HIERARCHAL GENETIC STRATIGRAPHY OF THE NEVA LIMESTONE MEMBER OF THE GRENOLA LIMESTONE AND ESKRIDGE SHALE (LOWER PERMIAN) IN NORTHEASTERN KANSAS

by

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INTRODUCTION

Traditionally most studies of mid-continent stratigraphy have relied upon the identification of lithostratigraphic units, first termed cyclothems by Wanless and Weller in 1932. This term was used to describe the prevalent limestone-shale-limestone sequences of the mid-continent region. Weller (1930) suggested that cyclothemic sequences resulted from transgressions and regressions of epi-continental seas which may have been due to eustatic sea-level changes or tectonic effects, or a combination of the two.

Moore (1936) proposed the "ideal cyclothem" for Pennsylvanian rocks which included nine lithofacies in sequence thereby depicting an "ideal" transgressive-regressive cycle. Moore and Merriam (1959) later expanded this theory to describe "ideal cyclothems" of Permian age which contained red shales and evaporites, while lacking sandstones and coals. Heckel (1977) modified this concept by emphasizing late Paleozoic, mid-continent tectonics and proposed the "Kansas cyclothem" as a model which could prove useful in correlating transgressive-regressive sequences.

In practice, cyclothemic stratigraphy correlates rhythms or cycles of sedimentation. This method defines transgressive-regressive (T-R) units about 5-30 meters thick representing about 400,000 years; however it does not account for other scales of T-R units, and places little importance on non-marine facies.

Anderson and Goodwin (1980) ushered in a new era of stratigraphy when they suggested that the basic building blocks of sedimentation were small 1-5 meter upward shallowing genetic packages representing tens of thousands of years that they termed punctuated aggradational cycles (PACs). Busch and Rollins (1984) suggested that a more suitable framework for genetic stratigraphy should utilize a hierarchy of genetic stratigraphic units. Their hierarchy included six scales of T-R units (Fig. 1) wherein "Kansas cyclothems" are roughly equivalent to 5th order T-R units, while "PACs" can be 6th-order T-R units.

Hierarchal genetic stratigraphy correlates events such as deepenings, shallowings, and climate changes as defined by inspection of all lithofacies and biofacies, their facies contacts, and their relative relationships. This correlation of genetic T-R units is accomplished by aligning patterns in the hierarchy among different geographic locations relative to marker beds, or biozones (Busch and West, 1987). This method is thus more effective in correlating across lithofacies boundaries and developing paleogeography within a basin of deposition.

By example, previous authors (Busch et al., 1985, 1988, West, 1988, T. Barrett, 1989, Leonard, 1988, F. Barrett, 1989, and Clark, 1988) have shown it is possible to

HIERARCHY OF PERMO-CARBONIFEROUS T-R UNITS

BUSCH & ROLLINS, 1984 AND BUSCH, 1984	VAIL *et al.*, 1977	CHANG, 1975 AND RAMSBOTTOM, 1979	MOORE, 1936	GOODWIN AND ANDERSON, 1985	HECKEL, 1977 AND HECKEL, 1986	WANLESS AND WELLER, 1932
FIRST-ORDER 225-300 Ma	FIRST ORDER DEPOSITIONAL SEQUENCES					
SECOND-ORDER 20-90 Ma	SECOND ORDER DEPOSITIONAL SEQUENCES	SYNTHEMS				
THIRD-ORDER 7-13 Ma	THIRD ORDER DEPOSITIONAL SEQUENCES					
FOURTH-ORDER 0.6-3.6 Ma		MESOTHEMS				
FIFTH-ORDER 300-500 ka		CYCLOTHEMS	MEGACYCLOTHEMS	SHALLOWING PAC SEQUENCES	KANSAS CYCLOTHEMS; MAJOR CYCLES	CYCLOTHEMS
SIXTH-ORDER 50-130 ka			CYCLOTHEMS	PUNCTUATED AGGRADATIONAL CYCLES (PACs)	MINOR CYCLES	

Figure 1. Hierarchy of Permo-Carboniferous T-R units as utilized in this study (modified from Busch and Rollins, 1984).

delineate a hierarchy of genetic transgressive-regressive units for the late Paleozoic rocks of Kansas. This investigation utilizes this method, genetic stratigraphy, in an attempt to better understand the Neva Limestone Member of the Grenola Limestone and the Eskridge Shale, both temporally and spatially.

Purpose and Objectives

This study examines an interval of Permian strata in northeastern Kansas using hierarchal genetic stratigraphy (Busch and Rollins, 1984, Busch and West, 1987). Fifth- and sixth-order T-R units of the Busch and Rollins (1984) hierarchy (Fig. 1) will be considered. Objectives of the study are to: (1) define the genetic stratigraphic boundaries containing the Neva-Eskridge interval, (2) delineate sixth-order T-R units within the Neva-Eskridge interval at closely spaced localities over parts of five counties in northeastern Kansas, (3) devise an onshore to offshore biofacies scheme (after Brezinski, 1983) for the Neva-Eskridge interval,(4) construct detailed paleogeographic maps for times of maximum transgression relative to each sixth-order T-R unit recognized, and (5) deduce any sea-level and cryptic structural controls on sedimentation within the proposed study interval relative to the paleogeographic maps and paleoecological data. The paleogeographic maps at the level of sixth-order T-R units will suggest sea-level and structural controls on sedimentation that is more precise than most previous studies of the Permian in Kansas. The paleogeographic maps will also provide information about the extent of paleosols, lacustrine facies, alluvial deposits, and climate change surfaces (Busch and West, 1987) within the study interval.

Isopach maps of the Neva-Eskridge transgressive and regressive hemicycles will suggest relationships between pre-existing structural controls and the development of the Neva Limestone-Eskridge Shale interval within the basin of deposition.

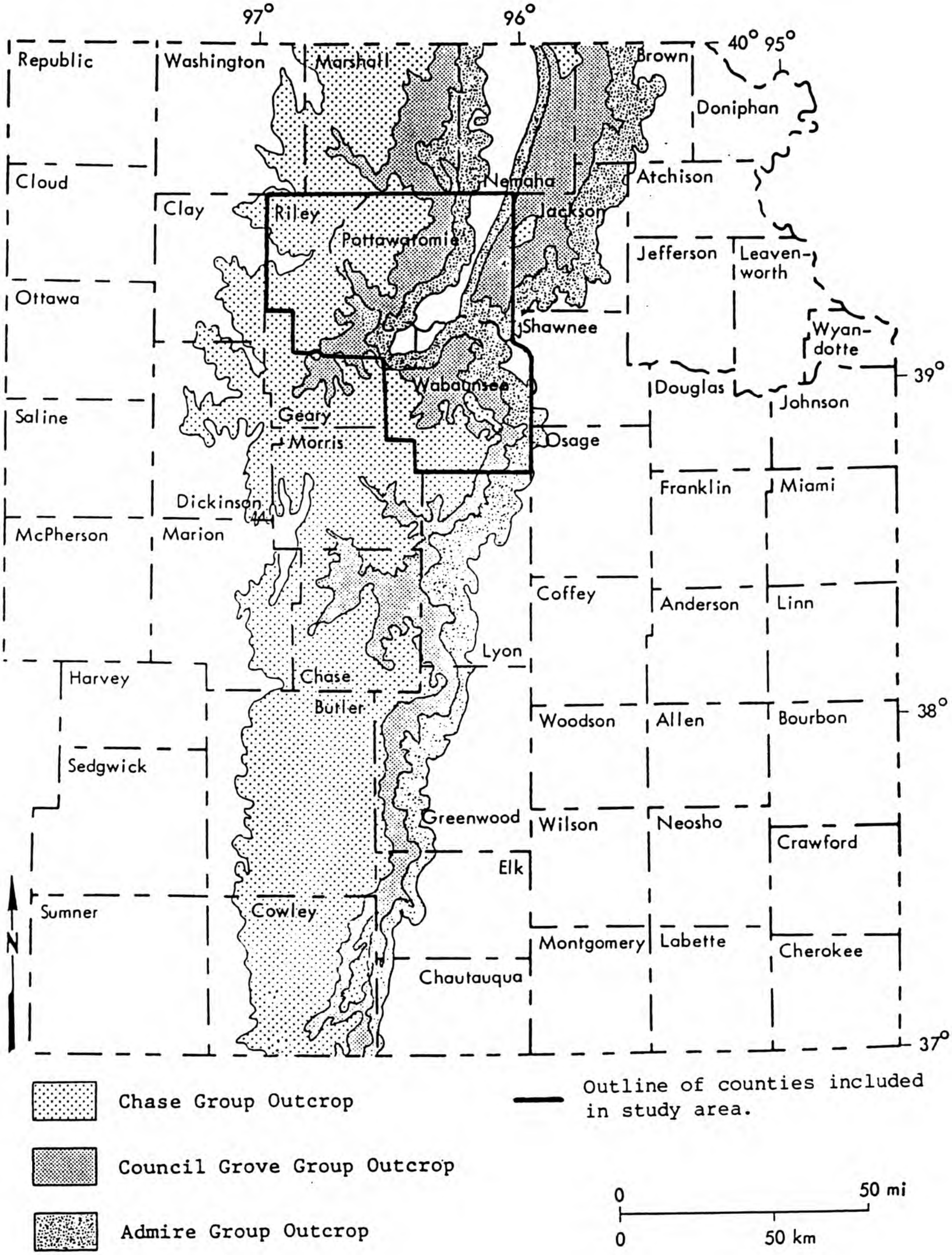
Due to its thickness, relative massiveness, and the porous and permeable zones it contains, the Neva Limestone Member is the most economically important member of the Council Grove Group. In northeastern Kansas it is extensively quarried for both road metal and building stone, and, where encountered in the subsurface, the Neva can be a prolific aquifer. The improved stratigraphic resolution evaluated in this study can provide a temporal-spatial framework for improved understanding of paleoceanography and increase our ability to predict the location of economic earth resources.

