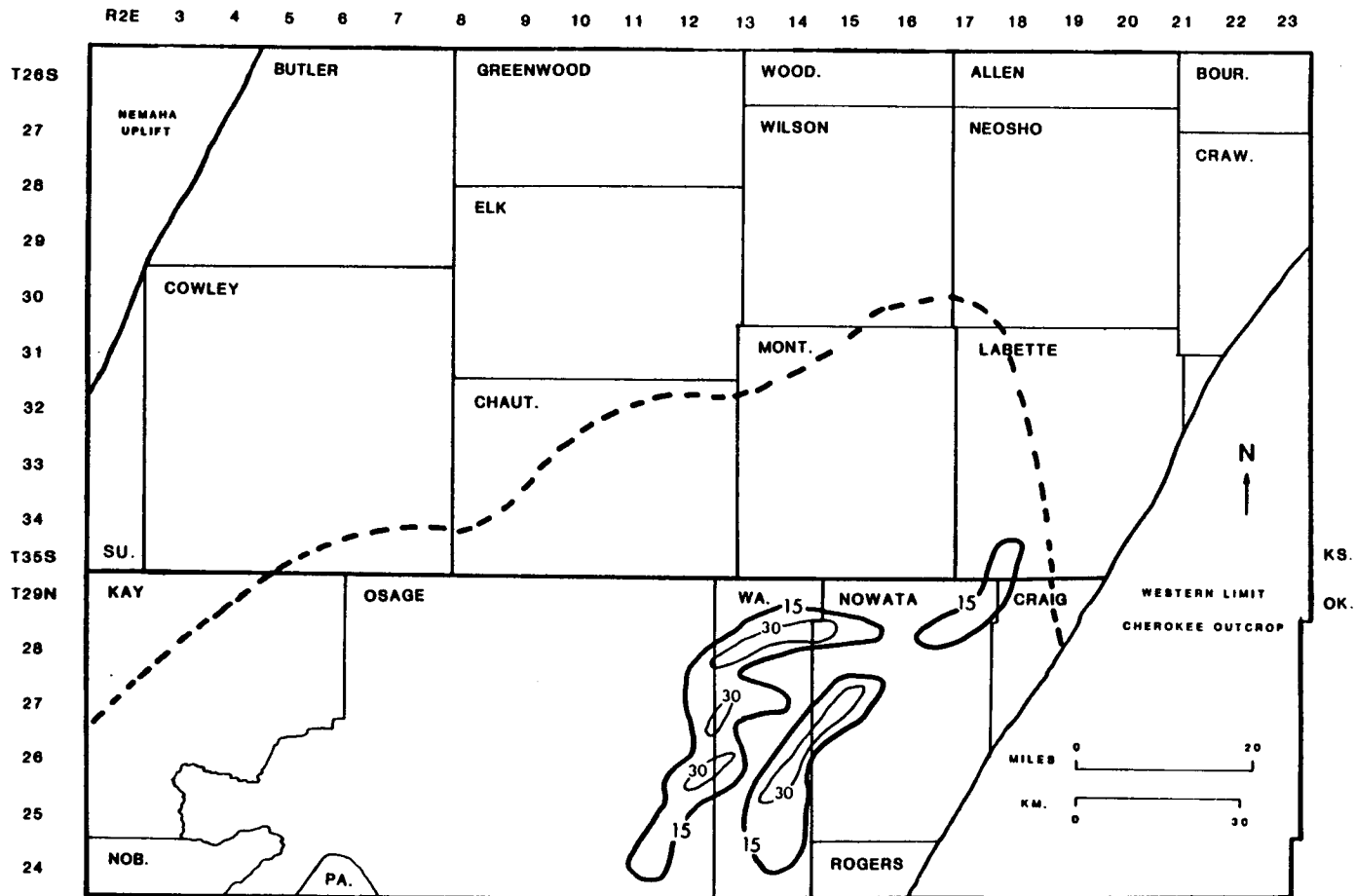


Figure 29. Sandstone isolith map that shows the thickest accumulations of sandstone within the Bevier Member. Domain 1-2 border is outlined by the dashed line. Contour interval = 15 feet.

E

E'

NW

SE

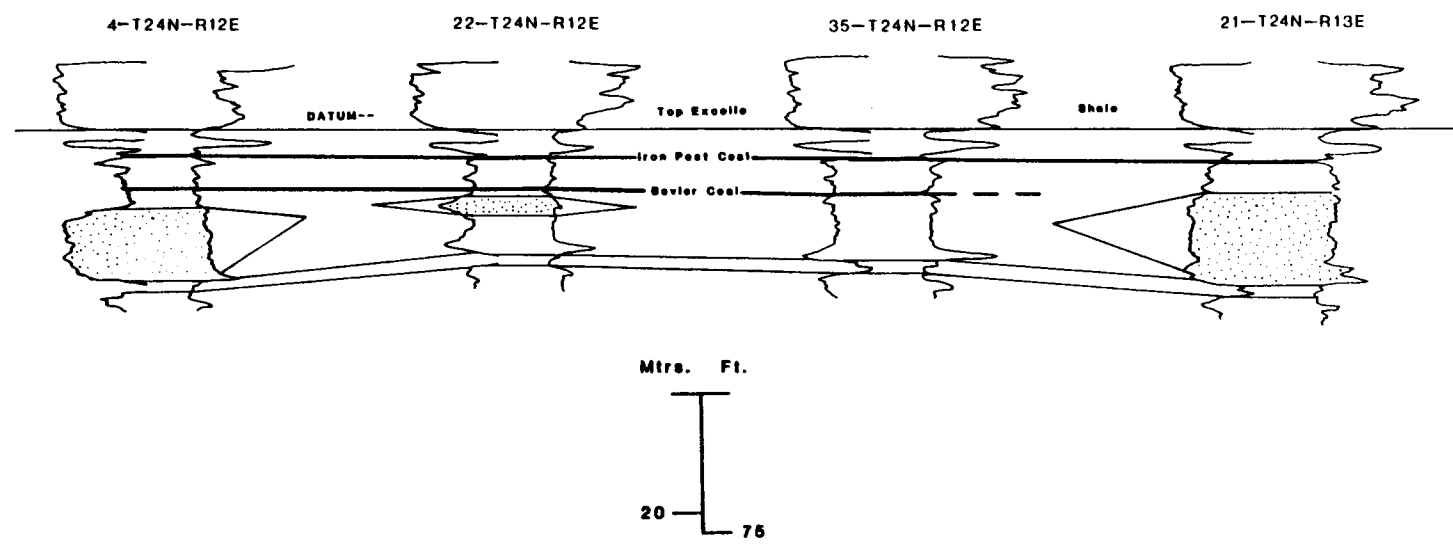


Figure 30. Cross-section E-E' shows the characteristics of regions between the thick sandstones. The Bevier Member thins, and becomes dominated by shale, siltstone, and thin sandstones with gradational basal contacts. See figure 2 for location.

northeast-southwest-trending zone between southern Labette County and the southern boundary of the study area in eastern Osage County (Figure 31). The maximum thickness of these sediments is 137 feet (41.8 meters) in section 3, T. 25 N., R. 9 E., Osage County, Oklahoma.

The gamma-ray log characteristics of the sediments within the Lagonda Member closely resemble those comprising the Bevier Member. Sandstones of up to 120 feet (36.6 meters) in thickness occur to the northwest of the belt of sandstones within the Bevier Member (Figures 32 and 33). Both the Ardmore Limestone and Oakley Shale are often absent below Bevier and Lagonda Member sandstones (Figure 34).

Lagonda sections with significant amounts of sandstone are slightly thicker than shale-dominated sections (Figure 35). This may be a result of the higher volume reduction that occurs within shales than within sandstone during compaction.

Interbedded thin sandstones with sharp basal contacts, siltstone, and shale are found in wells directly adjacent to these thick sandstones. The frequency of stacked sandstones separated by thin shale decreases with increasing lateral distance from the thicker sandstones.

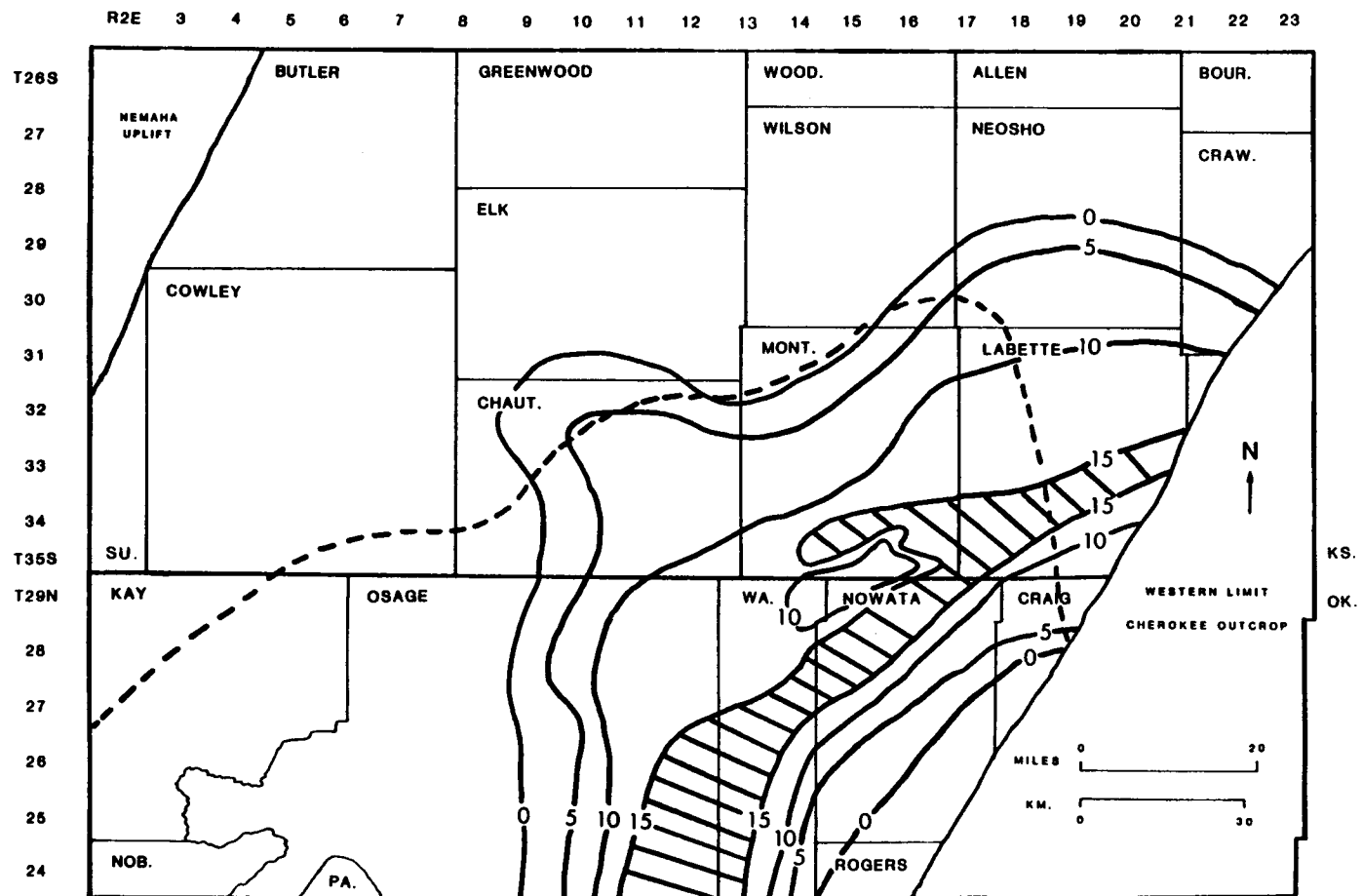


Figure 31. Isopach map of the Lagonda Member. The 0 foot contour outlines the area where the Bevier Coal is absent, while the thickest area (greater than 15 feet) is obliquely lined. (Contour interval = 5 feet).

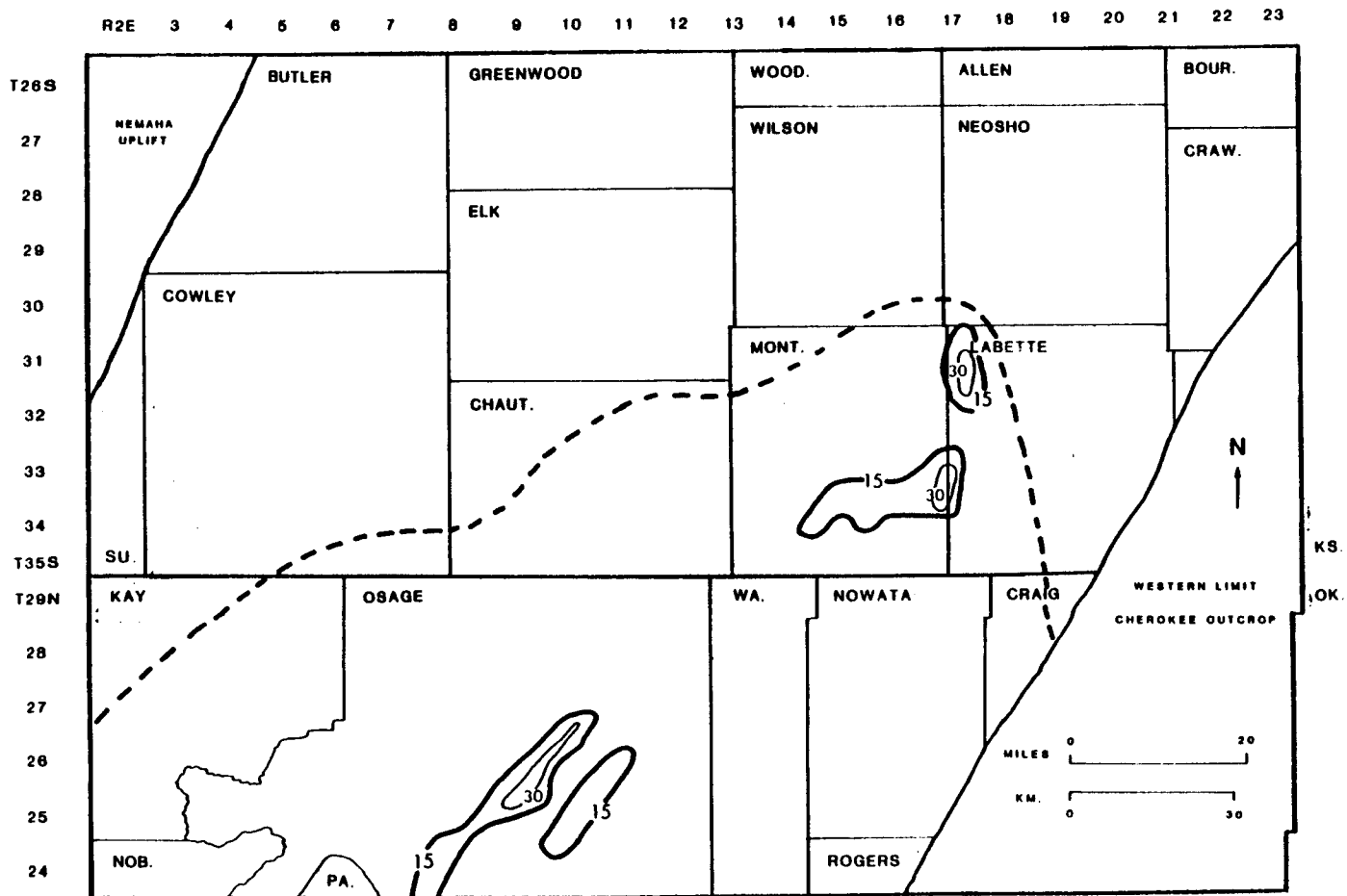


Figure 32. Sandstone isolith map that shows the thickest accumulations of sandstone within the Lagonda Member. Sandstones within this member lie to the northwest of those within the Bevier Member. (Contour interval = 15 feet).

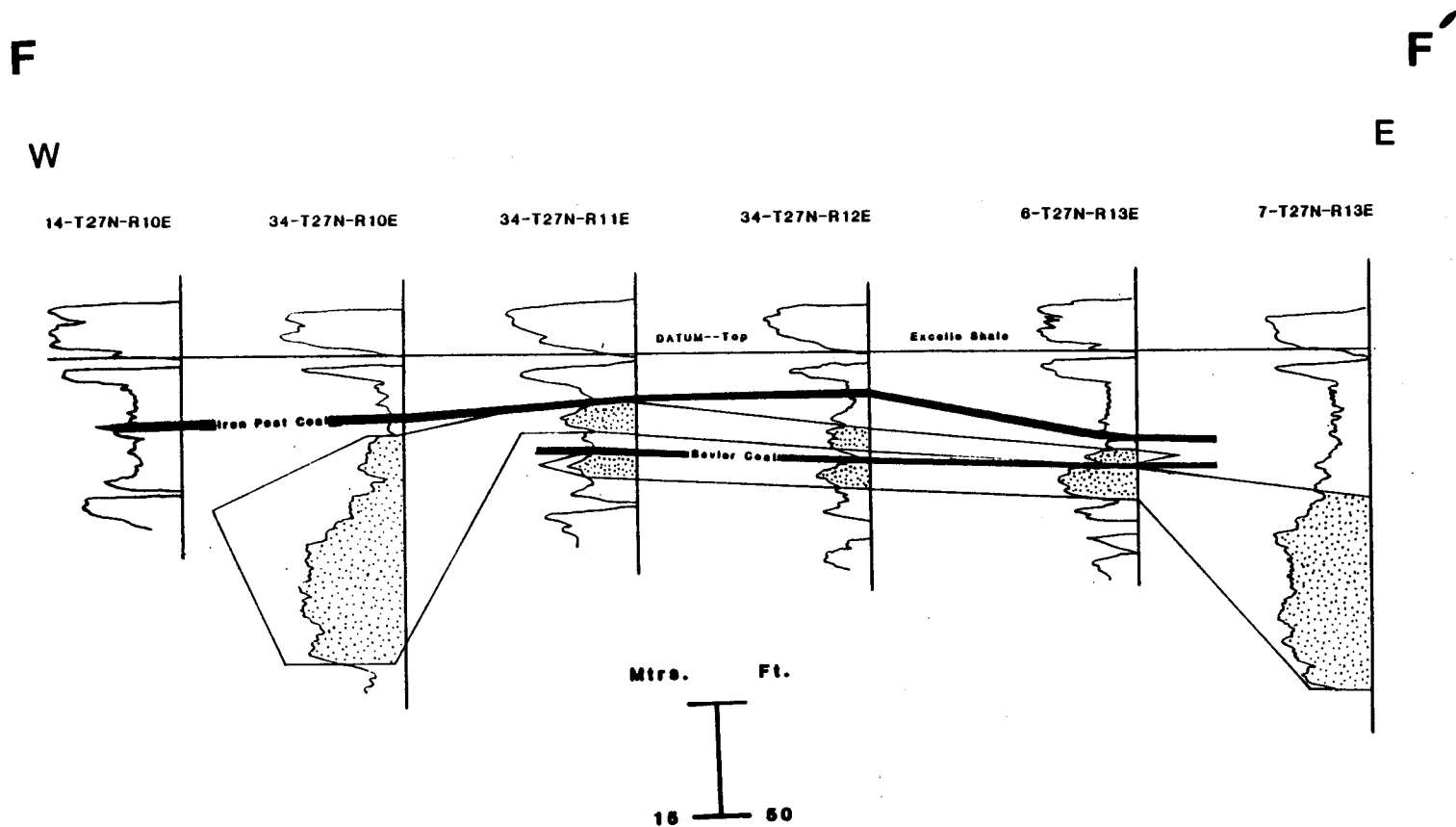


Figure 33. Cross-section F-F' shows the relationships of sandstones within both the Bevier and Lagonda members. Thicker sandstones are characterized by sharp basal contacts and gradational, upward-fining (higher gamma-ray count) upper contacts. See figure 2 for location.