Area of Investigation

This study is concentrated within a three county area of northeastern Kansas. Excellent exposures of rocks of the Council Grove Group are available in the counties of Riley, Wabaunsee, and Pottawatomie (Fig. 2). One measured section, in extreme northwestern Jackson County, Kansas, was also included. Measured sections in Morris and Chase counties were used in an effort to correlate to the type locality of the Neva Limestone near Elmdale in Chase county (see Appendix B, Locality #31).

The area of study lies within the Great Plains physiographic province and more specifically within the north-northeast trending Flint Hills subprovince. This subprovince derives its name from the abundance of chert (flint) found within the escarpment forming limestone units.

Figure 2. Map view of outcropping Lower Permian aged rocks in eastern Kansas (modified from Aber and Grisafe, 1982).



Geologic Setting

Previous Work.--The first published reports by early Kansas reconnaissance geologist G.C. Swallow (1866) included a "bed 84" which was described as the "dry bone limestone". This "bed 84" was later to be incorporated into the Neva Limestone Member. Early on, the Neva Limestone Member was involved in the Pennsylvanian-Permian boundary dispute as Swallow (1866) interpreted the "dry bone" limestone to represent the base of the Permian System. Consequently, Beede (1914) suggested the base of the Permian system should be at least 70 to 75 feet lower than the Cottonwood Limestone, so as also to include the Neva Limestone Member, which he mistakenly suggested contained the first appearance of Schwagerina. Moore and Moss (1934) provided evidence of a discontinuity and, combined with biotic and lithologic changes, defined the presently accepted boundary at the base of the Indian Cave Sandstone member of the Towle Shale (Admire Group).

Prosser (1895) formally named the Neva Limestone after the natural exposures found at the junction of the Diamond Creek and Cottonwood River valleys near the Neva railway station in Chase County, Kansas. He described the Neva as occurring 11 to 31 feet below the base of the then called Manhattan (Cottonwood) Limestone. Noting that the exposures near Neva did not display the lower part of the section, Condra and Busby (1933) suggested that a more suitable type locality would be found along a road cut 3/4 mile east of Elmdale in Chase County, Kansas (see Appendix B, Locality #31).

The Eskridge Shale was formally named by Prosser (1902) from exposures in the vicinity of Eskridge, Wabaunsee County, Kansas. The suggested type locality is located in a pasture one and one quarter miles south of Eskridge and displays only the upper half of the formation. A much more complete exposure occurs at Lake Wabaunsee in Wabaunsee County, Kansas (see Appendix B, Locality # 4).

Prosser (1895) originally included the Neva Limestone and Eskridge Shale as the upper members of his Wabaunsee Group (Fig. 3). Haworth (1896, p. 162) noted the importance of the Neva as follows: "Throughout the whole of the Wabaunsee Formation only one limestone is of any special interest, the heavy coarse looking system (Neva) lying 30 feet below the Cottonwood rock..."

Elias (1937) described the fossils associated with the lithologic sequences which compose the Lower Permian cycles of Kansas. He recognized seven non-marine through open marine facies and suggested that the repeated lithologies and biotas of the cycles were primarily controlled by water depth during deposition. He further postulated that the lower fusulinid rich shales of the Neva represented a water

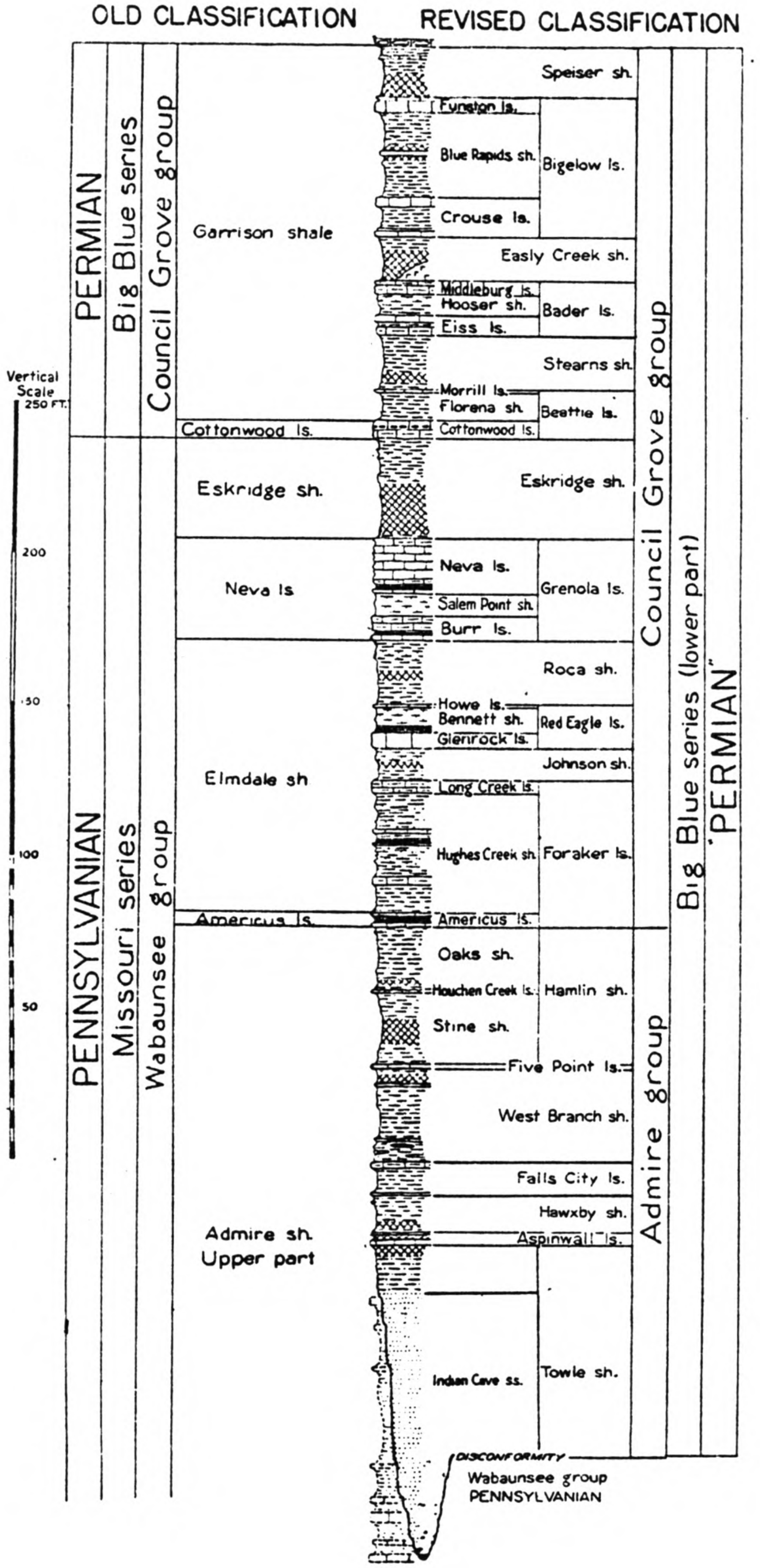


Figure 3. Old and revised classifications for Permo-Carboniferous rocks of Kansas (from Moore, 1936).

depth of between 160 and 180 feet, which he suggested represented the transgressive apex of the transgressive hemicycle. He interpreted the regressive hemicycle of the Eskridge Shale as representing a rapid retreat of the Grenola sea (Fig. 4). McCrone (1963) in his study of the underlying Red Eagle Cyclothem agreed that the depositional environments of the cyclothemic phases were principally controlled by water depth. However, he concluded that the Red Eagle Cyclothem was deposited in water depths ranging from intertidal to not more than 60 feet.

Wells (1950) recognized within the Eskridge Shale, two minor depositional cycles, based on two limestone zones and intervening red shale, within a major cycle. He stated that the variation of these near-shore deposits represented shoreline fluctuations in both the shoreward and seaward directions (Fig. 5). However, using lithostratigraphic methods he concluded that he could not directly correlate his minor cycles over wide areas. Pecchioni (1980) also encountered difficulty in using a cyclothemic approach in correlating units within the Eskridge Shale. She suggested that this was due to rapid lateral changes within the depositional environment. Pecchioni ascribed these changes to a series of fluvial-deltaic complexes which developed at the time of Eskridge deposition.