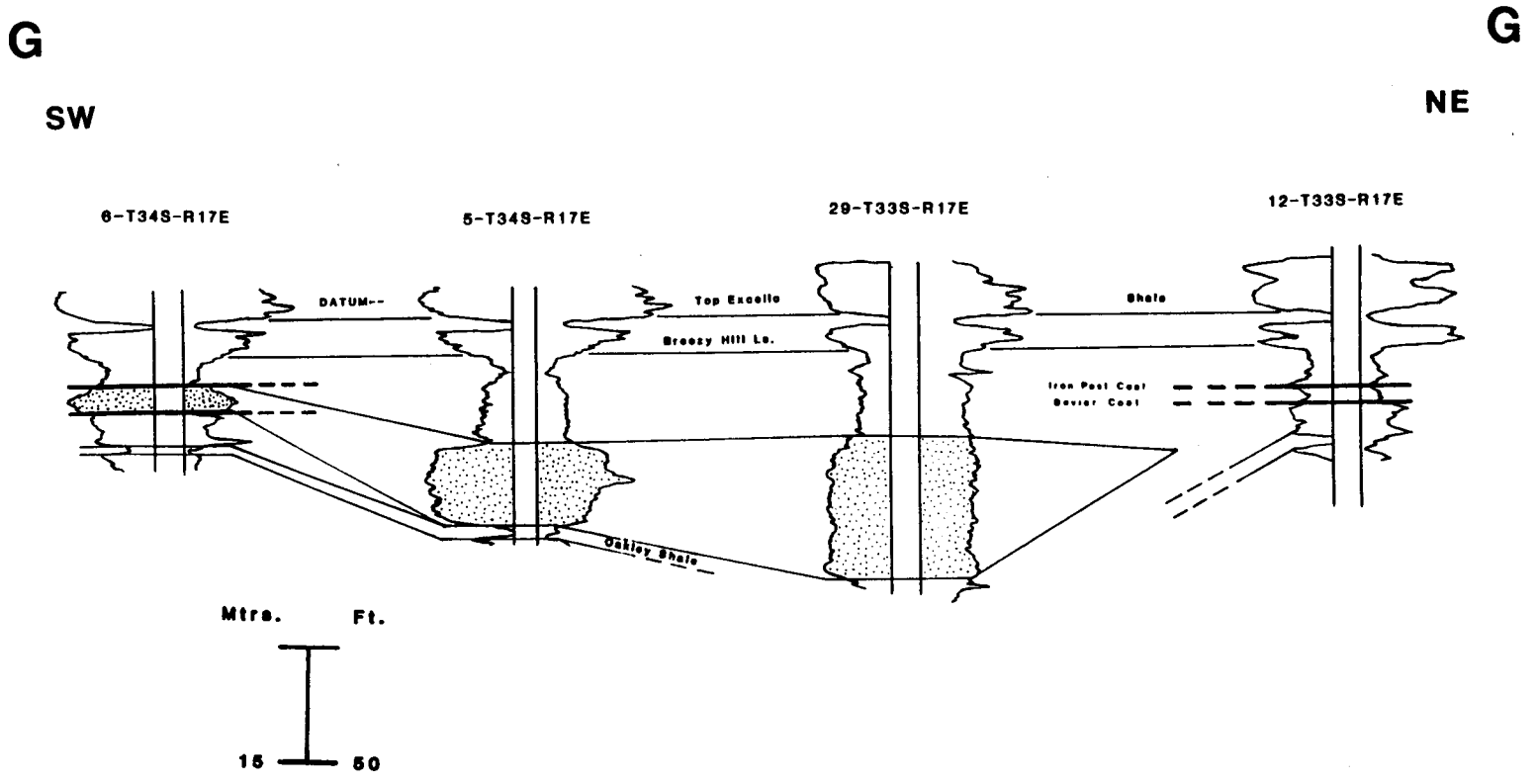


Figure 34. Cross-section G-G'. In the second well log from right, notice that the Oakley Shale and overlying Ardmore Limestone have been cut out by the sandstone channel form. See figure 2 for location.

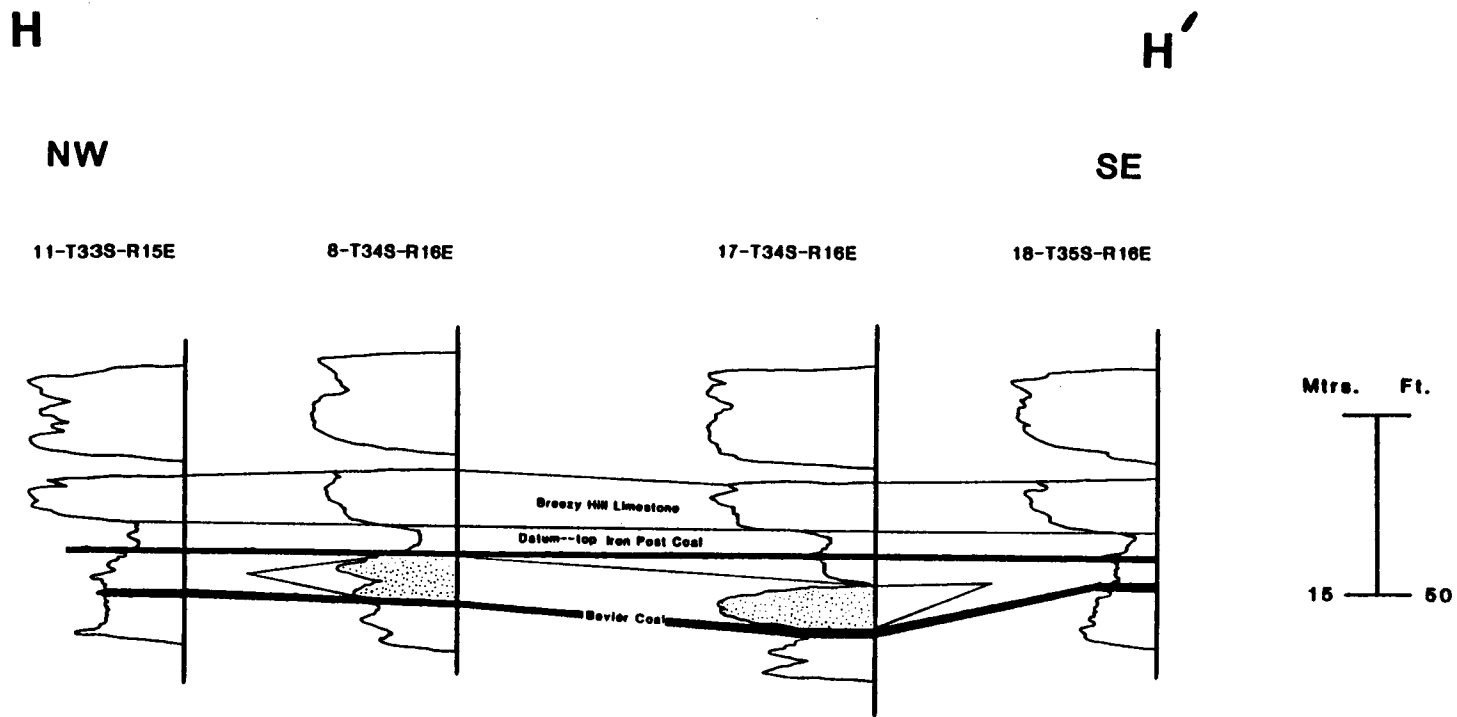


Figure 35. Cross-section H-H'. Notice that the central two wells have slightly thicker Lagonda Member sections than the two outer wells. This has resulted most likely from the greater volume reduction of pore space within shales than within sandstones. See figure 2 for location.

Mulky Member

Kinnison Shale

Within domain 2 the Kinnison Shale is composed primarily of shale and thin siltstone beds. As noted earlier, the Kinnison is thinner within domain 2, where it is less than 10 feet (3 meters) except in the extreme southwest part of the study area in Kay and Noble counties, Oklahoma, and along a narrow belt between western Labette County, Kansas and the southern border of the study area in Pawnee County, Oklahoma. In these areas the Kinnison varies in thickness from 11 to 24 feet (3.4 to 7.3 meters) (Figure 20). The thickening of Kinnison Shale in areas between Labette and Pawnee counties roughly coincides with the geographic relation of the thick lenticular sandstones within the Lagonda Member (Figure 32).

Breezy Hill Limestone

The Breezy Hill is thickest in a small area within southern Montgomery and eastern Chautauqua counties, Kansas, and northwest Nowata and northern Osage and Washington counties, Oklahoma, where its average thickness is 13 feet (4 meters), (Figure 36). This limestone reaches its maximum thickness of 18 feet (5.5 meters) in section 25, T. 34 S., R. 14 E., Montgomery County.

The thickness of the Breezy Hill decreases from domain

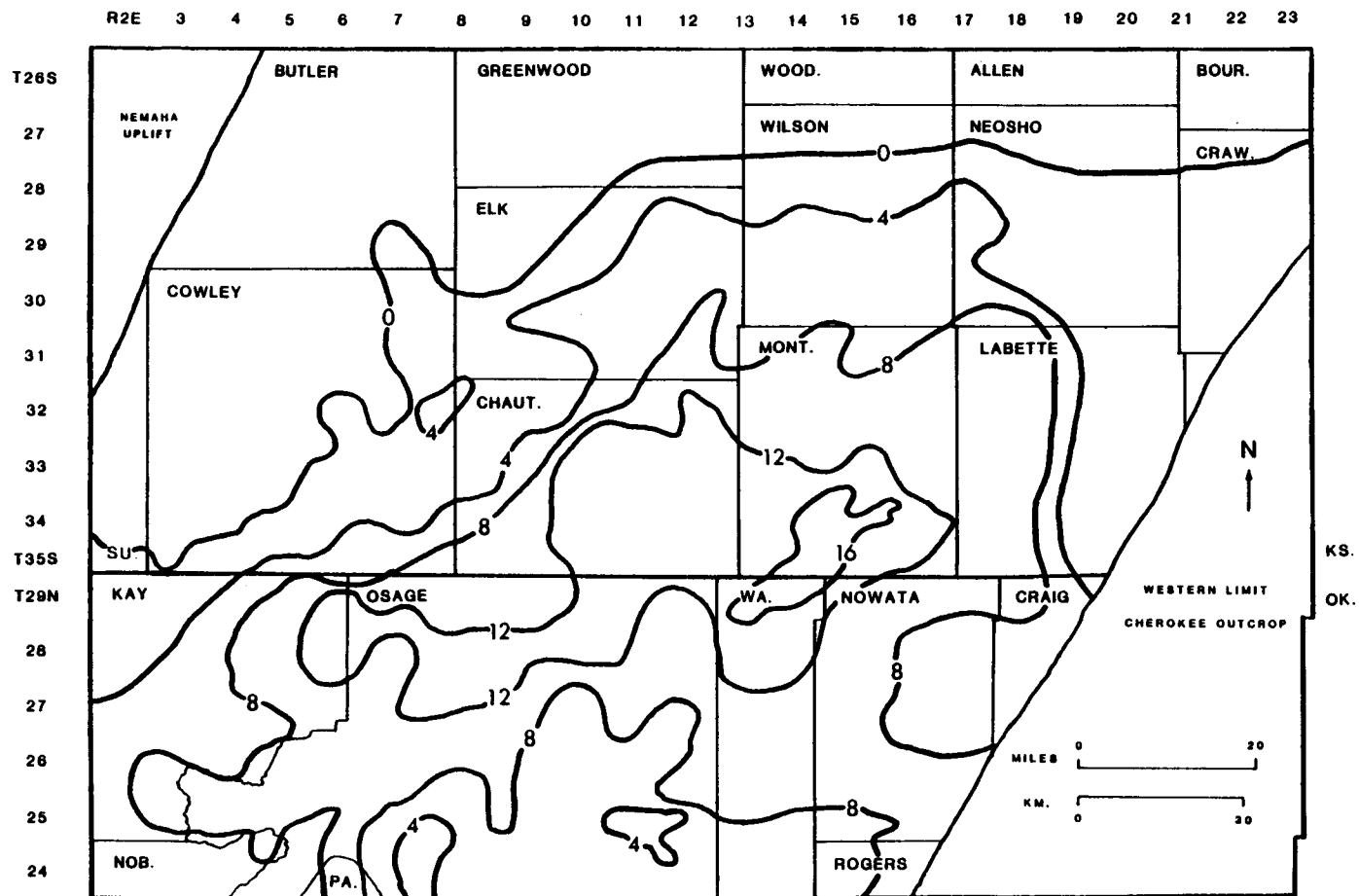


Figure 36. Isopach map of the Breezy Hill Limestone. The 8 foot contour line roughly outlines the domain 1-2 border. (Contour interval = 4 feet).

2 to domain 1. It was found that the limestone is thickest in wells where the Kinnison Shale is relatively thin. Within cross-section B-B' (Figure 21) the domain 1-2 border occurs at a point between the two central wells. The two wells within domain 2 are characterized by thick Breezy Hill (14 feet) and thin Kinnison Shale (8-12 feet) sections, while within the two domain 1 wells to the east, the Breezy Hill is much thinner (2 to 3 feet) and the Kinnison is much thicker (80 feet).

In some wells the gamma-ray curve drifts slightly lower (to the right) about 2 feet (0.6 meters) below the top of the Breezy Hill Limestone (westernmost well, Figure 34). This suggests the presence of a silty zone. Similar silty zones were noted in surface Breezy Hill sections in Rogers and Craig counties, Oklahoma, by Tillman (1952) and Lohman (1952). Tillman found a 1 foot (0.3 meter) shale bed introduced in the same position of a 9 foot (2.7 meter) section of Breezy Hill in section 18, T. 20 N., R. 15 E., Rogers County.

SANDSTONE PETROGRAPHY

The percentages of detrital and authigenic components are based on modal analyses of 9 thin sections from various Banzet sandstones (Table 1). Petrographic analyses in this study are restricted to sub-Iron Post sandstones in order to complement the work of Reinholtz (1982) and Lardner (1984) who studied sandstones that apparently overlie the Iron Post Coal¹. No subsurface samples were available, so only outcropping sandstones were examined.

Detrital Minerals

Monocrystalline Quartz

Monocrystalline quartz is the most abundant detrital grain type in sub-Iron Post sandstones, composing between 48 and 58 percent of the bulk rock. Most monocrystalline quartz grains exhibit slight undulose extinction (1 to 10 degrees rotation of stage). The sizes of individual grains range from very-fine-grained (0.05 mm diameter) to medium-grained (0.3 mm diameter) sand. Very-fine-grained quartz sand grains are generally angular to subrounded with

¹In their studies Reinholtz and Lardner appear to have mistaken the Iron Post Coal for the Bevier Coal.

	<u>SANDSTONE TYPE "A"</u>	<u>SANDSTONE TYPE "B"</u>	<u>SANDSTONE TYPE "A"</u>	<u>SANDSTONE TYPE "B"</u>
	(% of Detrital and Authigenic)		(% of Detrital)	
<u>DETRITAL</u>				
Quartz			83.5	78.9
Monocrystalline	54.0	50.7		
Polycrystalline	0.5	0.9		
Feldspar			15.2	17.6
Orthoclase	8.7	10.1		
Plagioclase	1.2	1.4		
Rock Fragments			1.2	3.4
Granitic rock frags	0.6	0.6		
Chert	0.2	1.6		
Mica				
Muscovite	2.7	4.0		
Biotite	0.1	0.0		
Matrix	3.6	0.0		
Glauconite	0.2	0.0		
Heavy Minerals	0.1	0.0		
<u>AUTHIGENIC</u>				
Carbonate Cement	11.6	0.0		
Clays	3.4	3.2		
Silica Cement	3.5	4.2		
Pyrite	2.3	2.1		
Iron Oxide	2.1	7.2		
<u>OTHER</u>				
Pore Space	5.2	13.9		

Table 1. Modal percentages of detrital and authigenic components of various type A and B sandstones. Percentages are based on 225 point counts of 9 samples. Individual point counts are located in Appendix B.

low sphericity, while fine to medium-grained quartz sand grains are subangular to subrounded with moderate to high sphericity. Grain shape and roundness is difficult to determine due to interlocking quartz overgrowths around many grains, except where early clay rims are present between the detrital grains and overgrowths.

Polycrystalline Quartz

Polycrystalline quartz grains are minor detrital constituents of these sandstones. These grains were identified as irregularly-sutured anhedral quartz crystals that display straight grain outlines. Mica commonly occurs as inclusions. Individual quartz crystals within these grains exhibit moderate undulose extinction (8 to 13 degrees rotation of stage). Polycrystalline quartz grains are subrounded to subangular, and range in size from 0.1 to 0.2 mm in diameter.