Laporte (1952) devised a scheme of biofacies development for the Cottonwood Limestone of the mid-continent. He

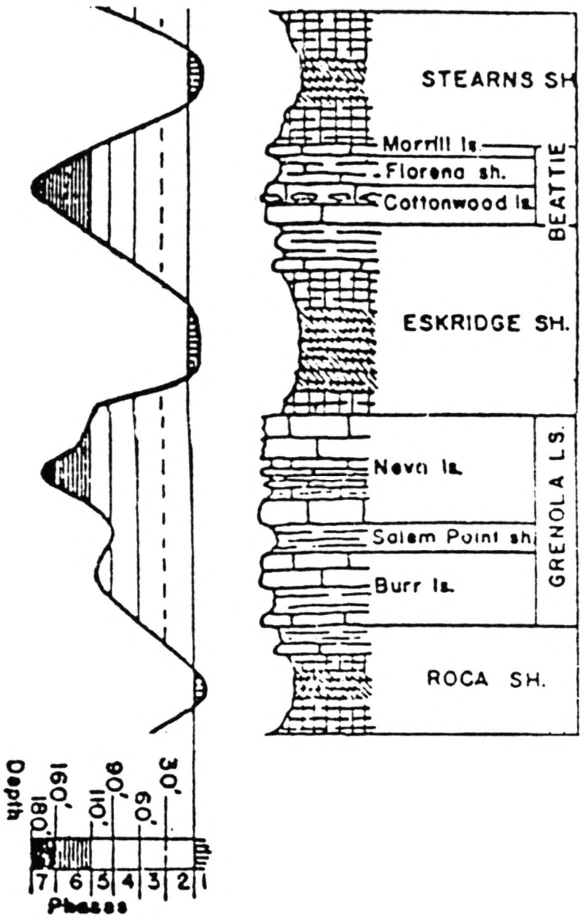


Figure 4. Composite geologic section of part of the Big Blue Series in northern Kansas, interpreted in terms of cyclic sedimentation and depth of deposition (modified from Elias, 1937).

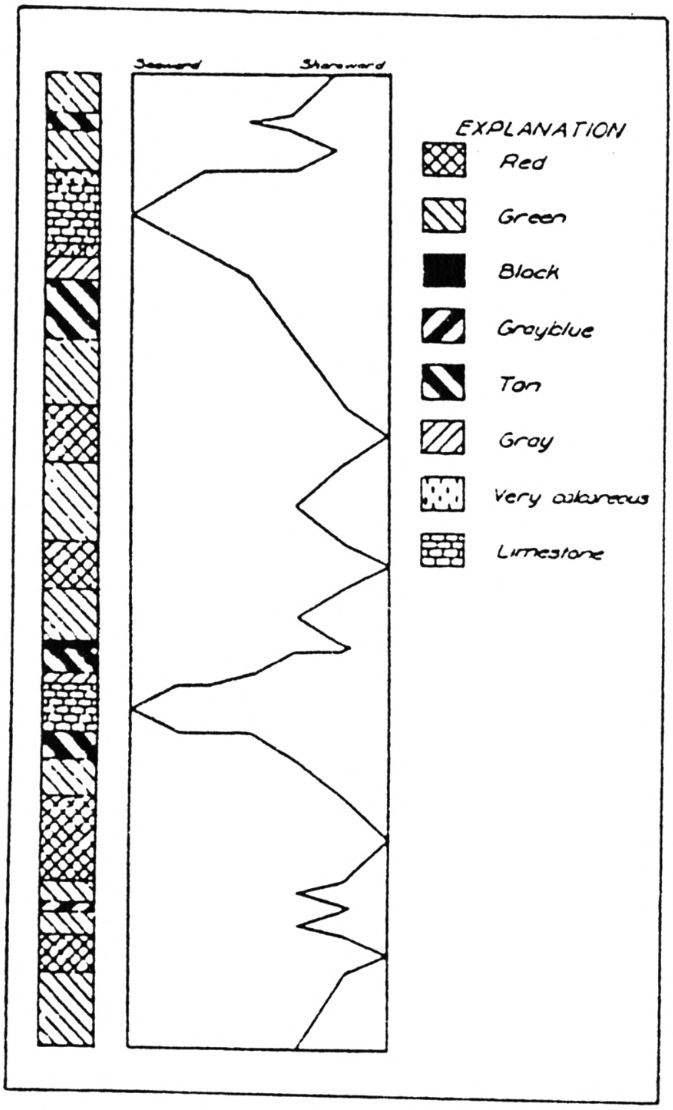


Figure 5. Generalized section of the Eskridge Shale with sea level curve to illustrate relative distance from shore (from Wells, 1950).

suggested the Greenwood Shoal of southeastern Kansas was an existing paleogeographic feature at the time of Cottonwood deposition. He based his assumption on the litho- and biofacies changes he observed across that feature. He concluded that water depth and its influence on turbulence, terrigenous influx, and circulation were the chief causes of facies differentiation within the Cottonwood Limestone.

Moore (1964) sketched his view of Late Eskridgean paleogeography (Fig. 6) and suggested that unpredictably large fluctuations of sea borders must have occurred in passing from Eskridge-type to Beattie-type paleogeography. He also envisioned the initial transgression of the Cottonwood sea to have covered all parts of Kansas (Fig. 7) and that each successsive unit above the Cottonwood Limestone Member (i.e. Florena Shale Member, Morrill Limestone Member, Stearns Shale) was deposited by a retreating shallow sea.

Other important paleoecological studies of Lower Permian rocks were conducted by Lane (1964), and Sanderson and Verville (1988). Lane observed gradual biotic changes upward through the Council Grove Group and related them to gradual restriction of the marine basin of deposition combined with the expansion of areas of non-marine deposition. Sanderson and Verville observed that the fusulinids of the Neva Limestone Member are predominently represented by by various species of Leptotriticites.

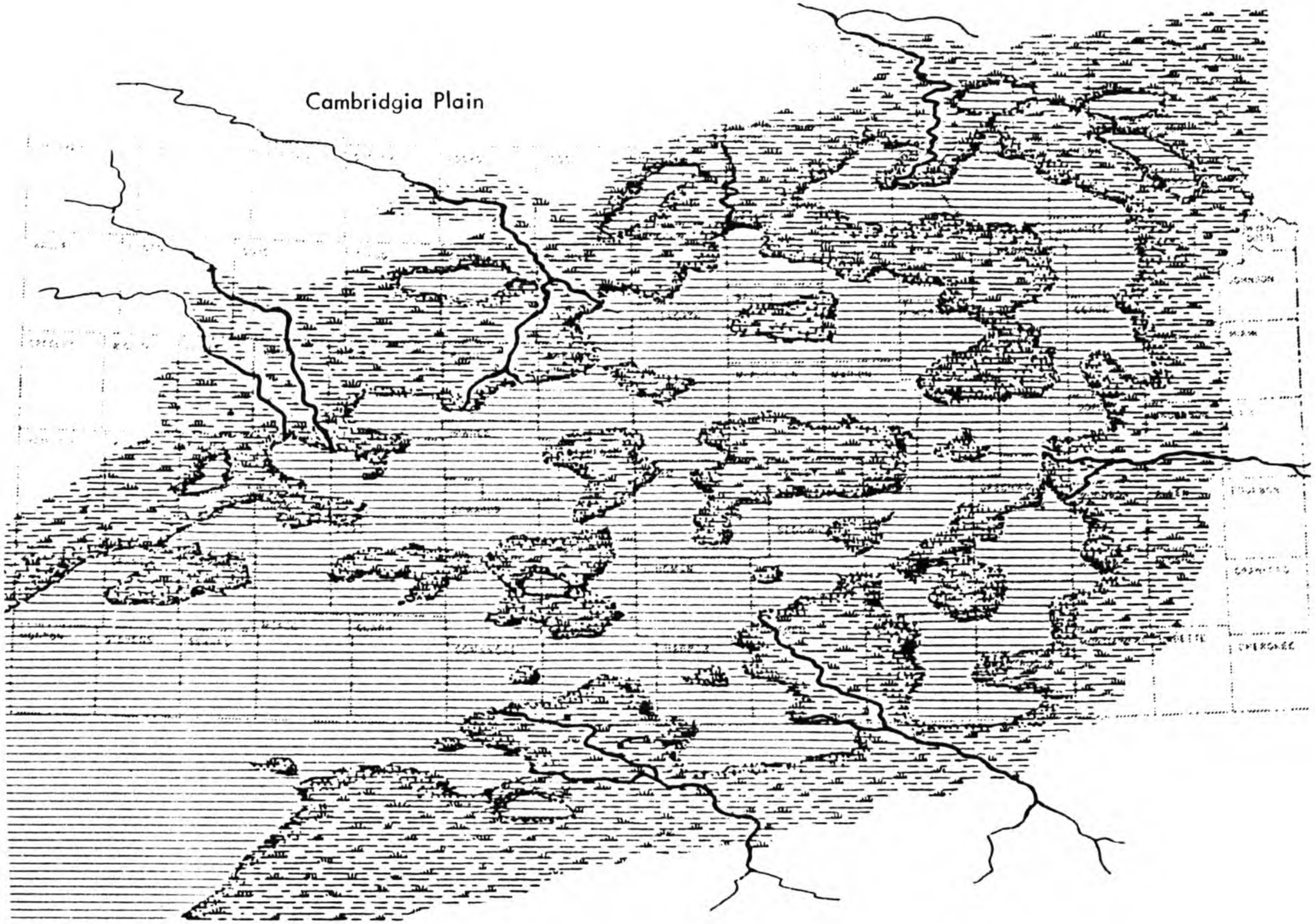


Figure 6. Paleogeography of early part of Beattie cyclothem (late Eskridge), (from Moore, 1964).