Potassium Feldspar

Orthoclase is the most abundant feldspar in sub-Iron Post sandstones, constituting from 5.8 to 12.9 percent of the bulk rock. It is present in nearly equal amounts in both type A and type B sandstones (Table 1). Orthoclase was identified on the basis of optical properties, including the presence of cleavage and Carlsbad twinning. Most orthoclase grains are very-fine to medium-grained

sand-sized grains, ranging from 0.1 to 0.2 mm in diameter, and are subangular to subrounded. Most grains are highly sericitized, often leaving clay-rich zones within orthoclase "ghosts".

Plagioclase Feldspar

Plagioclase feldspar is a minor constituent of type A and B sandstones, making up less than 2 percent of the bulk rock (Table 1). Plagioclase grains were identified on the basis of albite twinning. Measurements of the maximum extinction angles between adjacent twinned laminae (Michael-Levy Method) vary between 16 and 22 degrees, indicating that the plagioclase grains are of albite composition. Grains range in size from very-fine to fine-grained sand, and are subangular to subrounded with moderate sphericity.

Unlike orthoclase grains, plagioclase feldspar grains show little alteration due to weathering.

Rock Fragments

Rock fragments within sub-Iron Post sandstones include quartz-mica fragments and chert. Quartz-mica fragments are composed of foliated mica crystals found within elongate quartz grains. Size ranges for these grains are similar to those of monocrystalline quartz detritus.

Detrital chert is found in small quantities in these

sandstones. Grains are subangular to subrounded and range in size from 0.05 to 0.2 mm in diameter.

Muscovite

Muscovite is a persistent accessory mineral, ranging from 1.3 to 5.3 percent of the bulk rock. It occurs as colorless laths that range in size up to 0.77 mm in maximum dimension. Grains are usually found aligned roughly parallel to stratification. In well-packed sandstones muscovite grains are often bent around large, resistant detrital grains due to compaction before grain cementation.

Biotite

Biotite occurs as reddish-brown laths up to 0.2 mm in length that display strong pleochroism. It is found in trace quantities in sub-Iron Post sandstones. Iron oxide is often plentiful near biotite grains, indicating that it is a possible alteration product of biotite.

Glauconite

Glauconite is found in trace amounts in these sandstones. Because it is less resistant, glauconite grains are often found deformed between other detritus.

Heavy Minerals

Zircon, sphene, and tourmaline are present in trace

amounts. Grains are generally subrounded, and range in size from 0.05 to 0.15 mm.

Authigenic Minerals

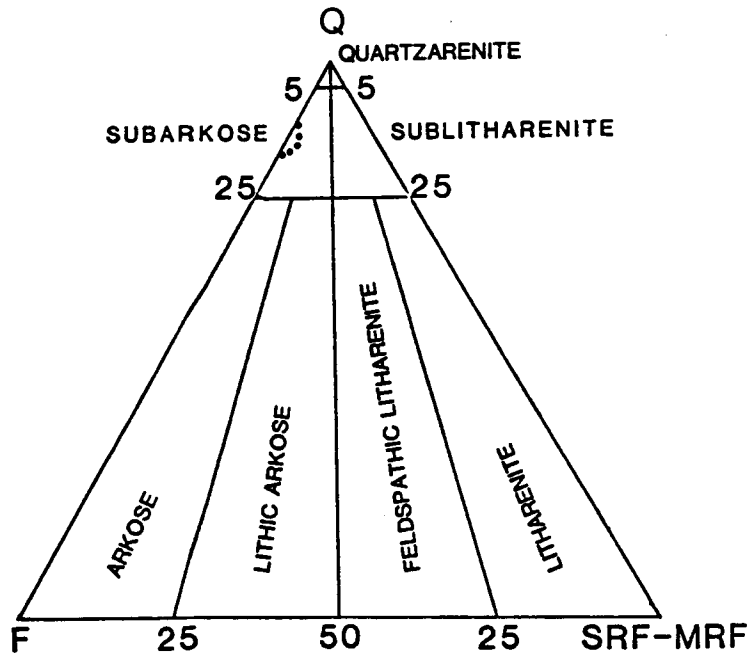
A variety of authigenic minerals have formed within sub-Iron Post sandstones. These include calcite, clays (kaolinite and sericite), silica cement, pyrite, and iron oxide. The characteristics of these minerals will not be discussed because their presence has little bearing on the objectives of this study.

Petrographic Distinction Between Type A and Type B Sandstones

Types A and B sandstones are texturally and compositionally dissimilar. Although both sandstones contain similar amounts of quartz and feldspar (Table 1), type A shows considerable amounts of clay matrix (up to 5.3 percent), calcite cement, and trace amounts of glauconite. Cements also include lesser amounts of kaolinite and quartz overgrowths.

Compositionally type A sandstones plot as subarkoses (Figure 37). Detrital grains are moderately-well packed, moderately-well sorted, mostly fine-grained, and show mainly point and long contacts with other detritus. Porosity is significant in clay and quartz-cemented sandstones (up to 13.3 percent) but is nonexistent in

TYPE A



TYPE B

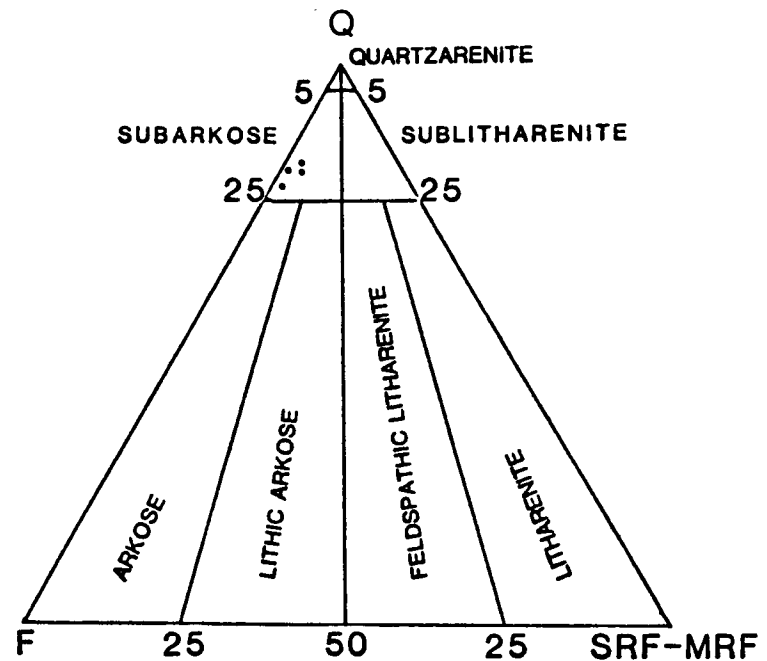


Figure 37. Classification of types A and B sandstones using Folk's (1974) classification scheme. Quartz field includes monocrystalline and polycrystalline quartz. Rock fragments include quartz-mica fragments and chert. Potassium and plagioclase feldspar were included in the feldspar field.

calcite-cemented samples.

Conversely, type B sandstones show a slightly higher percentage of muscovite, grains of which are aligned roughly parallel to stratification. Iron oxide is much more abundant in type B samples, and is concentrated near pore spaces. Authigenic cements include kaolinite and quartz overgrowths. Pyrite is locally abundant, often occurring near areas of high clay content and pore spaces.

Compositionally, type B sandstones also are classified as subarkoses. Samples are moderately-sorted, medium-grained, and show mostly concavo-convex and long contacts. Significant amounts of porosity (up to 16.9 percent) were found in all samples.

Provenance of Siliciclastic Material

It has been suggested that the sandstones of the Banzet Formation as well as older sandstones had a northern source, while Arkoma Basin siliciclastics of later Desmoinesian age came from the south and southeast (Dogan, 1970; Krumme, 1981). Many authors have proposed the Canadian Shield as a likely source of Cherokee sandstones. Wanless (in Krumme, 1981) stated that upper Cherokee sandstones of the Cherokee Shelf contain more angular detritus and more mica than the lower Cherokee sandstones, indicating that by the middle of the Pennsylvanian time, the sedimentary cover of part of the cratonic source area

had been removed and the underlying schists and phyllites became greater contributors to the sediments.

This is, in part, substantiated by the composition of Banzet sandstones in southeastern Kansas and northeastern Oklahoma. Core samples of sandstones that stratigraphically overlie the Iron Post Coal (studied by Reinholtz (1982) and Lardner (1984)) appear relatively similar in composition to sub-Iron Post sandstones examined in this report. All sandstones plot as subarkoses on Folk's classification scheme, and contain substantial quantities of undulose quartz, feldspar, and mica. Foliated quartz-mica fragments suggest a metamorphic source for a portion of the sediments.

Examinations of the provenance of both the Nemaha Uplift and the Ozark Uplift eliminate them as major sediment contributors to sub-Iron Post sandstones. Pennsylvanian rocks lap up onto Mississippian and older sedimentary rocks over most of the Nemaha Uplift (Merriam, 1963), while Mississippian cherty limestones are currently exposed over much of the Ozark Uplift (Branson and Huffman, 1965). It appears that the only crystalline rocks that were exposed on the Nemaha Uplift in Kansas during the Pennsylvanian occur in the western half of Nemaha County, Kansas, which is located along the Kansas-Nebraska border (Merriam, 1963), while the only crystalline rocks currently exposed on the Ozark Uplift occur in a 1200 square mile (3072 square kilometer) area within the St Francois

Mountains of southeastern Missouri (Kisvarsanyi, 1976). It appears that during the Pennsylvanian the two uplifts could not have shed the large amounts of feldspar and mica that are found in these sandstones. Also, larger amounts of chert would be expected if these two areas were significant contributors of sediment.

DEPOSITIONAL ENVIRONMENTS

Interpretations of the depositional environments of the Banzet Formation were based on lithologic interpretation of well-log signatures and the study of the sedimentary textures and structures and the vertical variability of outcropping Banzet strata.

Numerous authors have proposed that the thick sandstones and associated siliciclastics within the Ardmore Limestone-Excello Shale interval in southeastern Kansas and northeastern Oklahoma resulted from the southward progradation of delta systems upon the Cherokee Shelf. As cores and cuttings were not available, conclusions are based on the comparison of well-log signatures from wells within the study area to signatures of logs that are characteristic of known depositional facies within a deltaic complex.

Depositional Environments of Lithologic Entities

Ardmore Limestone

The presence of brachiopods, echinoderms, bryozoans, corals, and crinoid remains identifies the Ardmore Limestone as a marine deposit (Schell, 1955). The Ardmore is present throughout the study area, so during its

deposition marine waters prevailed over the Cherokee Shelf.

The lower part of the Ardmore is often more fossiliferous and more calcareous than the upper part, indicating that the water in which the Ardmore was deposited became increasingly more turbid as deposition progressed (Schell, 1955).

Bevier Member

Evaluation of available data suggests that the sediments within the Bevier Member were deposited on the delta plain of a southward-prograding delta (Figure 38). Two groups of deposits associated with the delta plain facies have been interpreted in the study area. These are 1) abandoned distributary channel deposits, and 2) overbank and bay-fill deposits.

Thick sandstones are relatively narrow and elongate, and laterally discontinuous (Figure 29). Characteristic are abrupt basal contacts (sharp gamma-ray deflections at their bases) and upward increases in gamma radiation, indicating increased clay content. Within known deltaic complexes, this type of signature is indicative of a high-energy channel environment (Selley, 1978). Channel sandstones are generally cleanest at the base (low gamma counts) where fine particles do not settle because of turbulence. It appears that these distributary channels were erosive, because, in some wells, the Verdigris

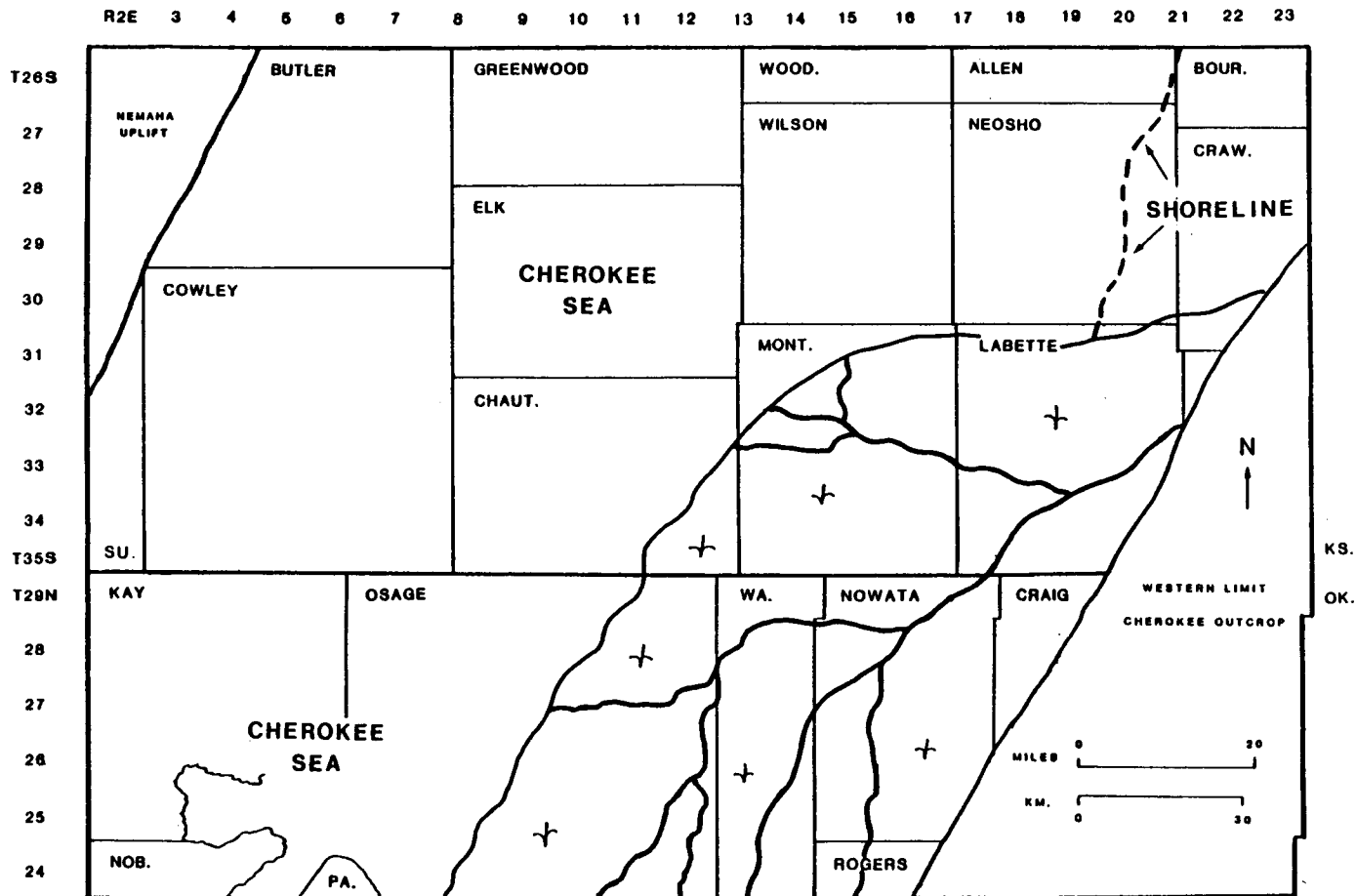


Figure 38. Paleogeographic reconstruction of the Bevier Member, illustrating initial deltaic progradation into the study area from the northeast.

Limestone and Oakley Shale are missing below thick channel sandstones. Thick sandstones that crop out south of the southernmost exposures of Bevier Coal in Rogers and Wagoner counties, Oklahoma, are characterized by southwest-southeast-trending cross-strata and irregular, erosional basal contacts, which are common attributes of channel sandstones (see sections 7 and 9, Appendix A).

Within interdistributary areas, log patterns and outcrops suggest interbedded shale, siltstone, and upward-coarsening sandstone. This lithic sequence comprises the largest percentage of the area within this delta. Stacked sandstone and shale sequences are found directly adjacent to channels, with the frequency of repeated sandstones and shales decreasing with increasing distance from the channel. Selley (1978) interprets this type of sequence within a deltaic setting as indicative of overbank and interdistributary bay-fill facies. The stacked upward-coarsening sandstones and intervening siltstone and shale may represent crevasse splays that have breached levees along main distributaries and have infilled the numerous interdistributary bays within the delta plain. Coleman and Prior (1982) state that although deposits resulting from a single crevasse splay are generally thin, subsidence and the repetition of subsequent crevasse splays may result in stacking of one bay fill after another, eventually building a thick sequence of delta-plain

deposits.

The presence of other deposits associated with the delta plain facies, such as natural levees, floodplains, and tidal channels could not be inferred from well log signatures, because identification of these is dependent upon the examination of sedimentary textures and structures.

The Bevier Coal most likely formed within lowland marshes and swamps that were subsequently inundated by marine deposits during abandonment and continuing subsidence of the delta lobe.