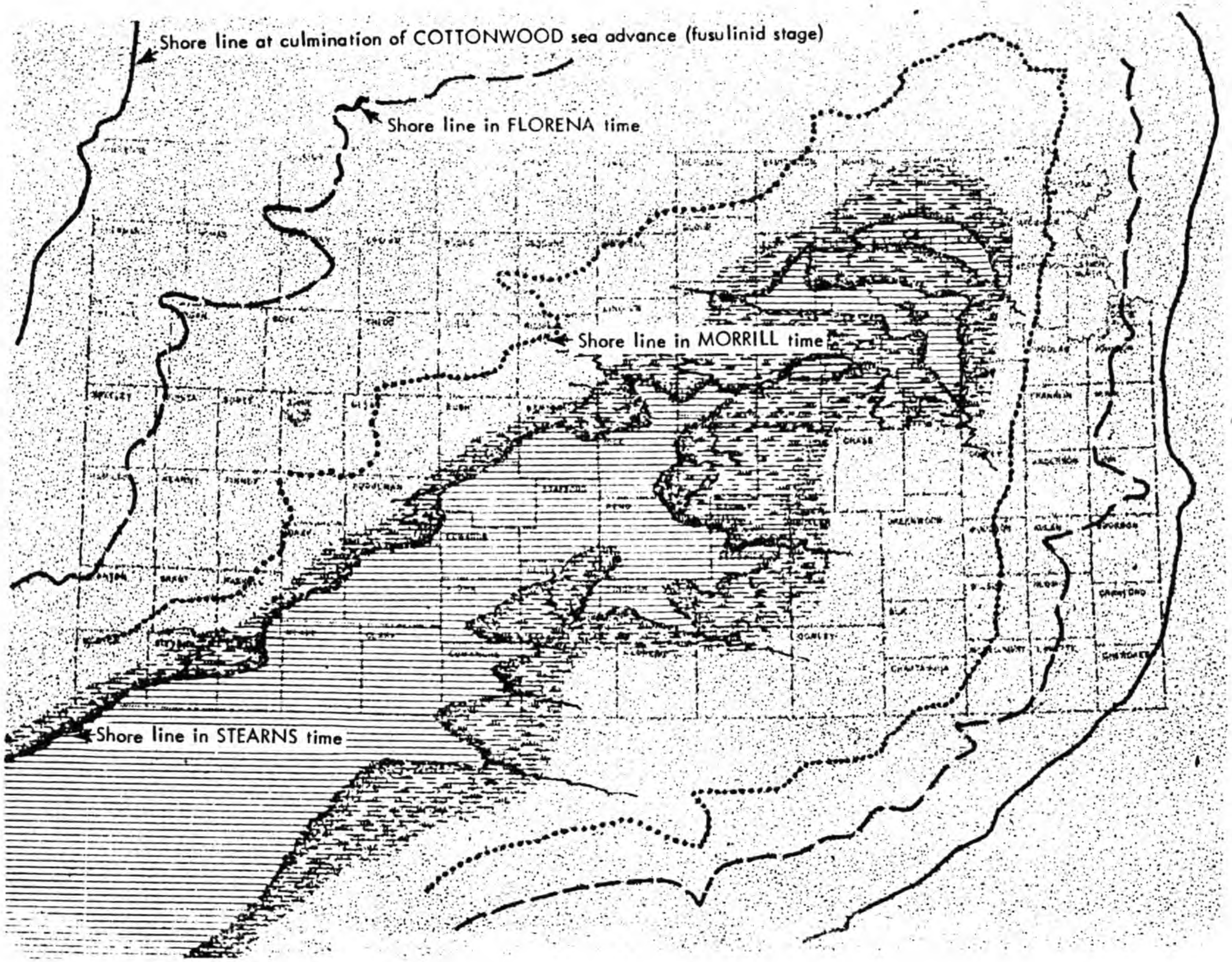


Figure 7. Shoreline development of the members of the Beattie cyclothem (from Moore, 1964).

Formal Lithostratigraphy.--The Council Grove Group is composed of approximately 320 feet of interbedded limestone and shale. The limestone units, in general, are less massively bedded and thinner than those that occur in the overlying Chase Group (Zeller, 1968). The Council Grove Group lies in the middle of three groups of Lower Permian rocks. Joined with the subjacent Admire Group and the superjacent Chase Group they comprise the Gearyan Stage (Fig. 8). O'Connor (1963) suggested that the Gearyan Stage and the overlying Cimmarronian Stage represent all rocks within the Lower Permian Series in Kansas.

The Neva-Eskridge interval encompasses parts of two formations of the Council Grove Group. The Neva Limestone is the uppermost and most prominent of the five members of the Grenola Limestone. This formation includes three limestone and two shale members and ranges in thickness from 32 to 54 feet. As first described by Condra and Busby (1933), the Grenola Limestone consists of the following members (descending order): Neva Limestone, Salem Point Shale, Burr Limestone, Legion Shale, and the Sallyards Limestone. The Grenola Formation (Fig. 9) is bounded by the underlying Roca Shale and the overlying Eskridge Shale. This division of rocks into mappable units, formations, is based primarily upon lithology. The Eskridge Shale has as its upper boundary the Cottonwood Limestone Member of the the Beattie Limestone.

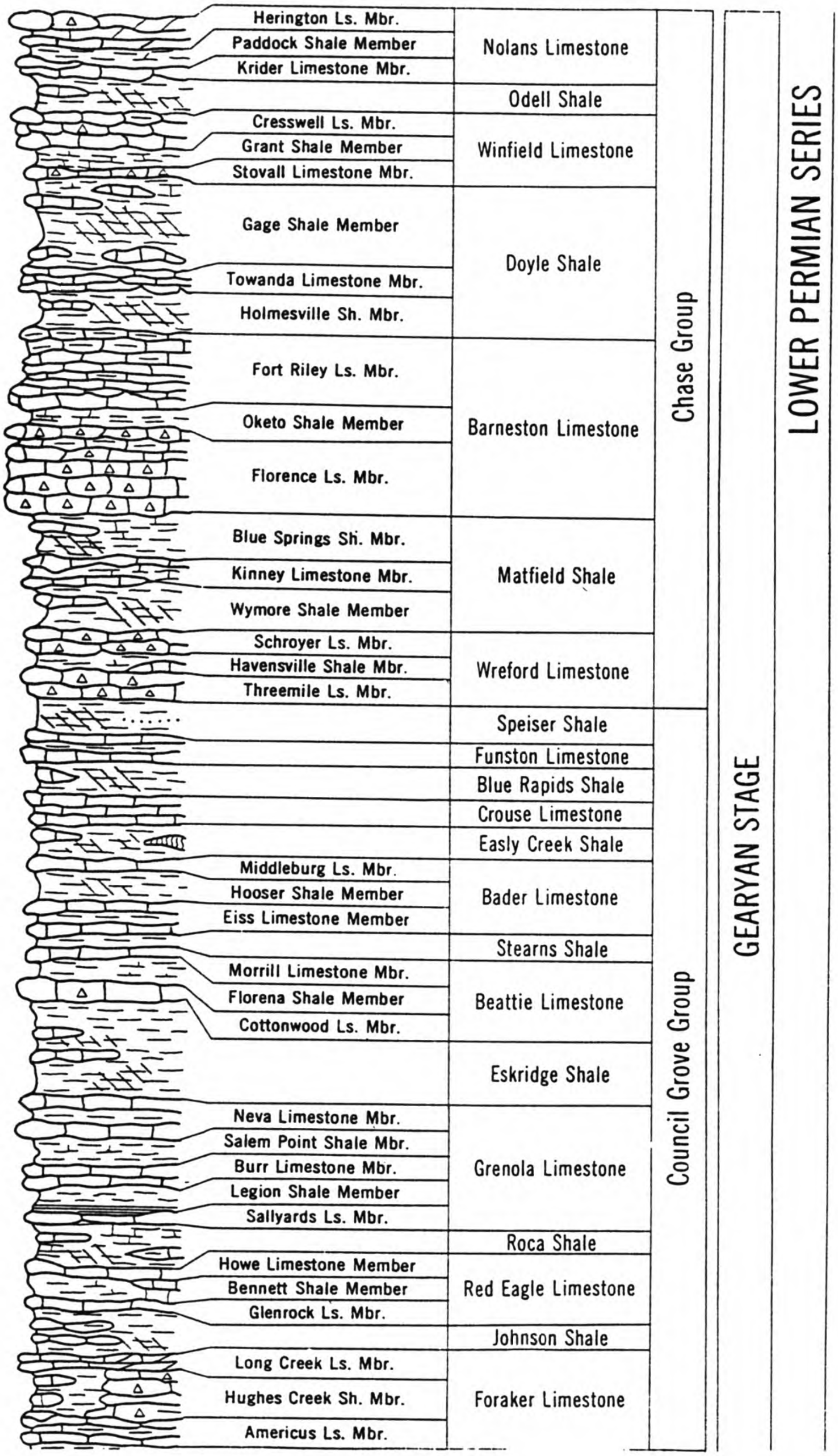


Figure 8. Classification of the Gearyan Stage of the Lower Permian Series in Kansas (from Zeller, 1968).