Lagonda Member

Well-log signatures of the sediments within the Lagonda Member are similar to those that compose the underlying Bevier Member. It appears that a second delta extended southward across the eastern part of the study area (Figure 39). Thick, lenticular sandstones are found to the north and northwest of those within the Bevier Member (compare figures 29 and 32). It appears that the area of Bevier Member channel development was a slight positive area during progradation of the second delta lobe, thus diverting the later distributary channels to topographically lower areas to the northwest. Gamma-ray well-log signatures of interdistributary areas also exhibit the same stacked shale, siltstone, and upward-coarsening sandstones that are prevalent in the Bevier Member deltaic

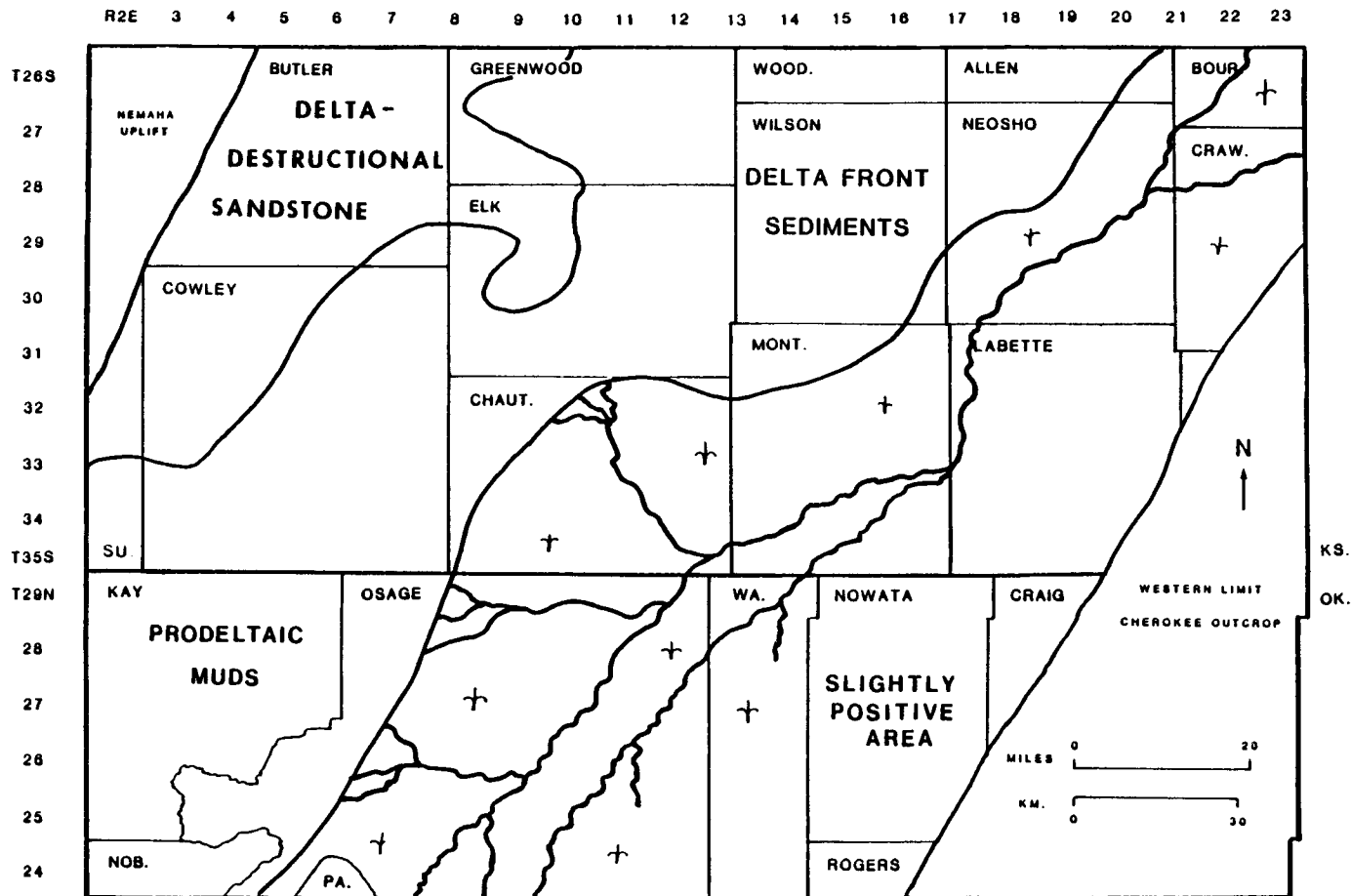


Figure 39. Paleogeographic reconstruction of sedimentation within the Lagonda Member. A second delta lobe has prograded into the eastern half of the study area, with distributary channel development to the north and northwest of earlier channels.

advance. Thus, it appears that crevasse splay deposition was widespread in the area.

Figure 27 shows that north of T. 30 S. the Bevier Coal and its underclay rest directly upon the Ardmore Limestone. However, the thickness of the Ardmore-Iron Post Coal interval is greater than 20 feet (6.1 meters) north of this township (Figure 40). Therefore, it seems that deposition of the sediments within the Ardmore-Iron Post interval north of T. 30 S. is likely related to the progradation of a second delta lobe.

Within Banzet outcrops in Kansas, a series of dark gray and black clayshales overlie the Bevier Coal. These shales are highly fossiliferous, containing mostly Desmoinesia muricatina (Howe, 1956). Unlike shales within the overlying Marmaton Group, the black shales above the Bevier do not contain phosphate nodules. However, in Oklahoma, only unfossiliferous, light to medium gray, carbonaceous shale overlies the Bevier. South of the southernmost extent of the Bevier Coal, the only outcropping Ardmore-Iron Post section that contains a black shale occurs at Lake Bixhoma, Wagoner County, located about 80 miles south of the Kansas-Oklahoma border.

Because of their limited lateral extent, lack of phosphate nodules, and presence of thin limestones above them, these black shales are interpreted as forming in a

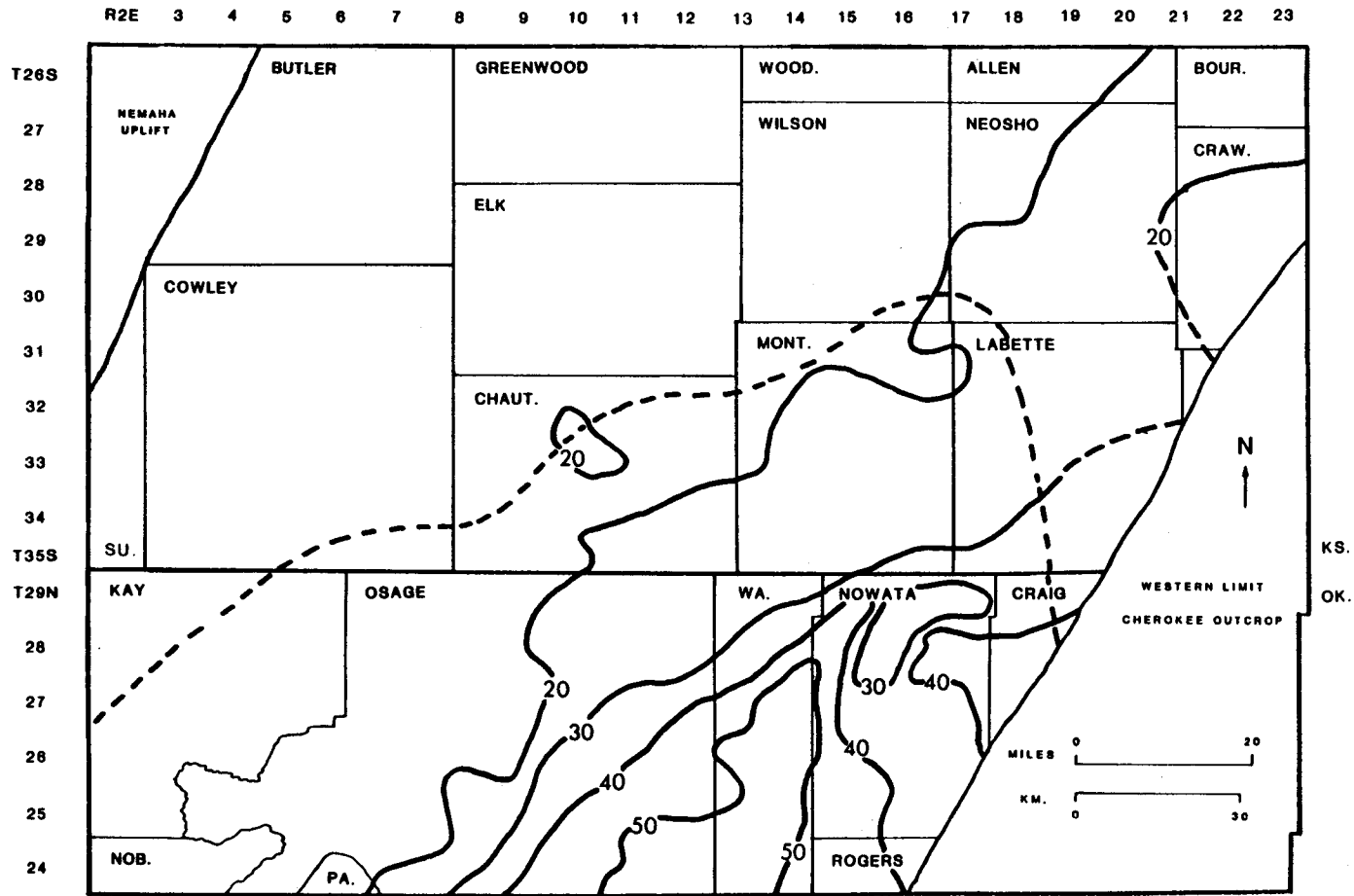


Figure 40. Isopach map of the interval between the Ardmore Limestone and the Iron Post Coal. (Contour interval = 10 feet).

quiet, nearshore environment resulting from delta subsidence. To explain the lack of black shales above the Bevier Coal in northeastern Oklahoma, Wright (1975) stated that as the sea transgressed the shelf, the water spread north of the Oklahoma portion of the Bevier Member delta lobe because the wedge of detrital sediments that underlies the Bevier Coal was thickest in Oklahoma, thus blocking the northward advance of the sea.

Delta-front clays and silts are found to the northwest of this delta lobe, apparently originating from sources to the north (Figure 39). In the extreme northwest part of the study area, the thin upward-coarsening sandstone is interpreted as a delta-destructive sandstone. This sandstone may have formed by the reworking of delta-front sediments during storms.

Mulky Member

"Middle Sandstone Zone"

After formation of Iron Post coal swamps and subsequent marine transgression, three delta lobes swept southward across parts of the northern half of the study area (Figure 41). Distributary channels and overbank and bay-fill deposits characteristic of the delta plain facies were identified. Unlike those of the two deltaic advances to the southeast, individual sandstones within the "middle sandstone zone" are much thinner and exhibit less vertical

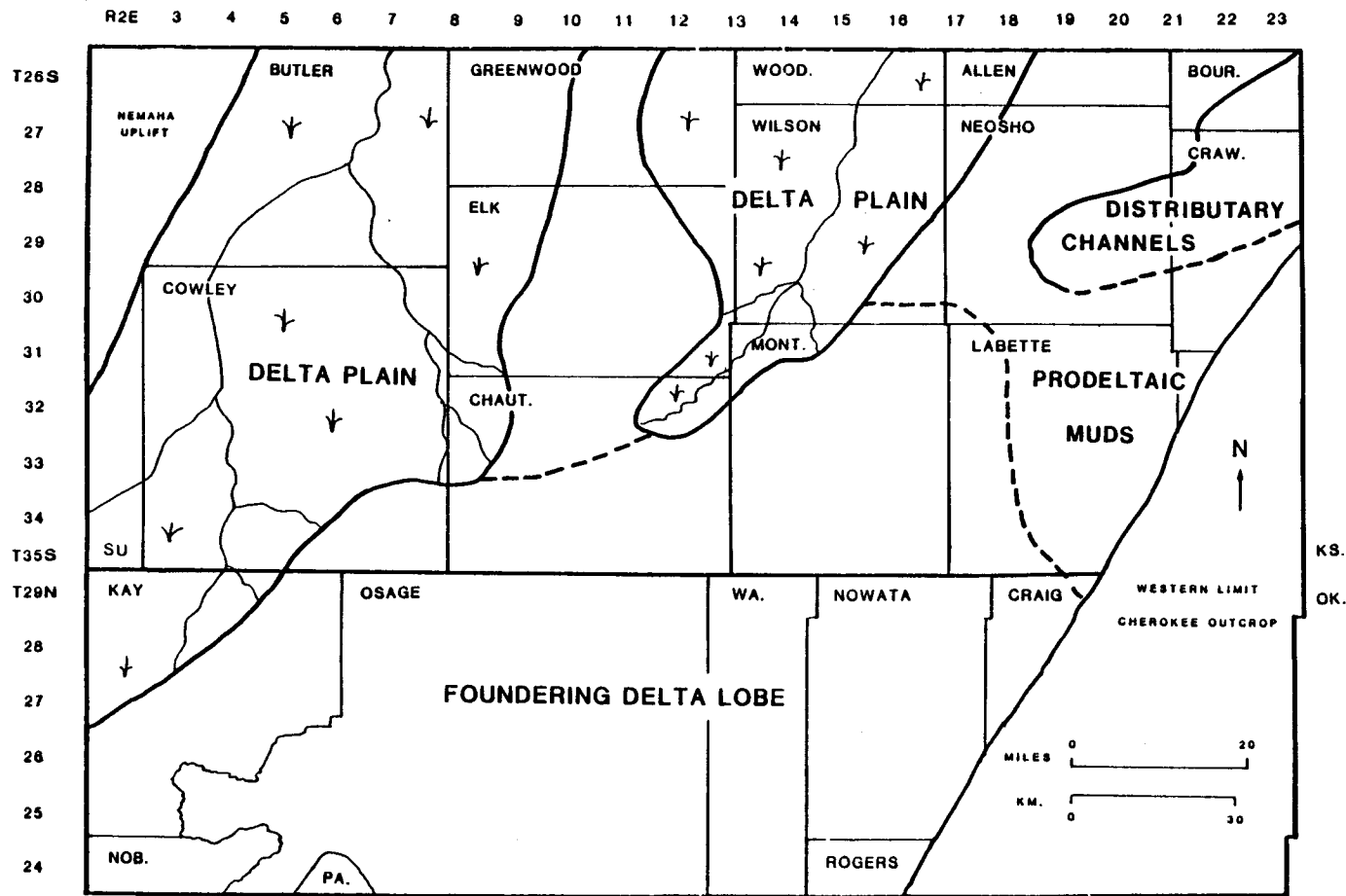


Figure 41. Paleogeographic reconstruction illustrating deposition of the sediments within the "middle sandstone zone". Three delta lobes advanced across the northern half of the study area, with the southern boundaries of the two larger lobes influenced by the foundering delta lobes to the southeast.

downcutting. This may be a result of the depositional slope of the northern half of the study area being much less than it was during earlier deltaic advances.

The southern boundaries of the "middle sandstone zone" delta lobes roughly follow the approximate northern boundary of the earlier deltaic advances (Figure 41). This indicates that the southeastern part of the study area was a slight topographic high, thus influencing the extent and direction of "middle sandstone zone" sedimentation.

In the extreme northeast corner of the study area an apparent small delta lobe is found in the same stratigraphic position as the "upper sandstone" (Figure 41). However, in some wells these deltaic sandstones underlie thin Breezy Hill Limestone, so progradation of this small delta appears related to other deltaic advances within the "middle sandstone zone". The extent of this delta lobe is not well delineated due to the poor well control in the area, but its existence helps explain the origin of the thick prodelta muds in eastern Labette County (Figure 41). A thick shale section is present along the Neosho River east of Oswego, Kansas, in section 15, T. 33 S., R. 21 E., Labette County (section 1, Appendix A). This section reflects accurately the well log signatures from the area south of this delta lobe.

Within domain 2 there is a slight thickening of

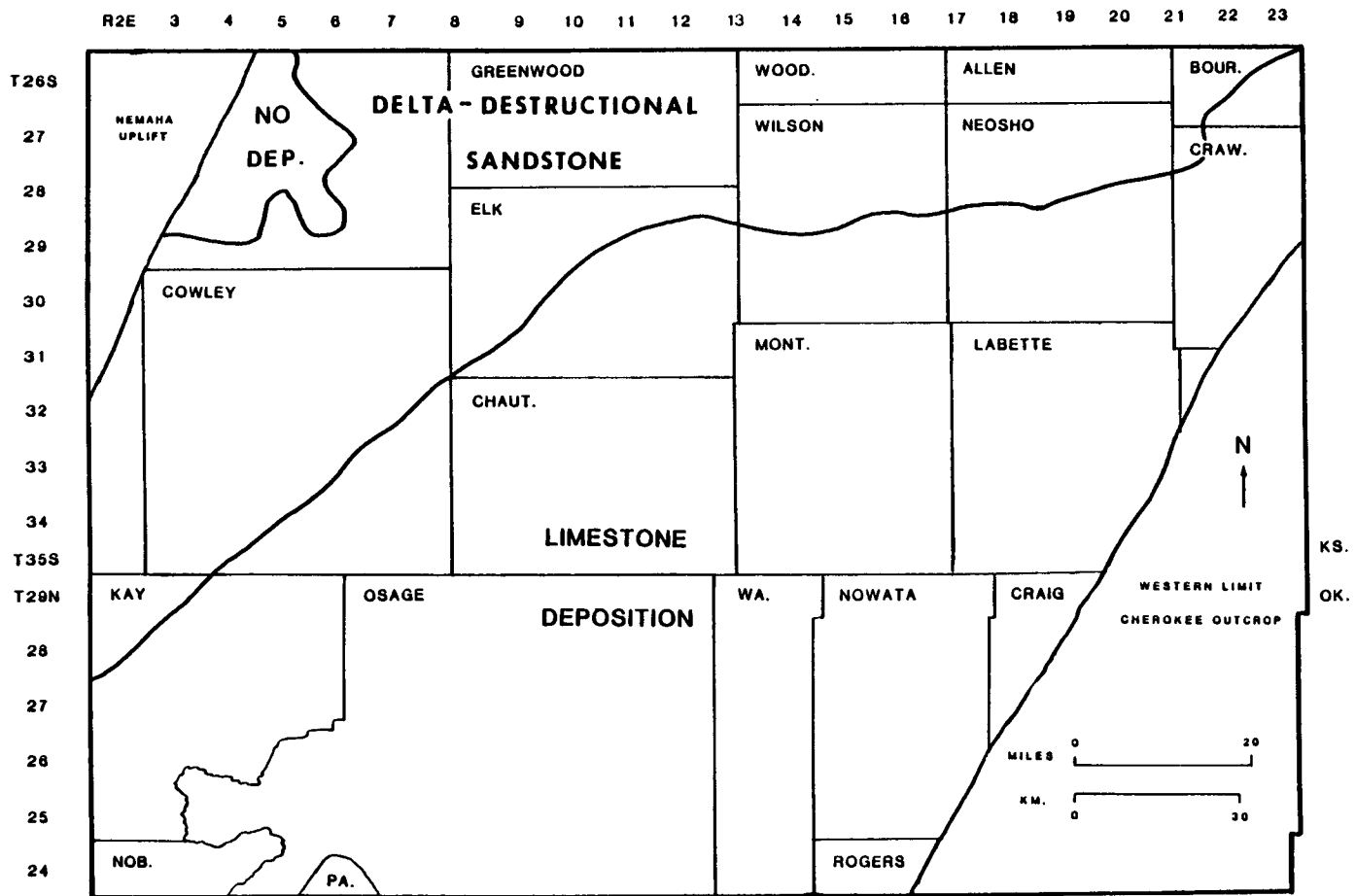


Figure 42. Paleogeographic reconstruction showing deposition of the "upper sandstone" and Breezy Hill Limestone.

Kinnison Shale in an area that coincides with the positions of the distributary channels in the underlying Lagonda Member. This thickening between Pawnee and Labette counties (Figure 20) resulted from deposition of fine-grained suspended load from these channels as the shoreline moved north through a later marine transgression.

"Upper Sandstone"--Breezy Hill Limestone

In the northern and northwestern portions of the study area an upward-coarsening sandstone is found directly underlying the Excello Shale (Figure 42). Due to its widespread distribution this sandstone is interpreted to have formed from the winnowing of delta-front sediments by storm-generated currents. Figure 25 shows the upward progression from prodelta muds to delta-slope muds and silts and to the delta-destructive sandstone.

This sheet sandstone is thickest in areas where the "middle sandstone zone" is thinnest (compare figures 22 and 24). Because compaction causes greater volume reduction in shales than in sandstones, shale-dominated areas where the "middle sandstone zone" is poorly developed probably had slightly thinner sections between the Iron Post Coal and the sea floor, rendering them as slight topographic depressions. Sediment deposited in the area from channel mouths to the north may have been reworked by storm currents, with sandstone collecting within these topographic

depressions.

The cessation of sedimentation in the southern half of the study area resulted from the northward transgression of the latest Cherokee sea, making the sea in the southern part of the study area more distant from siliciclastic point sources, thus enhancing carbonate production (Figure 42). The Breezy Hill Limestone rapidly thickens upon the abandoned delta lobes within domain 2. It appears that the environmental conditions in this area were favorable for increased carbonate production relative to the rest of the shelf. A feasible explanation is that because the area appears to have been a topographic high, the lesser depth of the water column placed the surface of the delta lobe closer to the photic zone. The increase in light penetration may have spurred the growth of algae, thus forming a widespread algal mound upon the lobe.

The Breezy Hill Limestone appears to stratigraphically overlie the regressive "upper sandstone". Thin limestone that often caps this sandstone thickens southward into the main portion of the Breezy Hill.

CONCLUSIONS

Examinations of gamma-ray well logs and the structures and textures of outcropping Banzet rocks have led to the following interpretations.

1) Three major episodes of deltaic sedimentation occurred within the Banzet Formation. Deltaic lobes advanced over the Cherokee Shelf after formation of the Ardmore Limestone, Bevier Coal, and Iron Post Coal.

2) Within the subsurface the Iron Post Coal is much more laterally extensive than is the Bevier Coal. The Iron Post is present throughout southeastern Kansas and northeastern Oklahoma, but the lateral extent of the Bevier is restricted to the southeastern part of the study area.

3) The Kinnison Shale thickens to the north and west of outcropping Banzet sediments, resulting from the progradation of three delta lobes into the northern half of the study area, and the deposition of thick prodeltaic sediments to the northeast.

4) The Breezy Hill Limestone is thickest along the Kansas-Oklahoma border, and thins to the north and south. In many wells to the northwest it caps a delta-destructive sandstone, while to the northeast it overlies deltaic channel sandstone.

5) Mineralogy of sandstones helps substantiate earlier claims that the Canadian Shield was the principal source of siliciclastic detritus deposited over the Cherokee Shelf.

6) Both the Nemaha Uplift and Ozark Uplift did not supply appreciable amounts of sediment to the region.

7) Revisions in Kansas and Oklahoma stratigraphic nomenclature must accompany the naming of the Banzet and Verdigris Formations. The term Verdigris Limestone should be replaced with Ardmore Limestone. In northeastern Oklahoma, the terms Krebs and Cabaniss groups should be deleted and replaced with Cherokee. The terms Krebs and Cabaniss formations in Kansas and Senora Formation in northeastern Oklahoma should be dropped. Formation-naming of sub-Verdigris-Formation beds should delineate strata between easily-identifiable, widespread marker horizons such as limestones and black shales. Further gamma-ray well log studies of sub-Verdigris rocks should be accomplished to determine possible formational boundaries.

REFERENCES

- Aden, L.J., 1982. Clay mineralogy and depositional environments of Upper Cherokee (Desmoinesian) mudrocks, eastern Kansas, western Missouri, and northeastern Oklahoma: Unpublished Master of Science thesis, University of Iowa, 126 p.
- Anderson, K.H., and Wells, J.S., 1968. Forest City Basin of Missouri, Kansas, Nebraska, and Iowa: A.A.P.G. Bull., v. 52, p. 264-281.
- Astarita, A.M., 1975. Depositional trends and environments of "Cherokee" sandstones, east-central Payne County, Oklahoma: Unpublished Master of Science thesis, Oklahoma State University.
- Baker, D.A., 1958. Subsurface geology of southwest Pawnee County, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.
- Berry, C.G., 1967. Stratigraphy of the Cherokee Group, eastern Osage County, Oklahoma: Shale Shaker Digest V, p. 36-50.
- Berryhill, R.A., 1960. Subsurface geology of south-central Pawnee County, Oklahoma: Shale Shaker Digest III, p. 54-69.
- Branson, C.C., 1957. Oklahoma facies of Kansas formations: Kansas Geological Society, Twenty-first Annual Field Conference, p. 92-104.
- Branson, C.C., and Huffman, G.G., 1965. Geology, oil, and gas of Craig County, Oklahoma. Part 1 - Geology of Craig County: Oklahoma Geological Survey Bull. 99, 109 p.
- Brenner, R.L., 1982. Regional subsurface analyses of Upper Cherokee (Middle Pennsylvanian) siliciclastics, eastern Kansas - A preliminary report: G.S.A. Abstracts with Programs, v. 14, no. 3, p. 106.
- Candler, C.C., 1979. Subsurface stratigraphic analysis of selected sandstones of the "Cherokee" Group, southern Noble County, Oklahoma: Shale Shaker Digest VIII, p. 1-16.

- Chrisman, L.P., 1951. The geology of the Big Cabin Creek area, Craig County, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma, 66 p.
- Clayton, J.M., 1967. Paleodepositional environments of the "Cherokee" sands of central Payne County, Oklahoma: Shale Shaker Digest V, p. 95-111.
- Cole, J.G., 1970. Cherokee Group, east flank of the Nemaha Ridge, north-central Oklahoma, parts I and II: Shale Shaker Digest VI, p. 75-99.
- Coleman, J.M., and Prior, D.B., 1982. Deltaic sediments, in Scholle, P.A., and Spearing, D., eds., Sandstone Depositional Environments: A.A.P.G. Memoir 31, p. 139-178.
- Condra, G.E., 1949. The nomenclature, type localities, and correlation of the Pennsylvanian subdivisions in eastern Nebraska and adjacent states: Nebraska Geological Survey Bull. 16, 67 p.
- Dogan, N., 1970. Subsurface study of Middle Pennsylvanian rocks (from the Brown Limestone to the Checkerboard Limestone) in eastern Oklahoma: Unpublished Master of Science thesis, University of Tulsa.
- Ebanks, W.J., Jr., James, G.W., and Livingston, N.D., 1977. Evaluation of heavy-oil and tar sands in Bourbon, Crawford, and Cherokee counties, Kansas--Final Report: U.S. Dept. of Energy, BERG/RI-77/20.
- Folk, R.L., 1974. Petrology of sedimentary rocks: Hemphill Publishing Co., Austin, Texas, 182 p.
- Graves, J.M., 1958. Subsurface geology of a portion of Lincoln and Payne counties, Oklahoma: Shale Shaker Digest II, p. 1-22.
- Gruman, W.P., 1954. Geology of the Foyil area, Rogers and Mayes counties, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma, 99 p.
- Hanke, H.W., 1967. Subsurface stratigraphic analysis of the Cherokee Group in north-central Creek County, Oklahoma: Shale Shaker Digest V, p. 177-194.

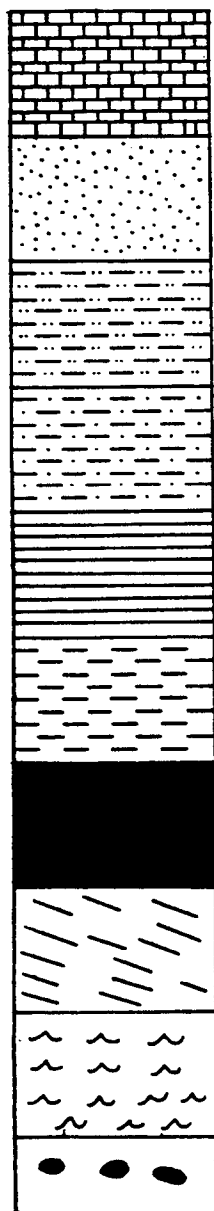
- Haworth, E., and Kirk, M.Z., 1894. A geologic section along the Neosho River from the Mississippian Formation of the Indian Territory to White City, Kansas, and along the Cottonwood River from the Wyckoff to Peabody: Kansas University Quarterly, v. 2, p. 104-115.
- Howe, W.B., 1951. Bluejacket Sandstone of Kansas and Oklahoma: A.A.P.G. Bull., v. 35, p. 2087-2093.
- Howe, W.B., 1956. Stratigraphy of pre-Marmaton Desmoinesian (Cherokee) rocks in southeastern Kansas: Kansas Geol. Survey Bull. 123, 132 p.
- Howe, W.B., and others, 1961. The stratigraphic succession in Missouri: Missouri Geol. Survey Report of Investigations, v. 40, second series, 185 p.
- Hulse, W.J., 1978. A geologic study of the Sallyards field area, Greenwood County, Kansas: Unpublished Master of Science thesis, University of Kansas, 152 p.
- Jewett, J.M., 1959. Graphic column and classification of rocks in Kansas: Kansas Geol. Survey chart.
- Kisvarsanyi, E.B., 1976. Studies in Precambrian geology of Missouri: Missouri Geological Survey Report of Investigations, v. 61, 190 p.
- Knight, K.L., 1983. Breezy Hill Limestone, a prelude to the major widespread Pennsylvanian cyclothems of Midcontinent North America: G.S.A. Abstracts with Programs, v. 15, no. 4, p. 257.
- Krumme, G.W., 1981. Stratigraphic significance of limestones of the Marmaton Group (Pennsylvanian, Desmoinesian) in eastern Oklahoma: Oklahoma Geological Survey Bull. 131, 70 p.
- Lardner, J.F., 1984. Petrology, depositional environments, and diagenesis of Middle Pennsylvanian (Desmoinesian) "Lagonda Interval" Cherokee Group in east-central Kansas: Unpublished Master of Science thesis, University of Iowa, 156 p.
- Lohman, C., 1952. Geology of the Whiteoak area, Craig and Rogers counties, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.
- McElroy, M.N., 1961. Isopach and lithofacies study of the Desmoinesian Series of north-central Oklahoma: Shale Shaker Digest III, p. 1-18.

- McGee, W.J., 1888. Notes on the geology of Macon County, Missouri: St. Louis Academy of Science Transcripts, v. 5, p. 305-336.
- Merriam, D.F., 1963. The geologic history of Kansas: Kansas Geological Survey Bull. 162, 311 p.
- Moore, G.E., 1979. Pennsylvanian paleogeography of the southern Mid-continent, in Hyne, N.J., ed., Pennsylvanian Sandstones of the Mid-continent: Tulsa Geological Society Special Pub. 1, p. 2-12.
- Moore, R.C., 1932. A reclassification of the Pennsylvanian System in the northern Mid-continent: Kansas Geological Society Sixth Annual Field Conf., p. 79-98.
- Moore, R.C., 1936. Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geological Survey Bull. 22, 256 p.
- Nelson, M.R., 1985. Petrology, Diagenesis, and Depositional Environment of the Lagonda Interval, Cabaniss Subgroup, Cherokee Group, Middle Pennsylvanian, in northeastern Kansas: Unpublished Master of Science thesis, University of Iowa, 176 p.
- Oakes, M.C., 1953. Krebs and Cabaniss Groups of Pennsylvanian age in Oklahoma: A.A.P.G. Bull., v. 37, p. 1523-1526.
- Pierce, W.G., and Courtier, W.H., 1937. Rocks and structure of southeastern Kansas: Kansas Geological Society, Eleventh Annual Field Conf., southeastern Kansas and northeastern Oklahoma, p. 17.
- Querry, J.L., 1958. Subsurface geology of south-central Kay County, Oklahoma: Shale Shaker Digest II, p. 338-408.
- Ravn, R.L., and others, 1984. Stratigraphy of the Cherokee Group and revision of Pennsylvanian stratigraphic nomenclature in Iowa: Iowa Geological Survey Technical Information Series, no. 12, 76 p.
- Reinholtz, P.N., 1982. Distribution, petrology, and depositional environment of the "Bush City Shoestring Sandstone" and "Centerville Lagonda Sandstone" in Cherokee Group (Middle Pennsylvanian), southeastern Kansas: Unpublished Master of Science thesis, University of Iowa, 180 p.

- Sartin, J.P., 1958. A cross-sectional study of the oil-producing rocks of Pennsylvanian age in northeastern Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.
- Schell, B.J., 1955. The stratigraphy and depositional history of the Verdigris-Higginsville interval in northeastern Oklahoma: Unpublished Master of Science thesis, University of Tulsa.
- Scott, J.D., 1970. Subsurface stratigraphic analysis, "Cherokee Group", northern Noble County, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma.
- Searight, W.V., and others, 1953. Classification of Desmoinesian (Pennsylvanian) of the northern Mid-continent: A.A.P.G. Bull., v. 37, p. 2747-2749.
- Selley, R.C., 1976. Subsurface environmental analysis of North Sea sediments: A.A.P.G. Bull., v. 60, p. 184-195.
- Selley, R.C., 1978. Concepts and methods of subsurface facies analysis: A.A.P.G. Education Course Notes Series no. 9, 86 p.
- Shipley, R.D., 1979. Local depositional trends of "Cherokee" sandstones, Payne County, Oklahoma: Shale Shaker Digest VII, p. 173-191.
- Tillman, J.L., 1952. Geology of the Tiawah area, Rogers and Mayes counties, Oklahoma: Unpublished Master of Science thesis, University of Oklahoma, 65 p.
- Ware, H.E., 1955. Surface and shallow subsurface investigation of the Senora Formation of northeastern Oklahoma: Shale Shaker Digest I, p. 403-419.
- Woody, M.D., 1983. Sedimentology, diagenesis, and petrophysics of selected Cherokee Group (Desmoinesian) sandstones in southeastern Kansas: Shale Shaker, v. 33, parts 9-10, p. 91-122.
- Wright, C.R., 1975. Environments within a typical Pennsylvanian cyclothem, in McKee, E.D., and Crosby, E.J., eds., Paleotectonic Investigations of the Pennsylvanian System in the United States, Part II: U.S.G.S. Prof. Paper 853, p. 73-84.
- Zeller, D.E., 1968. The stratigraphic succession in Kansas: Kansas Geological Survey Bull. 189, 81 p.

Appendix A

Partial and complete stratigraphic sections of various Banzet Formation outcrops. Sections appear in order from north to south.



LIMESTONE

SANDSTONE

SILTSTONE

SILTSHALE

CLAYSHALE

CLAYSTONE

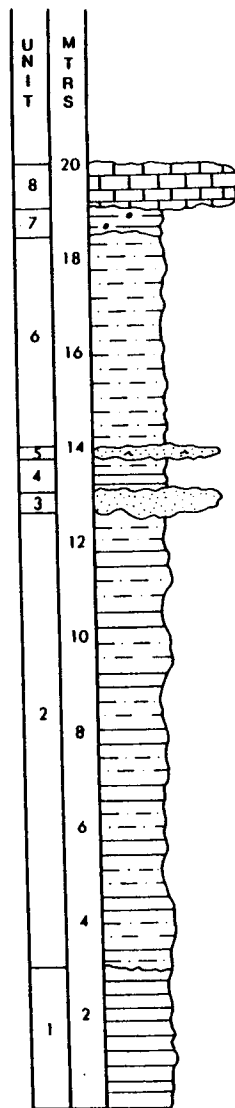
COAL

CROSS-STRATA

SMALL-SCALE RIPPLES

CONCRETIONS

Blackjack Creek Ls.
Excellio Shale



SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$, sec. 15, T. 33 S., R. 21 E.
Labette County, Kansas
Measured up hill from Riverside Park Road
by Robert L. Brenner (1980)

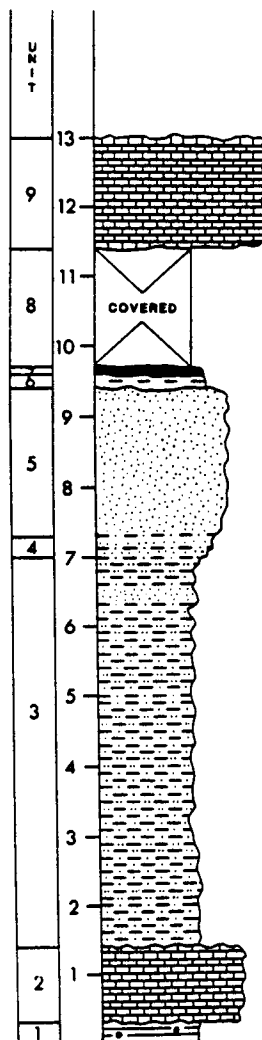
- Unit 8 (19-20 M): Limestone; wackestone-packstone; grains appear to be mostly crinoidal debris; basal contact sharp.
- Unit 7 (18.5-19.0 M): Clayshale; black, with phosphate nodules; fissile; base not exposed.
- Unit 6 (13.9-18.5 M): Siltshale; with scattered thin, ripple-laminated beds; sharp basal contact.
- Unit 5 (13.7-13.9 M): Sandstone; fine-grained; ripple-laminated; shale partings near gradational base.
- Unit 4 (13.0-13.7 M): Clayshale with silty beds near top; medium gray; highly fissile; abruptly gradational base.
- Unit 3 (12.6-13.0 M): Sandstone; fine-grained; load structure at base causes unit thickness to vary; no visible stratification; basal contact sharp, no evidence of erosion.
- Unit 2 (3.0-12.6 M): Interbedded siltshale and clayshale; medium gray; some plant remains on stratification planes.
- Unit 1 (0-3.0 M): Clayshale; medium gray; tan weathering; base not exposed.