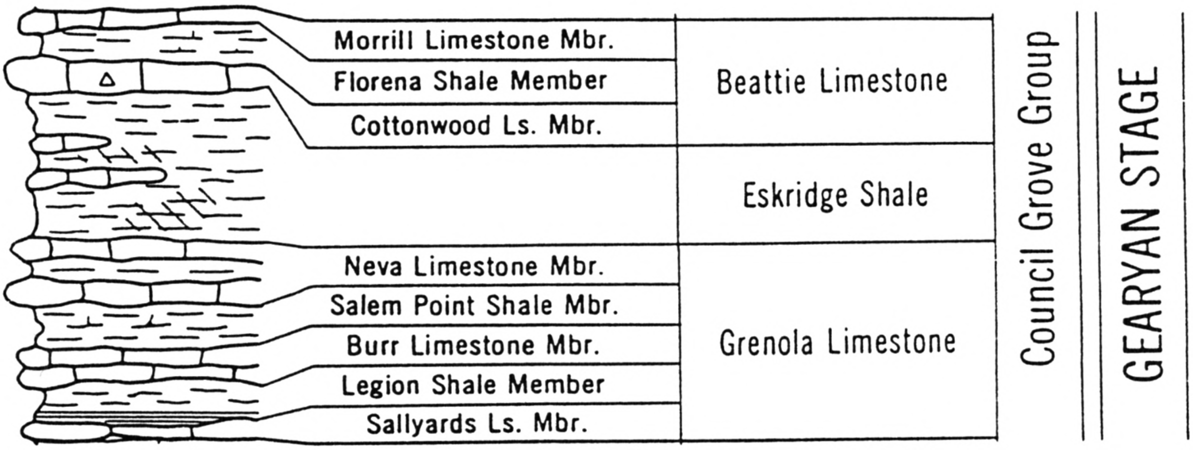


Figure 9. Classification of members and formations that lie within the interval studied (from Zeller, 1968).

<u>Outcrop Occurrence and Characteristics</u>.--The Neva Limestone and Eskridge Shale crop out from southeastern Nebraska south along most of the distance across east-central Kansas, beyond which it is exposed southward into Oklahoma. The easternmost exposures trend along a NE-SW strike from which the formations dip regionally westward (Condra and Busby, 1933). Drilling records have traced the Neva Limestone and Eskridge Shale across western Kansas and into eastern Colorado, and north-central Oklahoma.

Mudge and Yochelson (1962) reported that the Neva Limestone maintained an average thickness of 17 feet across Kansas. They reported that the Neva ranged in thickness from 9 feet in Lyon County, Kansas (center of the outcrop belt) to 28 feet in Cowley County, Kansas (near southern end of outcrop belt). Prosser and Beede (1902, p. 2) stated, "the Neva is frequently a massive blue-grey stratum, 7 or more feet in thickness, often breaking down along the outcrop into large blocks having steep angles and rough, jagged surfaces and weathering to a surface not dissimiliar to that of bleached bones." An idealized diagram for the Neva member (Fig. 10) was suggested by Mudge and Yochelson (1962) as consisting of seven units of interbedded limestone and shale that could be traced for a considerable distance.

The Eskridge Shale as reported by Mudge and Yochelson (1962) averages 31 feet in thickness and ranges from 22.5

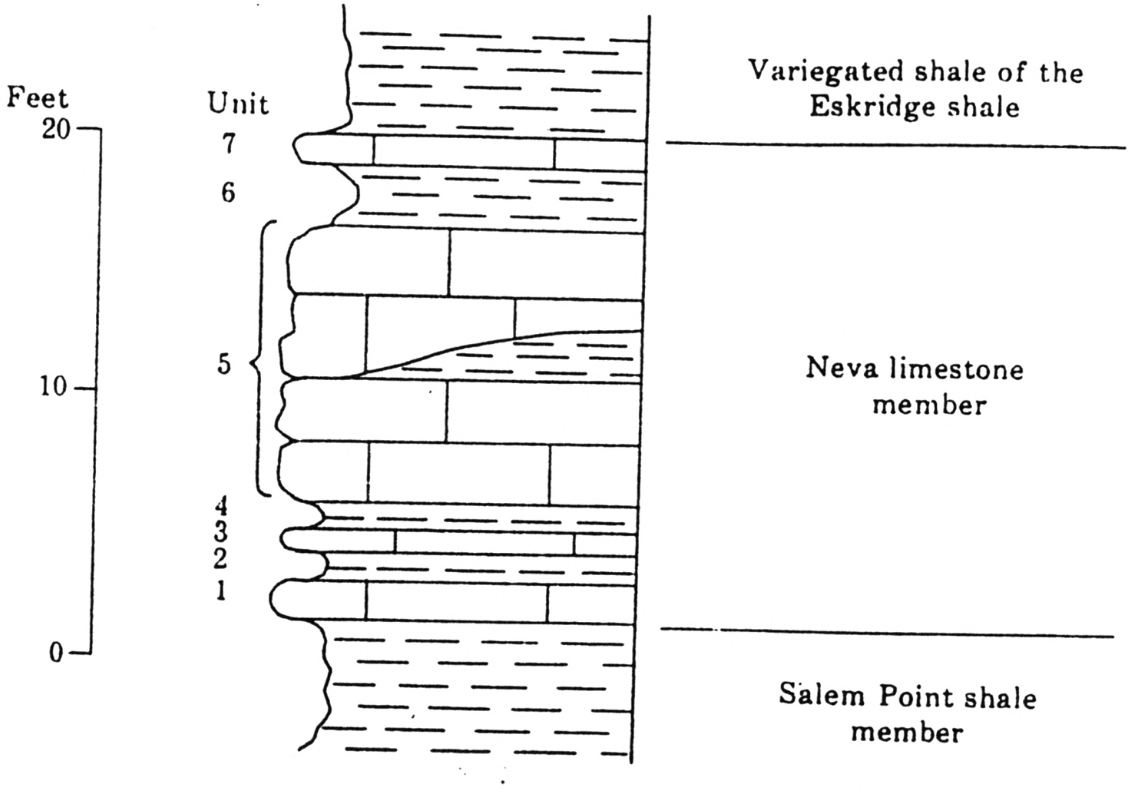


Figure 10. Idealized diagram for the Neva Limestone Member in Kansas (from Mudge and Yochelson, 1962).

feet in southern Kansas to 41 feet in northern Kansas. Prosser (1902, p. 709) stated that, "Between the Neva and the next higher massive limestone (Cottonwood) is a mass of shales, with perhaps some thin limestone layers, varying from 30 to 40 feet in thickness. The shales are of greenish, chocolate, and yellowish color, and usually form covered slopes between the two conspicuous limiting limestones." Mudge and Yochelson (1962) informally subdivided the Eskridge Shale into seven units (Fig. 11) and suggested that with local exceptions the units could be recognized in most counties along the outcrop.

<u>Structural Setting</u>.--The three county area of investigation directly overlies the Nemaha Anticline (Fig. 12), a NE-SW trending element that crosses Kansas from Nemaha County on the north to Sumner County on the south and extends into Nebraska and Oklahoma (Merriam, 1963). The Nemaha Anticline separates the Forest City Basin on the east from the Salina Basin on the west.

The Nemaha Anticline was one of the many structures formed near the end of the Mississippian or at the beginning of the Pennsylvanian which define the structural framework evident in Paleozoic beds. Merriam (1963) suggested that post-Paleozoic movements did not materially alter the pre-Desmoinesian, post-Mississippian structures.

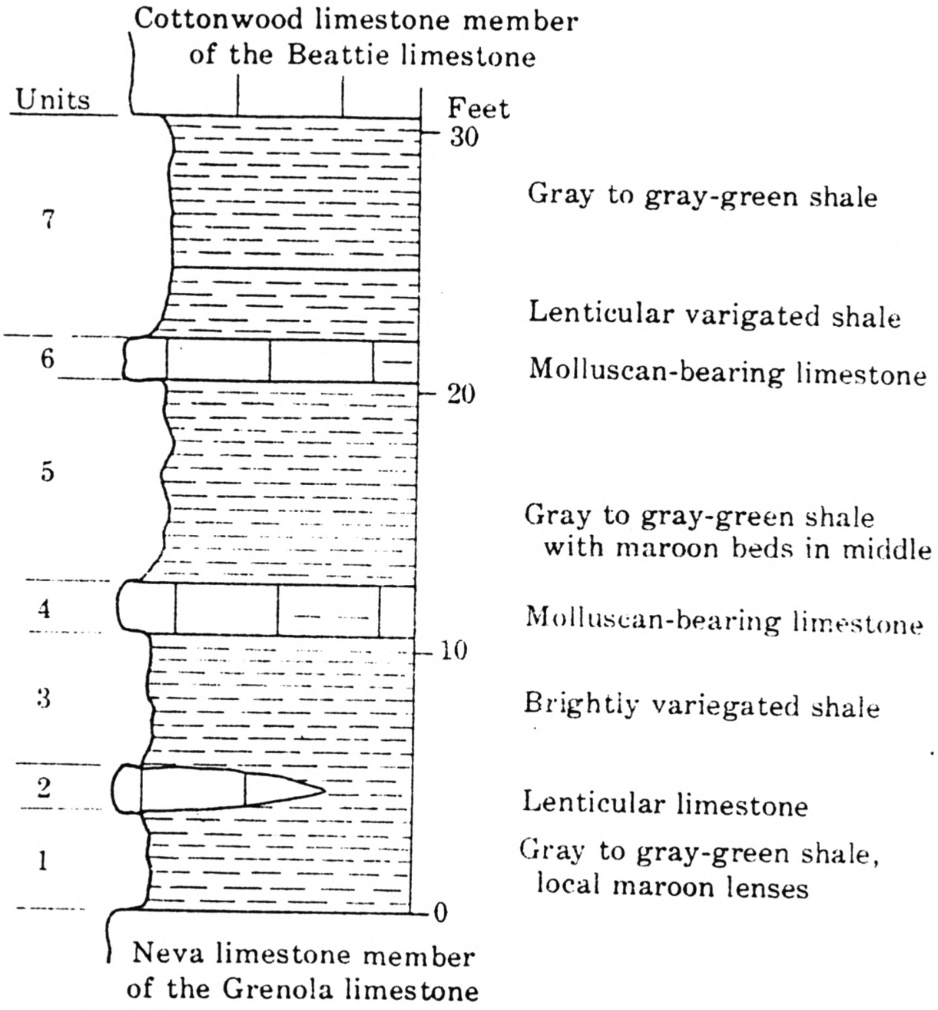


Figure 11. Idealized diagram for the Eskridge Shale in Kansas (from Mudge and Yochelson, 1962).

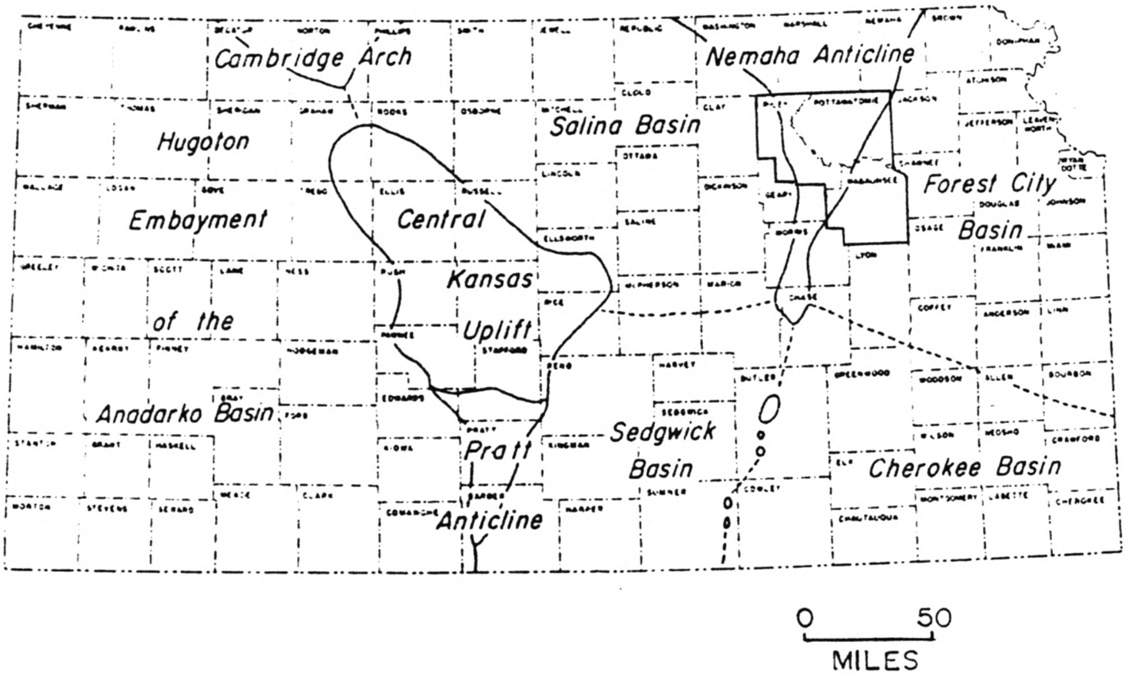


Figure 12. Major structural features of Kansas during pre-Desmoinesian post-Mississippian time (from Merriam, 1963).

Permian rocks of Kansas are included in the Prairie Plains Monocline and dip gently toward the west at about 25 feet per mile (Merriam, 1963). Minor structures found within the study area include the Brownville Syncline, the Alma-Davis Anticline, and the Abilene Anticline (Fig. 13). The Brownville Syncline lies just east of, and parallel to the Nemaha Anticline. It forms the relatively steep west flank of the Forest City Basin (Merriam, 1963). The Alma-Davis Anticline, a prolific petroleum producing structure, lies approximately 15 miles to the east and parallel to the Brownville Syncline. Shenkel (1959) described the Abilene Anticline as situated on the east flank of the Salina Basin. He reported that the southern part of the anticlinal axis runs nearly parallel to the Nemaha Anticline, however the northern part of the axis intersects the west flank of the Nemaha Anticline. It was in this area of intersection that all pre-Pennsylvanian sedimentary rocks had been uplifted and removed by post-Mississippian, pre-Desmoinesian erosion.

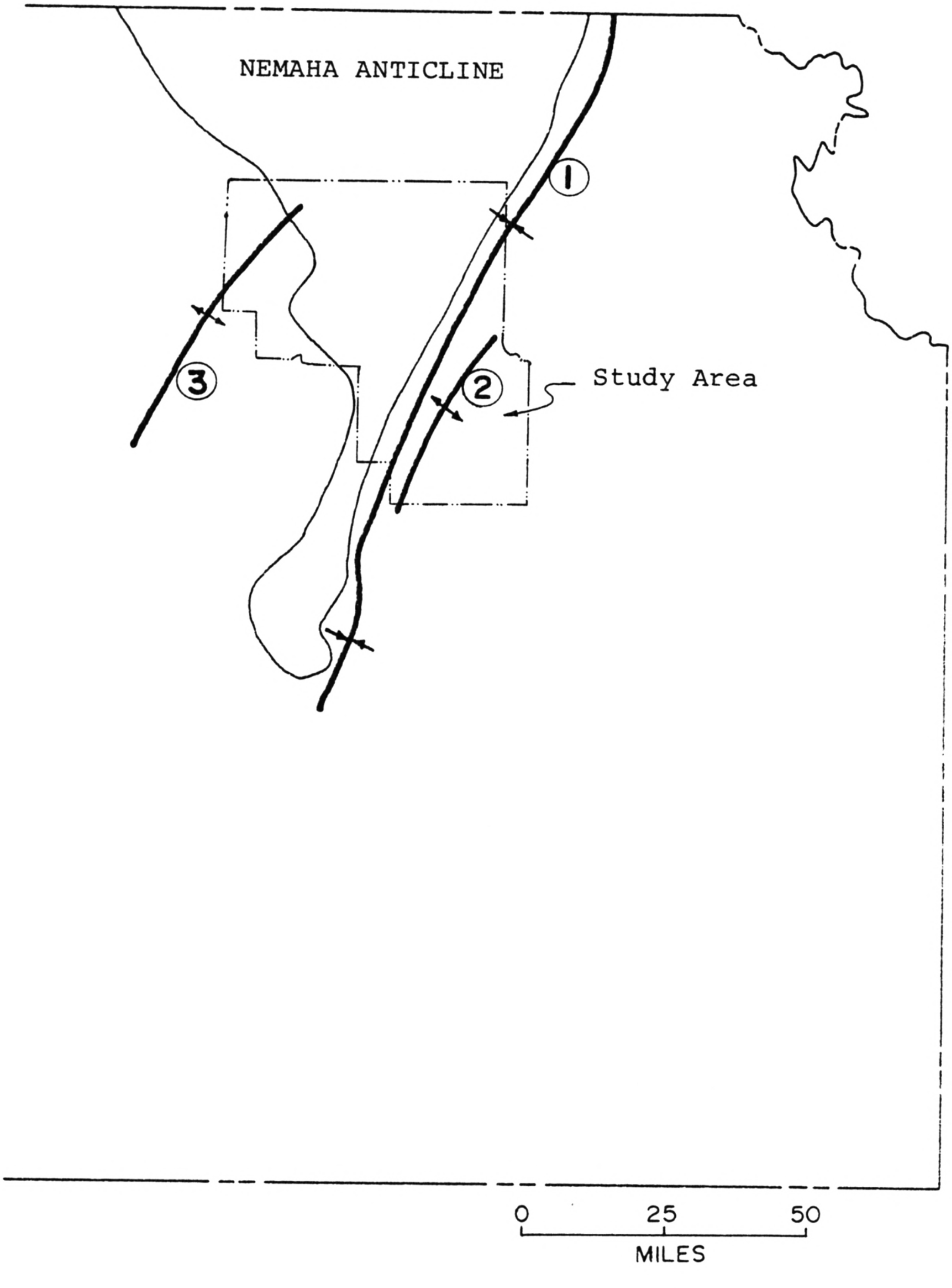


Figure 13. Minor structures in northeastern Kansas. 1.) Brownville Syncline; 2.) Alma-Davis Anticline; 3.) Abilene Anticline. (modified from Merriam, 1963).