Blackjack Creek Ls.

Iron Post Coal

Ardmore Ls.

Oakley Shale



2

SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$, sec. 30, T. 28 N., R. 20 E.
Craig County, Oklahoma
Measured in roadcut along Highway 10
by Robert L. Brenner (1980)

Type section of the Banzet Formation and principal
reference section of the Verdigris Formation.

Unit 9 (not measured): Limestone;
fossiliferous.

Unit 8 (9.7-11.4 M): Covered.

Unit 7 (9.6-9.7 M): Coal; poorly exposed.

Unit 6 (9.4-9.6 M): Claystone; medium
light gray.

Unit 5 (7.3-9.4 M): Sandstone; fine to
medium-grained; regular laminae at
base, mottled toward top; central
part poorly exposed.

Unit 4 (7.0-7.3 M): Interstratified sandstone
and siltshale; fissile beds less than
1 cm thick; gradational lower contact.

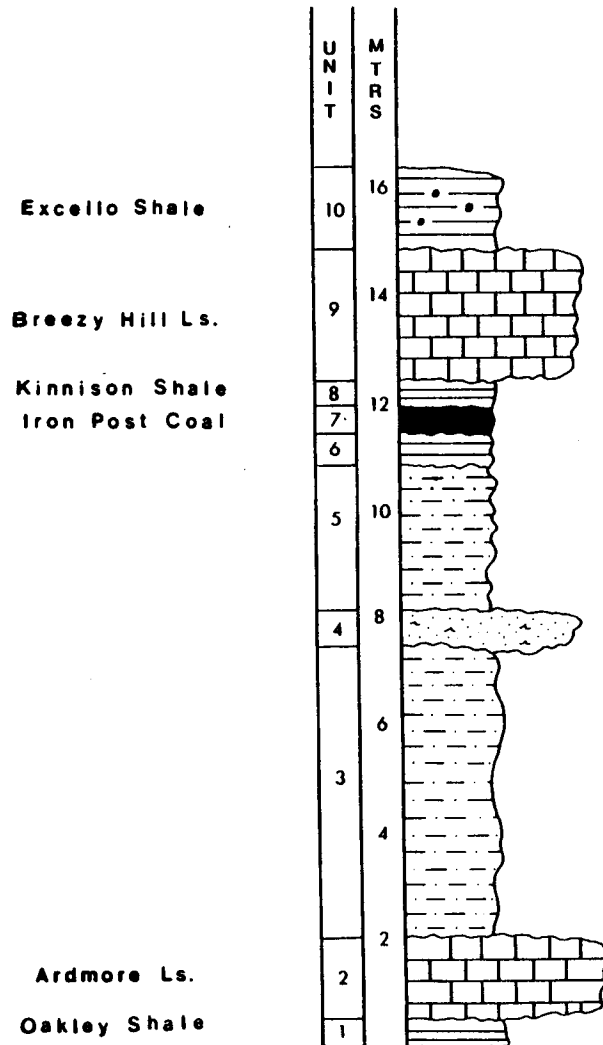
Unit 3 (1.4-7.0 M): Siltshale; medium gray;
contains some thin siltstone and
sandstone beds which increase in
frequency upward.

Unit 2 (0.3-1.4 M): Limestone; wacke-packstone.

Unit 1 (0-0.3 M): Clayshale; black; contains
phosphate nodules.

* A complete Banzet section was measured
less than $\frac{1}{2}$ mile west of this section,
in NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$, section 36, T. 28 N.,
R. 19 E., Craig County. This section
is listed in Branson and Huffman (1965),
p. 101.

SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 27 N., R. 19 E.
 Craig County, Oklahoma
 Measured along road, 0.2 miles south of NE corner,
 northward along road up the hill by
 Chrisman (1951), revised by Denesen (1983)

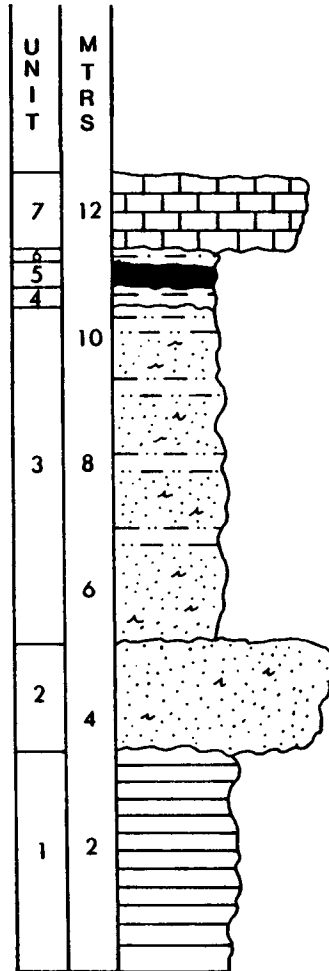


- Unit 10 (14.8-16.3 M): Clayshale; black; contains phosphate nodules.
- Unit 9 (12.4-14.8 M): Limestone; gray; weathers brown; fossiliferous.
- Unit 8 (11.9-12.4 M): Clayshale; gray; poor fissility.
- Unit 7 (11.4-11.9 M): Coal.
- Unit 6 (10.8-11.4 M): Clayshale; buff; highly fissile; gradational lower contact.
- Unit 5 (8.1-10.8 M): Siltshale; gray; micaceous; highly fissile; abrupt lower contact.
- Unit 4 (7.5-8.1 M): Sandstone; medium-grained; tan; thick-bedded; rippled; micaceous; abrupt basal contact.
- Unit 3 (2.0-7.5 M): Siltshale; gray; micaceous; abrupt lower contact.
- Unit 2 (0.5-2.0 M): Limestone; dark gray; weathers brown; fossiliferous.
- Unit 1 (0-0.5 M): Clayshale; black; contains phosphate nodules; lower contact covered.

4

SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$, sec. 7, T. 23 N., R. 17 E.
 Rogers County, Oklahoma
 Measured in abandoned strip pit by Denesen (1983)

Breezy Hill Ls.
 Kinnison Shale
 Iron Post Coal



- Unit 7 (11.3-12.5 M): Limestone; silty; buff; fossiliferous.
- Unit 6 (11.1-11.3 M): Siltshale; brown; poor fissility.
- Unit 5 (10.7-11.1 M): Coal.
- Unit 4 (10.5-10.7 M): Claystone; brownish-gray; mottled; sharp, irregular lower contact.
- Unit 3 (5.2-10.5 M): Interbedded fine-grained sandstone and siltstone; massive to rippled; light gray on fresh surfaces, light brown on weathered ones; sharp basal contact.
- Unit 2 (3.5-5.2 M): Sandstone; fine-grained; slabby, with some ripple laminae present; gray on fresh surfaces, orange-brown on weathered ones; sharp basal contact.
- Unit 1 (0-3.5 M): Clayshale; medium-gray; micaceous; highly fissile; unfossiliferous; lower contact obscured.

5

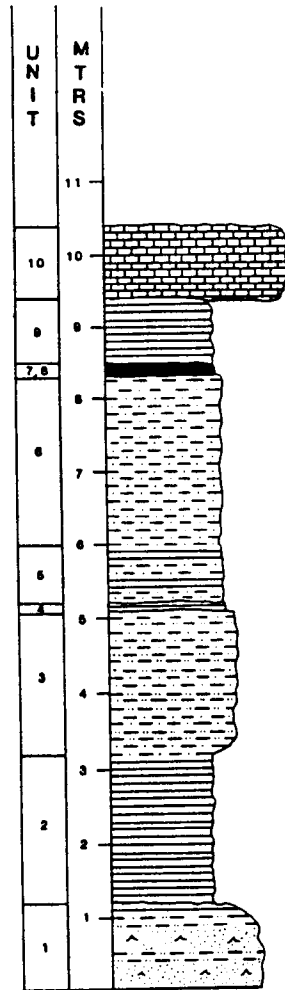
NW¼ NW¼ NW¼, sec. 2, T. 21 N., R. 15 E.
Rogers County, Oklahoma

Measured in roadcut, 0.6 miles west of NE¼ of sec. 2
by Tillman (1952), revised by Denesen (1983)

Breezy Hill Ls.

Kinnison Shale

Iron Post Coal



- Unit 10 (9.4-10.3 M): Limestone; fossiliferous.
- Unit 9 (8.5-9.4 M): Clayshale; light gray to buff; poorly fissile; fossiliferous.
- Unit 8 (8.3-8.5 M): Coal.
- Unit 7 (8.2-8.3 M): Claystone; blue-gray; sticky when wet; abundant coal fragments; gradational lower contact.
- Unit 6 (6.0-8.2 M): Siltshale; light brown; poor fissility; gradational lower contact.
- Unit 5 (5.2-6.0 M): Interbedded siltshale and clayshale; light brown at top, grades to light gray at base; undulose fissility; abundant carbonized plant fragments; abrupt lower contact.
- Unit 4 (5.1-5.2 M): Clayshale; dark gray; poor fissility; gradational basal contact.
- Unit 3 (3.2-5.1 M): Interbedded thin-bedded siltstone and fissile siltshale; light brown at top, grades to light gray near base; highly micaceous along fissility planes; lower contact marked by color change.
- Unit 2 (1.2-3.2 M): Clayshale; dark gray; highly fissile; abrupt lower contact.
- Unit 1 (0-1.2 M): Interbedded slabby, very fine-grained sandstone and siltstone; medium brown; rippled; micaceous; becomes coarser at top; lower contact obscured.

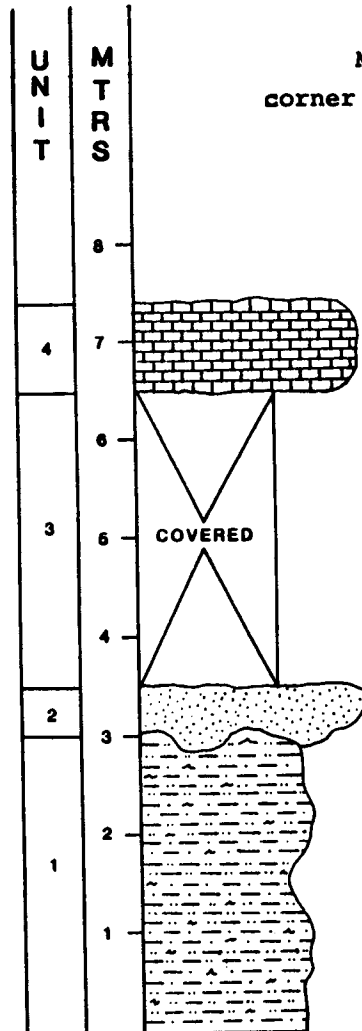
6

N $\frac{1}{2}$ N $\frac{1}{2}$ NW $\frac{1}{4}$, sec. 23, T. 21 N., R. 15 E.

Rogers County, Oklahoma

Measured in bank along road, 0.25 miles east of NW corner of sec. 23, by Tillman (1952), revised by Denesen (1983)

Breezy Hill Ls.



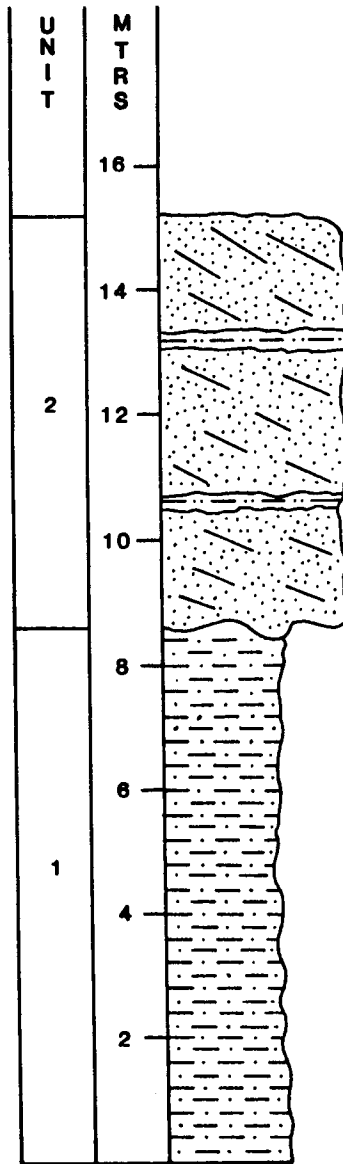
Unit 4 (6.5-7.4 M): Limestone; fossiliferous; upper and lower contacts covered.

Unit 3 (3.5-6.5 M): Covered interval.

Unit 2 (3.0-3.5 M): Sandstone; medium-grained; massive; weathers dark brown; bed thickness uneven due to load structures at base; abrupt basal contact.

Unit 1 (0-3.0 M): Interbedded rippled, fine-grained siltstone and thinly laminated siltshale; tan; carbonaceous; lower contact obscured.

"lower sandstone #1"



7

SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$, sec. 16, T. 20 N., R. 15 E.
Rogers County, Oklahoma
Measured in roadcut east of River Hill Cemetery
along U.S. Highway 66 by Denesen (1983)

Unit 2 (8.7-15.4 M): Sandstone; medium-grained; light brown; massive, with SW-SE-trending high-angle planar cross sets interrupted by thin layers of thin-bedded, rippled siltstone; red clay ironstone concretions are aligned along planes of cross stratification; irregular, erosional basal contact.

Unit 1 (0-8.7 M): Siltshale; medium gray; well developed wavy fissility; lower contact not exposed.

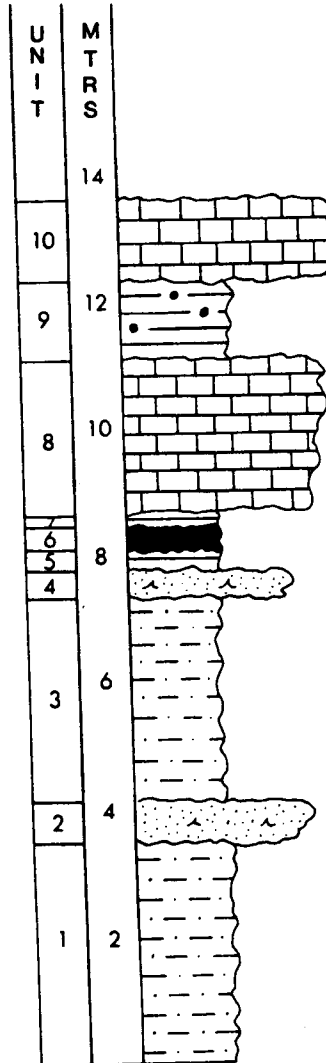
SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$, sec. 31, T. 20 N., R. 15 E.
 Rogers County, Oklahoma
 Measured along Highway 33, west of Spunky Creek
 by Tillman (1952), revised by Denesen (1983)

Blackjack Creek Ls.

Excellio Shale

Breezy Hill Ls.

Iron Post Coal



Unit 10 (12.3-13.6 M): Limestone; light gray; fossiliferous.

Unit 9 (11.1-12.3 M): Clayshale; black; contains phosphate nodules.

Unit 8 (8.6-11.1 M): Limestone; light gray; massively bedded; fossiliferous.

Unit 7 (8.4-8.6 M): Clayshale; brown; poor fissility.

Unit 6 (8.0-8.4 M): Coal.

Unit 5 (7.7-8.0 M): Clayshale; light gray; iron-stained; poor fissility; sharp basal contact.

Unit 4 (7.3-7.7 M): Sandstone; medium-grained; medium brown; ripple-stratified; sharp, undulose basal contact.

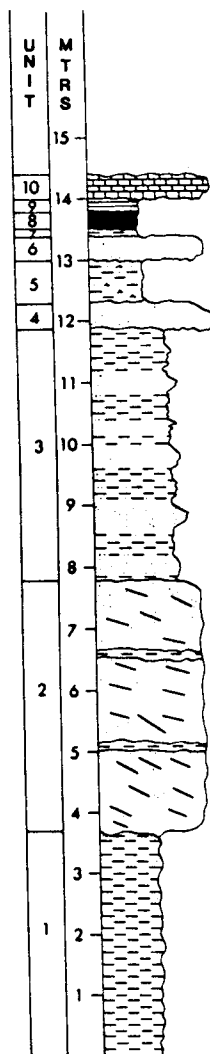
Unit 3 (4.1-7.3 M): Siltshale; light gray at top, becomes progressively darker at base; locally interrupted by sparse, ripple-laminated siltstone; sharp basal contact.

Unit 2 (3.8-4.1 M): Sandstone; medium-grained; light gray; massive to rippled; sharp, undulose basal contact.

Unit 1 (0-3.5 M): Interbedded clayshale and siltshale; medium gray; undulose fissility; locally interrupted by thin-bedded, light gray, rippled siltstone; lower contact covered.

Breezy Hill Ls.
Kinnison Shale
Iron Post Coal

"lower sandstone #1"



9
NE¼ NE¼ NE¼, sec. 7, T. 19 N., R. 15 E.
Wagoner County, Oklahoma
Measured in roadcut, northwest
from creek by Denesen (1983)

- Unit 10 (14.0-14.4 M): Limestone; silty; fossiliferous.
- Unit 9 (13.8-14.0 M): Clayshale; brown; poor fissility; sharp basal contact.
- Unit 8 (13.6-13.8 M): Coal.
- Unit 7 (13.4-13.6 M): Siltshale; orange-brown; poor fissility; upper contact poorly exposed; sharp, irregular basal contact.
- Unit 6 (13.0-13.4 M): Sandstone; fine-grained; medium-brown; massive; sharp basal contact; with load structures at base.
- Unit 5 (12.3-13.0 M): Siltshale; light brown; thinly ripple-laminated.
- Unit 4 (11.9-12.3 M): Sandstone; fine-grained; light brown; thick-bedded; abruptly-gradational basal contact.
- Unit 3 (7.8-11.9 M): Interbedded thin-bedded siltstone and fine-grained sandstone; light brown; becomes coarser near top; sharp basal contact.
- Unit 2 (3.7-7.8 M): Sandstone; medium-grained; tan to buff; SW-SE-trending cross-strata locally interrupted by siltshale partings; sharp basal contact.
- Unit 1 (0-3.7 M): Siltstone; brownish-gray; thin-bedded; some carbonized plant fragments along stratification planes; lower contact covered.