Methods of Study

This study incorporates a two phase approach of (1) detailed field work with (2) supporting laboratory observations. The field work consisted of studying bed-by-bed 27 closely spaced outcrops within the main area of investigation (Fig. 14). A core from nothern Riley County (Amoco #1 Hargrave, Locality #28 on Fig. 14) was also described in detail for comparison with outcrop data. Initial field investigations concentrated on the rocks of the Grenola, Eskridge, and Beattie Formations. The focus of the study then narrowed to the Neva Limestone Member and Eskridge Shale because this interval was interpreted to represent a fifth-order genetic transgressive-regressive unit (Neva-Eskridge 5th-order T-R unit).

Measured sections were chosen based upon their geographic location relative to other measured sections, and the relative completeness of section. Sections were measured using a measuring tape and a hand-held Brunton compass. Oriented field samples were collected and studied in the laboratory.

Laboratory work included study of thin and polished sections of limestones, and disaggregation of mudrocks. Fifty-three thin sections were examined for both their biotic and lithologic characteristics using a polarizing

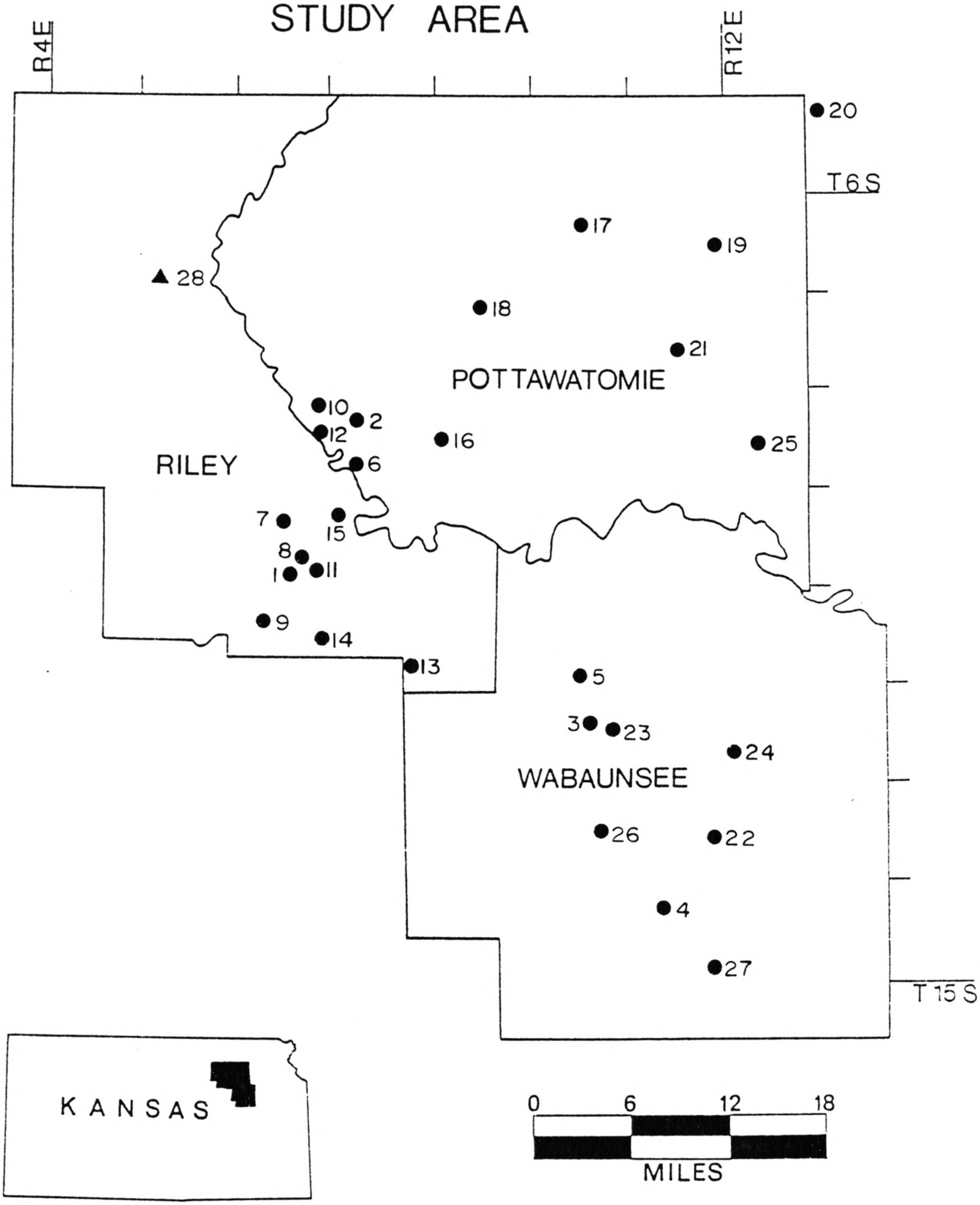


Figure 14. Location map of measured sections (1-27) and core (28) for Riley, Pottawatomie, and Wabaunsee Counties, Kansas.

petrographic microscope. Using these data, the limestones were classified using the carbonate classification schemes of Folk (1962) and Dunham (1962). Mudstone samples were placed in Quaternary-O solution until they disaggregated. Upon disaggregation the samples were washed, sieved, and dried. The washed/sieved residues were examined using a 10X hand lens and binocular microscope. Biotic components were identified to genus whenever possible.

The hierarchal T-R unit approach to outcrop description and correlation entails the detailed description of closely spaced outcrops and cores. A nested hierarchy is constructed by dividing a 5th-order T-R unit which represents a net transgressive-regressive sequence of a cyclothemic scale into smaller 6th-order T-R units which exhibit one net deepening-shallowing sequence. For example, when a 6th-order regressive facies such as a paleosol, is transgressed upon and overlain (after Walther's Law) by a transgressive facies such as a molluscan limestone, a genetic surface is then created that should be correlative over a wide area. As the sea regresses over the area another paleosol develops which comprises the top of this 6th order T-R unit. Thus 6th order T-R units, which comprise larger T-R units, are bounded by correlative transgressive genetic surfaces. A sea-level curve is then constructed for the 5th-order T-R unit relative to each measured section, and correlation of 6th-order T-R units is accomplished by aligning the sea-level curve patterns. This method assumes that all transgressive genetic surfaces that are correlative over a wide area must be allogenic, as for example when they are controlled by eustatic sea-level rise. Those transgressive units which do not correlate are considered autogenic and due to rather local sedimentary events such as delta switching. Allogenic units that are present in a small area can prove to be autogenic as the geographic area is expanded.

Recognition and Interpretation of Biofacies

The biofacies scheme used in this study was patterned after the Brezinski (1983) biofacies model for Late Carboniferous onshore to offshore biotic changes. This scheme relies upon the concept that organisms characteristically respond to environmental changes. It is also assumed that different biofacies are encountered seaward from shore as the result of an environmental stress gradient. Brezinski (1983) recognized four distinct marine biofacies (Fig. 15) for the Ames (Virgilian) marine interval of the central Appalachian Basin. His biofacies consisted of a nearshore, high diversity molluscan biofacies, a transgressive opportunistic biofacies dominated by the brachiopod *Neochonetes*, an offshore high diversity *Composita*-*Neospirifer* biofacies developed at the transgressive apex, and a regressive *Crurithyris* biofacies.