10

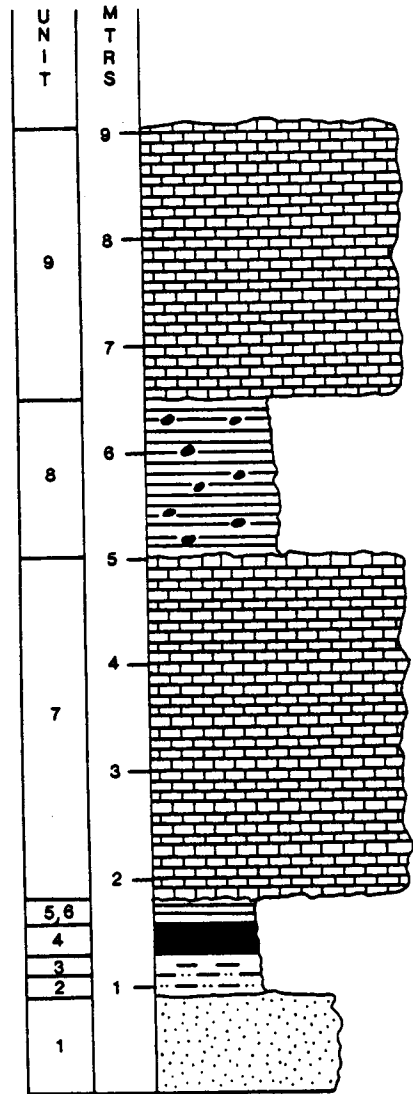
NW¼ NW¼ NW¼, sec. 17, T. 19 N., R. 15 E.
 Wagoner County, Oklahoma
 Measured in roadcut from top of hill to covered
 area at base of slope, by LeRoy A. Hemish (1981)

Blackjack Creek Ls.

Excello Shale

Breezy Hill Ls.

Kinnison Shale
 Iron Post Coal



Unit 9 (6.5-12.6 M): Limestone, light gray with light yellow-brown staining; irregularly-bedded; silty, fossiliferous.

Unit 8 (5.0-6.5 M): Clayshale; black; highly fissile; contains phosphate nodules; poorly exposed.

Unit 7 (1.8-5.0 M): Limestone; light gray; medium to thin-bedded; fossiliferous.

Unit 6 (1.7-1.8 M): Clay; buff; highly calcareous.

Unit 5 (1.6-1.7 M): Clayshale; reddish-brown to black; highly carbonaceous and coaly in lower part.

Unit 4 (1.3-1.6 M): Coal.

Unit 3 (1.1-1.3 M): Claystone light gray.

Unit 2 (0.9-1.1 M): Siltstone; light gray with orange mottling.

Unit 1 (0-0.9 M): Sandstone; fine-grained; light gray; thin-bedded; basal contact not exposed.

Appendix B

Modal percentages of detrital and authigenic components
of individual type A and type B sandstone samples.

Type "A" Sandstones---5 Samples

	<u>Section 9</u> <u>Unit 4</u>	<u>Section 9</u> <u>Unit 6</u>	<u>Section 6</u> <u>Unit 2</u>	<u>Section 4</u> <u>Unit 2</u>	<u>Section 8</u> <u>Unit 4</u>
<u>DETRITAL</u>					
Quartz					
Monocrystalline	121	113	118	130	126
Polycrystalline	2	1	2	0	1
Feldspar					
Orthoclase	13	18	16	29	22
Plagioclase	4	2	1	4	2
Mica					
Muscovite	5	5	11	7	3
Biotite	0	0	1	0	0
Rock Fragments					
Granitic rock frags	0	2	3	0	2
Chert	0	0	0	0	2
Matrix	7	9	10	12	2
Glauconite	0	1	0	0	0
Heavy Minerals	0	1	0	0	0
<u>AUTHIGENIC</u>					
Carbonate Cement	0	68	0	0	63
Clays	11	8	7	5	7
Silica Cement	15	0	12	12	0
Pyrite	11	3	5	4	3
Iron Oxide	11	8	0	3	2
<u>OTHER</u>					
Pore Space	15	0	30	14	0

Type "B" Sandstones---4 Samples

	Section 7 Unit 2 3.3 m from base	Section 7 Unit 2 6.2 m from base	Section 9 Unit 2 0.6 m from base	Section 9 Unit 2 4.0 m from base
<u>DETRITAL</u>				
Quartz				
Monocrystalline	107	119	118	112
Polycrystalline	0	2	3	3
Feldspar				
Orthoclase	28	23	20	20
Plagioclase	4	2	3	4
Mica				
Muscovite	12	9	7	8
Biotite	0	0	0	0
Rock Fragments				
Granitic Rock Frags	2	0	2	1
Chert	0	5	8	2
Matrix	0	0	0	0
Glauconite	0	0	0	0
Heavy Minerals	0	0	0	0
<u>AUTHIGENIC</u>				
Carbonate Cement	0	0	0	0
Clays	8	10	4	7
Silica Cement	9	10	7	12
Pyrite	6	3	4	6
Iron Oxide	16	11	26	12
<u>OTHER</u>				
Pore Space	33	31	23	38

Appendix C

Tables of data obtained from well logs used in study.

DEFINITIONS OF COLUMN HEADINGS

QTR = Quarter of a quarter of a quarter section.
 Northwest $\frac{1}{4}$ = 1 Southwest $\frac{1}{4}$ = 3
 Northeast $\frac{1}{4}$ = 2 Southeast $\frac{1}{4}$ = 4
 NE $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ = 214 SW $\frac{1}{4}$ NE $\frac{1}{4}$ = 032 NW $\frac{1}{4}$ = 001

TOP CHER = Depth of the base of the Excello Shale.

BASE ARD = Depth of the base of the Ardmore
 Limestone or top of the Oakley Shale.

BH = Thickness of the Breezy Hill Limestone.

KINN = Thickness of the Kinnison Shale.

IP-A = Thickness of the Ardmore Limestone - Iron
 Post Coal interval.

LAG = Thickness of the Lagonda Member.

BEV = Thickness of the Bevier Member.

SS#1 = Thickness of the "lower sandstone #1".

SS#2 = Thickness of the "lower sandstone #2".

MSSZ = Footage of sandstone within the "middle
 sandstone zone".

UPPSS = Thickness of the "upper sandstone".

Kansas Well Logs

QTR	SEC	TWP	RGE	DATUM	TOP CHER	BASE ARD	BH	KINN	IP-A	LAG	BEV	SS#1	SS#2	MSSZ	UPPSS
414	35	26S	05E	1308	2499	2589	00	75	11			4	0	0	
341	03	26S	05E	1339	2384	2458	00	60	11			6	6	2	
244	26	26S	05E	1339	2528	2612	00	70	10			6	2	0	
323	04	26S	05E	1325	2339	2409	00					5	0	0	
003	29	26S	06E	1355	2514	2611	00	76	14			6	11	0	
112	26	26S	06E	1435	2543	2635	00					7	3	2	
003	28	26S	06E	1398	2547	2640	00	77	13			6	10	5	
424	26	26S	06E	1440	2552	2628	00								
111	26	26S	07E	1450	2458	2561	00	88	12			6	0	0	
223	29	26S	07E	1460	2515	2610	00					5	9	2	
241	22	26S	07E	1480	2491	2577	00								
432	22	26S	07E	1493	2493	2592	00	78	16			6	3	1	
411	29	26S	08E	1553	2438	2539	00	81	9			2	4	6	
341	10	26S	08E		2254	2350	00	82	12			7	4	5	
441	22	26S	08E		2138	2236	00	83	11			7	5	12	
001	22	26S	08E	1387	2150	2248	00					2	4	4	
144	23	26S	09E		1815	1916	00					5	7	0	
114	13	26S	09E		1750	1852	00	87	12			3	9	8	
001	33	26S	09E	1342	2017	2122	00					2	4	4	
333	07	26S	10E	1163	1792	1890	00	83	12			5	9	3	
144	06	26S	10E	1189	1772	1870	00					4	10	3	
411	18	26S	10E	1093	1748	1845	00	78	12			5	2	5	
214	08	26S	11E	1063	1549	1623	00					4	0	4	
223	24	26S	11E	1110	1530	1598	00	54	15			3	0	11	
321	08	26S	12E	1111	1473	1545	00	58	11			3	4	8	
441	11	26S	12E	1008	1291	1363	00	59	11			3	6	8	
332	30	26S	12E	1129	1532	1609	00					3	12	0	
021	36	26S	12E	1050	1324	1388	00					2	0	11	
142	26	26S	13E	974	1152	1224	00	50	16			5	4	0	
242	13	26S	14E		992	1073	00	62	13			3	0	0	
002	27	26S	14E	931	1064	1137	00					3	0	6	
132	02	26S	14E	1055	1190	1256	00					3	0	0	
142	19	26S	15E	1056	1094	1173	00					3			
422	24	26S	17E		679	780	00					2	8	0	
000	22	26S	17E		626	719	00	74	16			0	2	6	
212	13	26S	18E	985	641	730	00								
443	02	26S	18E		602	692	00	72	14			0	0	9	
222	05	26S	19E		635	726	00	71	15			3	0	3	
231	16	26S	20E	983	510	607	00					0	0	11	
221	21	26S	21E		517	610	00								
413	19	26S	21E		493	594	00	74	20			0	2	9	
000	19	26S	22E		451	564	00	85	25			0	0	0	
122	27	26S	22E		245	363	00	88	25			0	0	4	
241	35	27S	04E	1289	2427	2500	00								
134	26	27S	05E	1279	2484	2564	00								
000	27	27S	05E	1346	2591	2671	00	65	11			4	14	0	
242	15	27S	05E	1335	2572	2660	00	74	11			6	2	0	
221	33	27S	06E	1370	2532	2620	00	68	16			6	2	1	
213	08	27S	06E		2531	2622	00	73	13			6	7	4	
022	35	27S	06E	1458	2185	2276	00	75	13			0	4	0	
023	28	27S	06E	1321	2470	2552	00	65	13			5	6	0	
414	26	27S	07E	1475	2514	2605	00								
324	14	27S	07E		2478	2562	00	68	11			5	13	1	
313	20	27S	07E	1456	2524	2604	00	64	11			5	13	5	
424	13	27S	08E	1370	2112	2209	00								
341	25	27S	08E	1409	2144	2236	00	69	17			10	9	6	
141	18	27S	09E	1375	2104	2198	00								
043	06	27S	10E	1182	1877	1956	00	62	13			4	7	2	

QTR	SEC	TWP	RGE	DATUM	TOP CHER	BASE ARD	BH	KINN	IP-A	LAG	BEV	SS#1	SS#2	MSSZ	UPPSS
111	24	29S	03E	1229									4	18	2
334	23	29S	04E	1275	2753	2854	00	64	12			5	9	0	
324	25	29S	04E	1264	2698	2766	00								
000	02	29S	04E	1198	2594	2673	00					4	6	0	
003	29	29S	05E		2651	2737	00					5	16	9	
011	18	29S	05E		2734	2811	00	62				5	16	0	
000	25	29S	05E	1284	2586	2671	00	68	16			5	7	1	
214	16	29S	06E		2562	2634	00								
122	03	29S	06E	1437	2617	2700	00					6	4	2	
121	19	29S	06E	1361	2607	2679	00								
312	20	29S	06E		2568	2657	00					7	6	7	
023	10	29S	07E	1521	2596	2672	00	62	17			8	12	5	
003	14	29S	07E		2497	2577	03					8	7	3	
114	19	29S	08E	1523	2464	2542	00								
000	19	29S	08E	1545	2481	2559		55	18			4	11	2	
422	05	29S	09E	1240	2090	2162	00	50	13			4	1	2	
231	34	29S	09E	1185	2001	2071	00	52	13			2	5	0	
421	34	29S	10E	1011	1670	1744	00					5	0	0	
031	13	29S	10E	1096	1733	1807	00	54	15			3	3	3	
114	17	29S	11E	1100	1652	1722	00	49	12			4	0	8	
314	12	29S	12E	1056	1321	1394	00	52	13			2	1	4	
000	20	29S	13E	1135	1398	1468	04					0	2	3	
022	23	29S	13E	840	1112	1184	00	54	13			0	3	7	
332	01	29S	14E	876	808	883	05	54	14			0	7	4	
223	28	29S	15E	1004	938	1066	00								
134	24	29S	17E		612	708	05	72	20			0	2	0	
341	30	29S	17E		630	790	06					47	0	2	
311	36	29S	17E		662	758	03					0	0	0	
002	02	29S	20E		338		02	84	20			0	0	0	
000	22	29S	21E												
032	24	30S	03E	1209	2928	2996	00	68	12			7	9	5	
441	02	30S	03E	1242	2978	3061	00					11	13	1	
312	10	30S	03E	1191	2675	2744	00					3	11	4	
224	22	30S	04E	1232	2700	2780	00								
332	01	30S	04E	1229	2664	2746	00					7	10	9	
000	15	30S	04E		2689	2768	00	63	12			5	10	2	
312	11	30S	04E	1200	2651	2734	00					3	12	10	
244	13	30S	04E	1287	2730	2813	00	68	11			5	9	0	
004	23	30S	04E	1268	2750	2830	00	68	10			4	11	4	
423	33	30S	04E	1205	2730	2809	00					6	8	8	
031	08	30S	05E	1276	2664	2745	00	65	11			5	4	0	
114	33	30S	05E		2689	2775	00								
324	20	30S	05E	1319			00	71	13			5	0	6	
444	03	30S	06E	1436	2602	2687	00	65	15			5	5	0	
111	19	30S	06E	1344	2632	2716	00	66	17			8	10	6	
342	31	30S	06E	1391	2693	2782	00	67	17			8	5	6	
444	29	30S	07E	1103	2606	2680	00	55	16			3	6	2	
321	12	30S	07E	1443	2465	2542	02	56	15			3	9	0	
443	10	30S	08E	1567	2530	2599	00	50	15			4	5	5	
033	25	30S	08E	1330	2258	2332	02	53	16			4	5	0	
112	09	30S	09E		2139	2212	00	49	15			6	5	0	
324	09	30S	09E		2260	2332	00					0	5	16	
412	35	30S	09E	1229	2017	2085	04	48	13			3	4	0	
442	14	30S	10E	1026	1680	1755	04								
111	26	30S	10E	1051	1706	1756	03					6	2	0	
043	30	30S	11E	1048	1614	1679		48	11			0	0	5	
444	15	30S	12E	945	1263	1333	03	51	13			2	0	7	
421	33	30S	13E	909	1154	1222	04								
131	18	30S	13E	908	1187	1258	10	42	12			0	0	0	
133	07	30S	13E		1236	1307	04	45	14			0	0	0	
441	34	30S	14E	900	984	1055	05								
000	08	30S	15E		971	1047	05	45	19			0	0	0	
022	01	30S	16E		689	766	05	44	19			0	0	0	
000	21	30S	16E		655	715	00		17			0	4	0	

QTR	SEC	TWP	RGE	DATUM	TOP CHER	BASE ARD	BH	KINN	IP-A	LAG	BEV	SS#1	SS#2	MSSZ	UPPSS
244	25	30S	16E		686	746	06						0	0	0
332	26	30S	16E		651	706	06								
431	26	30S	17E	786	466	524	06								
243	01	30S	17E		702	780	08	34		09	19	0	0	0	0
311	22	30S	17E		718	784	12					0	0	0	0
000	31	30S	18E		600	660	09	31	20						
134	32	30S	19E		476	587	03	78		10	15	0	5	0	0
022	29	31S	03E	1205	2966	3038	00						7	11	2
000	33	31S	03E	1185	2874	2944	00								
021	15	31S	03E												
213	36	31S	04E	1230	2752	2836	00	64	16			9	8	0	
241	20	31S	05E	1227	2657	2741	00	65	15			9	7	0	
113	21	31S	05E	1276	2761	2846	02	66	15			8	5	0	
034	36	31S	05E	1354	2812	2900	00	70	15			4	0	7	
002	36	31S	05E	1352	2752	2836	00								
313	31	31S	06E	1376	2807	2892	00	66	15			0	4	0	
444	07	31S	06E	1356	2652	2738	00	66	14			10	5	0	
223	14	31S	07E	1420	2555	2634	02	54	18			3	0	0	
124	16	31S	08E	1432	2448	2524	03	55	16			3	0	0	
233	03	31S	08E	1457	2407	2475	00	45	17			3	0	4	
314	17	31S	09E	1127	2004	2076	00	53	13			0	5	5	
322	16	31S	09E	1178	1983	2055	02	53				0	0	6	
113	10	31S	10E	1045	1694	1756	00	46	10			0	0	0	
143	15	31S	11E	1057	1568	1634	04	44	12			0	0	0	
123	29	31S	11E	1116	1676	1742	04	43	13			2	0	0	
000	23	31S	13E	915	1054	1129	06								
412	17	31S	13E	1008	1292	1360	04	44	15			0	0	0	
032	22	31S	14E	869	1066	1115	07	30	16			0	4	0	
441	26	31S	14E		1048	1102	07								
221	15	31S	14E	908	1040	1104	06								
032	20	31S	14E	869	1056	1116	07	30	17			0	4	0	
113	14	31S	15E		766	816	07	19	17			0	2	0	
341	23	31S	15E		779	836	06	26	18			0	3	0	
311	10	31S	15E		757	812	08	23	18			0	3	0	
122	13	31S	16E		755	809	09	17	21			3	0	0	
000	02	31S	16E		629	682	15	20		10	06	0	0	0	0
234	23	31S	16E	840	660	715	11	17	19			2	0	0	
000	34	31S	17E		511	710	07					120	0	0	
133	30	31S	17E		640	692	09	18	19			3	0	0	
422	27	31S	17E		530	667	05					53	0	0	
023	08	31S	17E		716	772	08	14		10	17	0	2	0	0
000	05	31S	17E		714	849	05					19	0	0	
032	29	31S	18E	990	514	557	07					3	0	0	
212	19	31S	18E	990	580	643	07	7		10	16	0	4	0	0
023	03	31S	21E		57	164	00					6	0	4	
343	26	32S	02E	1182								2	23	2	
344	27	32S	02E	1175	3162	3225	00	44	14			2	15	2	
343	26	32S	02E	1182				43	12			2	23	2	
314	36	32S	02E	1130	3070	3140	00	54	12			5	17	5	
032	17	32S	02E	1250											
344	02	32S	03E	1185	2938	3020	00	67	12			0	15	0	
314	09	32S	03E	1172	2951	3027	00								
332	15	32S	04E	1185	2778	2864	00								
012	22	32S	04E	1195	2769	2852	00								
112	13	32S	05E	1294	2770	2854	00					0	0	0	
003	13	32S	05E	1293	2792	2880	00	71	14			0	6	6	
321	33	32S	05E	1252	2830	2920	02	71	15			3	2	0	
444	16	32S	06E	1336	2815	2897	02	62	15			0	10	6	
323	32	32S	06E	1317	2840	2927	00	69	13			0	2	0	
142	05	32S	06E	1338	2751	2836	02	65	15			0	2	6	
143	10	32S	07E	1377	2614	2691	00	56	15			3	14	0	
224	21	32S	07E	1323	2604	2682	00	57	14			0	6	0	
022	04	32S	08E	1438	2463	2540	06	52	15			2	0	0	
411	18	32S	08E		1311	1366	07	27	16			4	4	4	
211	34	32S	08E	1075	2096	2169	02	55	13			2	9	9	

QTR	SEC	TWP	RGE	DATUM	TOP	BASE	BH	KINN	IP-A	LAG	BEV	SS#1	SS#2	MSSZ	UPPSS
					CHER	ARD									
442	20	32S	09E	1084	1963	2038	03	55	13				0	4	0
134	13	32S	09E	1074	1852	1923	00	52		04	11	0	0	0	2
323	17	32S	09E	1101	1985	2057	04	52	13			0	0	0	0
444	32	32S	09E		1985	2049	00	47		04	10	0	0	3	0
004	28	32S	10E	1074	1684	1745	06	20	17				0	0	0
113	02	32S	10E		1726	1790	00	46	11				0	0	6
444	04	32S	10E	1095	1753	1819	03	47		04	10		0	0	0
124	08	32S	11E	1066	1604	1668	07	21	16				0	0	0
232	31	32S	11E	1095	1646	1706	13	26	16				0	8	0
214	06	32S	11E	1013	1603	1668	05	43	12				0	0	0
121	17	32S	11E		1622	1685	07	37	14				0	0	0
134	20	32S	11E	1008	1567	1628	09	32	14				0	1	0
312	18	32S	11E	1071	1622	1686	09	37	16				1	0	0
233	04	32S	11E	1097	1642	1705	03	40	13				1	0	0
312	21	32S	12E	1052	1460	1516	11								
032	14	32S	12E	913	1210	1256	13	14	10				0	3	0
211	03	32S	12E		1258	1322	05	39	15				0	0	0
441	06	32S	13E		1257	1318	11	30	16				3	6	0
322	26	32S	13E	940	873	918	09	10	18				2	0	0
211	32	32S	14E	851	1044	1090	11	08	20				4	0	0
014	06	32S	15E	922	1011	1049	09	11		08	14	0	0	0	0
234	35	32S	15E	791	794	844	09	09	26				2	0	0
004	01	32S	16E		682	735	10	17		07	10	0	0	0	0
114	16	32S	16E		745	795	09	11	21				5	0	0
422	17	32S	16E	771	677	728	10	12	21				10	0	0
442	19	32S	16E	760									10	0	0
004	08	32S	16E		667	717	09								
000	26	32S	17E	831	520	588	06	18		11	14	4	0	0	0
123	02	32S	17E		524	673	04						55	0	0
332	03	32S	17E		515	613	08	20					66	0	0
311	09	32S	17E		546	610	08	20		19	08	3	0	2	0
113	34	32S	18E		463	539	11	30		12	16	2	3	0	0
422	08	32S	22E	895	6	108									
323	10	33S	02E	1138	3110	3177	00								
112	33	33S	03E	1114	3107	3191	00	65	14				2	6	2
234	14	33S	03E	1163	3117	3208	00								
004	23	33S	04E	1095	2836	2935	00								
221	13	33S	04E	1117	2845	2960	00	80	30				6	2	3
442	10	33S	05E	1256	2822	2913	00	73	14				4	0	4
021	14	33S	05E	1191	2782	2872	00	74	14				0	0	0
012	35	33S	05E	1257	2860	2948	00	71	13				0	2	0
322	18	33S	06E	1307	2832	2919	00	67	13				0	2	2
023	07	33S	06E	1284	2808	2894	00	68	14				0	0	0
421	36	33S	06E	1179	2486	2566	00	61	14				0	0	6
332	06	33S	07E	1304	2634	2714	00	61	14				0	2	4
021	18	33S	07E	1179	2444	2524	00	58	14				0	2	3
331	21	33S	08E	1235	2459	2531	00	52		03	09	0	0	2	4
432	08	33S	08E	1033	2207	2280	00	56	13				0	2	4
442	25	33S	08E	1014	2032	2098	00	38	13				0	0	9
124	28	33S	08E	1054	2239	2307	02	49	13				0	4	4
131	07	33S	09E	1064	2028	2102	02	53	13				0	4	2
004	05	33S	09E	1051	1948	2018	04	57	13				0	4	0
023	14	33S	09E	1106	2022	2088	13								
001	14	33S	09E	1072	1935	1991	08	30	11				0	1	0
332	16	33S	10E		959	1654	1710	03							
114	02	33S	10E	1020	1707	1768	13	07		16	18	0	4	0	0
331	20	33S	11E	1018	1638	1682	08								
111	19	33S	11E		1590	1639	07	08		09	16	0	1	0	0
322	30	33S	11E		1606	1653	10	10		05	12	0	0	3	0
224	18	33S	12E	810	1300	1354									
002	14	33S	12E	934	1220	1266	13	06	19				0	0	0
113	10	33S	13E	822	1182	1228	12	08	18				0	0	0
421	25	33S	13E	847	1120	1164	11								
334	13	33S	14E		940	987	11								
442	35	33S	14E		998	1046	12	07		07	15	0	0	0	0

Oklahoma Well Logs

QTR	SEC	TWP	RGE	DATUM	TOP	BASE	BH	KINN	IP-A	LAG	BEV	SS#1	SS#2	MSSZ	UPPSS
					CHER	ARD									
341	15	24N	03E	958	3416	3458	06	16	14				2	0	0
042	34	24N	03E	1020	3523	3572	06	23	16				4	0	0
041	08	24N	03E	1073	3610	3650	06	15	14				0	0	0
111	03	24N	04E	1008	3180	3216	06	12	12				3	0	0
314	23	24N	04E	915	3194	3242	05	24	14				0	0	0
312	16	24N	04E	1012	3234	3274	05	16	13				0	0	0
322	34	24N	05E	876	2783	2824	04	16	14				0	0	0
013	16	24N	05E	874	2879	2918	06	10	17				0	0	0
043	05	24N	05E	870	2887	2925	07	09	17				2	0	0
012	24	24N	06E	895	2461	2498	07	05	18				0	0	0
122	03	24N	06E	1019	2628	2664	07	06	17				3	0	0
003	31	24N	06E	899	2746	2784	06	12	19				3	0	0
421	22	24N	07E	947	2240	2288	04	14	21				0	0	0
003	12	24N	08E	950	2002	2045	06	06	25				0	0	0
212	01	24N	08E	1087	2146	2190	05	08	25				66	0	0
333	35	24N	08E	846	1946	1995	05	05	32				6	0	0
023	23	24N	08E	944	2015	2060	05	08	27				5	0	0
013	21	24N	09E	984	1982	2034	05	05	32				0	0	0
441	35	24N	09E	924	1869	1927	05	05	44				0	0	0
343	15	24N	09E	909	1804	1855	06	05	35				0	0	0
113	03	24N	09E	931	1778	1824	07	05	30				2	0	0
032	36	24N	10E	776	1328	1376	11	10	23				1	0	0
001	05	24N	10E	895	1675	1733	04	02	45				9	0	0
223	21	24N	10E	801	1614	1676	05	03	48				4	0	0
242	30	24N	10E	914	1809	1867	06	02	43				3	0	0
004	09	24N	11E	821	1356	1418	04	04	46				0	0	0
444	16	24N	11E	770	1313	1378	05	04		18	34	2	3	0	0
004	29	24N	11E		1196	1262	04					0	4	0	0
233	04	24N	11E	890	1490	1549	05	03	47			0	2	0	0
124	31	24N	12E	873	1276	1344	05					7	0	0	0
443	04	24N	12E	874	1184	1265	04	04		17	49	34	0	0	0
002	22	24N	12E	880	1219	1284	04	03		16	34	9	0	0	0
000	35	24N	12E		1242	1311	05	04		18	38	0	0	0	0
211	21	24N	13E	710	926	1009	05								
311	19	24N	13E	718								0	5	0	0
311	35	24N	14E		470	536	06	03	47			3	0	0	0
142	18	24N	14E	625	634	702	05	03	55			7	0	0	0
321	08	24N	14E	670	662	732	06	03	53			11	0	0	0
311	21	24N	15E	703	439	497	07	03	41			4	0	0	0
124	33	24N	16E	668	387	444	07	03	40			2	0	0	0
322	24	24N	16E		3	54	08	03	38			2	0	0	0
422	32	25N	03E	911	3428	3466	07	12	13				0	0	0
000	14	25N	03E	1046	3355	3392	09	11	13				3	1	0
332	04	25N	03E	991	3310	3347	08						2	3	0
014	08	25N	04E	1088	3244	3279	08								
042	34	25N	04E	1005	3156	3191	05	10	13				0	0	0
011	16	25N	04E	1003											
312	21	25N	05E	975	2866	2900	08	07	14				3	0	0
004	06	25N	05E	1035											
214	03	25N	05E	990	2841	2877	07	08	13				0	0	0
231	34	25N	05E	1009	2916	2954	07	08	17				0	0	0
213	12	25N	05E	1027	2827	2863	07	07	15				4	0	0
224	34	25N	06E	1046	2639	2676	07	07	17				6	0	0
324	04	25N	06E	1006	2606	2639	08	08	14				2	0	0
321	22	25N	06E	1064	2664	2698	07	05	16				4	0	0
004	15	25N	06E	989	2580	2616	06	08	16				8	0	0
433	32	25N	07E	997	2468	2508	06	12	17				3	0	0

QTR	SEC	TWP	RGE	DATUM	TOP CHER	BASE ARD	BH	KINN	IP-A	LAG	BEV	SS#1	SS#2	MSSZ	UPPSS
000	06	26N	15E		3027	846	09	04	46			7	0	0	0
043	33	26N	16E		2934	408	09	03	40			9	0	0	0
014	33	26N	17E	675	3089	101	08	03	31			4	0	0	0
414	08	27N	02E	1055		3463		44	23			0	24	0	0
034	29	27N	02E	1028		3490	08	13	17			4	3	0	0
121	22	27N	03E	1151		3066	06	15	12			0	5	0	0
341	01	27N	04E	1070	2934	2973	08	14	12			1	2	0	0
322	28	27N	04E	1082	3089	3123	07	13	11			0	3	0	0
133	13	27N	05E	1097	2822	2859	08	10	12			2	0	0	0
141	32	27N	05E	1095	2910	2942	06	10	11			3	1	0	0
334	34	27N	06E	1040	2615	2647	09	08	10			1	0	0	0
032	14	27N	06E	1119	2634	2669	09	09	11			5	0	0	0
233	32	27N	07E	1219	2638	2674	10	09	11			3	0	0	0
000	12	27N	07E	1108	2234	2293	12					2	0	0	0
434	32	27N	08E	1045	2230	2268	10	08	08			0	0	0	0
341	12	27N	08E	973	1962	2000	14	09	09			0	0	0	0
224	05	27N	08E	1063	2164	2200	14	08	09			1	0	0	0
111	07	27N	09E	1103	2059	2099	13	10	10			0	0	0	0
344	20	27N	09E	962	1900	1940	11	10	12			0	0	0	0
321	33	27N	09E	977	934	976	10	10	16			0	0	0	0
001	14	27N	10E		1570	1628	07	18	28			0	0	0	0
223	06	27N	10E	1033	1742	1790	10	16	18						
432	34	27N	10E	906	1538	1678	06						61	0	0
232	05	27N	11E	880	1465	1522	10	11	28			3	0	0	0
004	16	27N	11E	962	1500	1558	10	11	30			0	0	0	0
000	34	27N	11E		1448	1514	09								
003	34	27N	12E	680	990	1063	06	15		20	23	2	4	0	0
002	28	27N	12E	837	1281	1358	07					2	0	0	0
342	07	27N	12E	845	1361	1427	10	18	32				3	0	0
423	05	27N	13E	715	872	941	09	17		11	25	12	0	0	0
121	06	27N	13E	691	949	1026	10	24		13	26	12	1	0	0
000	35	27N	13E		932	1002	08	12		13	28	0	0	0	0
413	09	27N	13E		891	1036	07					62	0	0	0
244	12	27N	14E		860	923	10								
000	17	27N	14E		912	988	10	07	51			10	0	0	0
000	28	27N	15E		572	636	11								
123	22	27N	15E	736	553	656						43	0	0	0
424	35	27N	15E		470	523	09	06	31			5	0	0	0
312	13	27N	15E		823	965	10					88	0	0	0
044	35	27N	16E	690	267	312	08	05	30			0	0	0	0
444	17	27N	16E		452	504	08	06	30			4	0	0	0
443	04	27N	17E	812	285	336	06	05	34			0	0	0	0
000	08	27N	18E		108	171	06	04	48			6	0	0	0
032	09	28N	02E	1139	3302	3383									
221	27	28N	02E	1123	3218	3392	02	66	06					5	0
000	02	28N	02E		3313	3392	03	69	13					3	0
432	35	28N	03E	1262	2967	3014	05	21	14				2	4	0
333	11	28N	03E	1018	2920	2985	04	46	09				0	6	0
024	03	28N	03E	1108	3006	3082	02	59	12				0	0	0
144	25	28N	04E	1101	2886	2933									
411	09	28N	04E	1129	3000	3042		10							
242	28	28N	05E	1132	2853	2892	10	08	12				1	0	0
414	29	28N	06E	1160	2797	2835	11	08	12				0	0	0
332	36	28N	07E	1205	2384	2420	10	09	11				0	0	0
333	09	28N	07E	1248	2539	2576	11	07	11				0	0	0
003	13	28N	08E	1274	2654	2694	13	08	14				0	0	0
112	16	28N	08E	1066	2150	2186	13	08	11				0	0	0
411	33	28N	08E	1079	2175	2212	13	08	12				0	0	0
222	34	28N	09E	1008	1848	1892	12	08	19				0	3	0
421	03	28N	10E	837	1344	1391	12								
144	29	28N	10E	1026	1704	1754	11	15	20				1	0	0
422	16	28N	10E	894	1552	1603	12	09		11	13	0	1	0	0
423	28	28N	11E	830	1394	1450	11	14		13	12	0	0	0	0
001	13	28N	11E	882	1388	1444	11	16		12	12	0	0	0	0
001	08	28N	12E	713	1150	1212	10	19	25				6	0	0

QTR	SEC	TWP	RGE	DATUM	TOP CHER	BASE ARD	BH	KINN	IP-A	LAG	BEV	SS#1	SS#2	MSSZ	UPPSS
003	33	28N	12E	883	1290	1353	13	23	21			0	0	0	0
002	02	28N	13E		1009	1064	12					3	0	0	0
444	12	28N	13E	850	991	1149	10					82	0	0	0
000	36	28N	13E		1055	1126	12	13		16	23	0	0	0	0
000	08	28N	14E	842	1024	1176	13	04				66	0	0	0
324	30	28N	14E	809	943	1006	14	09		13	20	0	0	0	0
143	05	28N	15E		788	935	11	18				71	0	0	0
444	06	28N	15E		798	974	11	17				86	0	0	0
421	07	28N	15E		826	985	11	13				41	0	0	0
000	17	28N	15E		824	898	07					6	0	0	0
044	24	28N	16E		384	438	06	06				5	0	0	0
241	15	28N	16E	699	357	407	10	14	20			2	0	0	0
002	08	28N	16E	759	493	555	08	20	27			0	4	0	0
323	06	28N	16E		578	649	08	20		16	22	2	9	0	0
111	30	28N	17E		379	438	06	06	41			2	0	0	0
113	07	28N	17E		381	442	06	08	40			16	0	0	0
442	04	28N	18E	848	202	257	06	07	33			2	0	0	0
000	18	28N	18E		229	298	05	04	55			5	0	0	0
000	30	28N	18E	800	219	275	06	05	37			4	0	0	0
113	15	28N	19E	905	70	131	06	06	42			1	0	0	0
041	22	28N	19E	888	56	116	05								
234	13	29N	02E	1140				74	10				0	5	0
112	21	29N	03E	1136	3018	3103	04	60	09				0	5	0
424	17	29N	04E	1206	2920	2994									
342	33	29N	04E	1199	3004	3064									
000	20	29N	04E	1187											
032	14	29N	05E	1226	2699	2746	09	21	12				2	1	0
011	13	29N	05E	1215	2715	2763	08	22	11				0	1	0
444	22	29N	06E	1249	2706	2746	12	10	10				3	2	0
443	32	29N	06E	1155	2667	2707	12	11	12				0	0	0
223	35	29N	07E	1328	2530	2565	11	07	11				0	0	0
421	17	29N	07E	1282	2573	2612	11	10	12				1	0	0
224	34	29N	08E	986	2013	2052	10	08	13				3	0	0
241	31	29N	09E	1002	1923	1960	11	06	15				0	0	0
432	16	29N	09E	958	1813	1856	10	07	19				2	0	0
344	36	29N	10E	797	1314	1361	12	12		10	09	0	6	0	0
000	16	29N	10E		1374	1420	12	07		12	09	0	0	0	0
133	21	29N	12E	777	1207	1266	10	18		09	12	0	0	0	0
231	33	29N	12E	746	1182	1243	11	20		10	13	0	6	0	0
434	34	29N	13E		996	1051	16	06		11	14	0	3	0	0
222	24	29N	13E	790	924	977	18	06		09	16	4	3	0	0
433	16	29N	14E	950	1050	1104	16	09		05	20	1	0	0	0
000	29	29N	14E		927	988	14	10		07	23	11	1	0	0
421	35	29N	15E		572	642	10	08		25	18	2	0	0	0
412	25	29N	17E	868	294	346	08	12	26			11	0	0	0
244	33	29N	18E	860	200	254	09	07		07	26	5			