Brezinski (1983) suggested that the presence of a relatively diverse marine biota, including numerous brachiopod genera, bryozoans, and corals, indicated open circulation of marine water. In general, the presence or absense of diverse stenotopic faunas should be good indicators of environmental conditions (i.e., circulation, water depth, terrigenous influx) which existed at the time of deposition. Fossil assemblages containing diverse

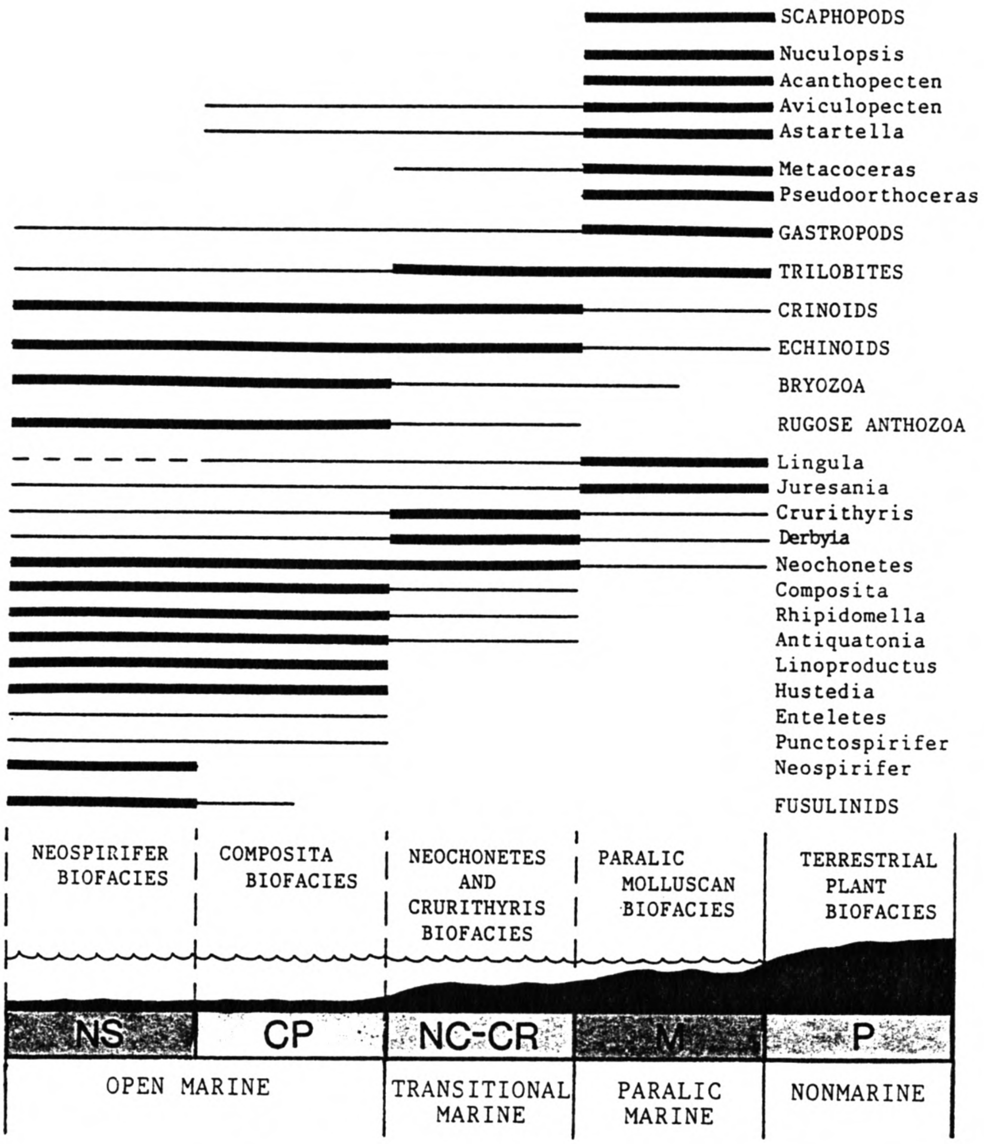


Figure 15. Biofacies model for late Carboniferous onshore to offshore biotic changes (modified from Brezinski, 1983).

eurytopic faunas (i.e., molluscan) are indicative of nearshore environments. Dodin (1974) applied the term "molluscan reversal" to this diversity increase in the nearshore direction. He attributed this anomaly to increased molluscan biomass resulting from nearshore detrital nutrient concentrations. In short, the relative amount of stenotopic faunas decreases shoreward while the relative abundance of eurytopic faunas increases in the shoreward direction.

Elias (1937) used the "orderly occurrence" of mollusks, brachiopods, and fusulinids to establish an onshore to offshore biofacies scheme for identification and correlation of Permian cyclothems. Elias identified (Fig. 16) five distinct biofacies (in order of shoreward appearence): (1) fusulinid, (2) calcareous brachiopod, (3) mixed fauna (4) molluscan, and (5) inarticulate brachiopod. Elias also suggested that green, and brown marine shales were indicative of shallow water deposition. He, furthermore, believed that persistent unfossiliferous red shales were developed during times of prolonged emergence.

Moore (1964) recognized paleontologically defined stages or phases in the transgressive and regressive parts of Pennsylvanian and Permian shallow sea oscillations. He suggested that at individual localities complete cyclothems may show distinguishable zones which in upward order consist of beds characterized by (1) inarticulate brachiopods or a molluscan assemblage generally dominated by clams, (2) a

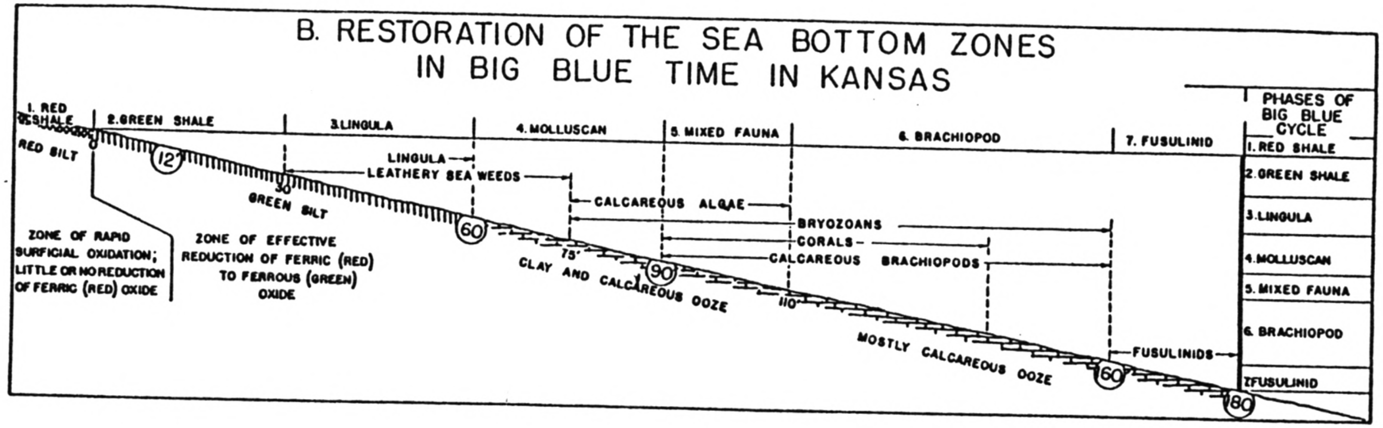


Figure 16. Elias's onshore to offshore litho- and biofacies scheme for the Big Blue Series (Lower Permian) of the mid-continent (from Elias, 1937).

varied fauna of brachiopods, bryozoans, corals, crinoids, and other marine invertebrates, (3) common to very abundant fusulinids, with or without associated other organisms, (4) an assemblage of mainly euryhaline brachiopods, ramose bryozoans, mollusks, and calcareous algae, (5) limestone composed predominantly of osagid-coated grains, and (6) nonmarine strata containing coal beds and land plant remains or unfossiliferous red and green shales, all of which intervene between sequences of marine deposits. Moore then grouped 20 representative organic assemblages for use as an aid in interpreting sea level changes for Pennsylvanian-Permian cyclothems.

Using the above stated concepts, a scheme of 13 offshore to onshore biofacies representing four distinct paleoenvironments were developed for the Neva-Eskridge 5th-order T-R unit of northeastern Kansas. The 5th-order T-R unit was divided into a number of both lateral and vertical, biotically distinct biofacies. Sixth-order T-R units were then defined when a biofacies representing a more open marine paleoenvironment (e.g. sea level rise) was interpreted to overlie a lesser marine or non-marine biofacies. The scheme was based upon the observed biotic changes and their relation to varying environmental conditions (i.e., sea-level changes). Paleoenvironmental interpretations were made based upon biotic assemblages (eurytopic vs. stenotopic), their relative abundance of taxa within each assemblage, taphonomy of the fossils (e.g. broken and abraded vs. whole, articulated and in life position), and biotic diversity.

The presence and absence of taxa (genera), which were used to define the distinct biofacies were described in relative terms. The terms abundant, common, scattered, and few were used in outcrop and laboratory analysis to indicate the relative amount of a specific genus within a given bed. As used in this study, the term abundant means that a specific taxa occurs throughout in the facies. Common refers to taxa which are numerous and readily found within the facies. The term scattered refers to a genus which is found infrequently within the facies. The term few applies to a genus of which only a couple of specimens can be found within a facies after close examination. Thus the dominant genus of a particular facies will characterize that biofacies.

The Neva-Eskridge biofacies scheme (Fig. 17) illustrates distinct biotic changes observed in this study and their paleoenvironmental interpretations for times of mean high sea level (MHSL). Four distinct paleoenvironments were also defined (in order of shoreward occurrence): open marine, transitional marine, marginal marine, and non-marine.

The open marine paleoenvironment is represented by the <u>Neospirifer</u>, <u>Leptotriticites</u>, and <u>Composita</u> biofacies (Table 1). Each of these biofacies is indicative of a

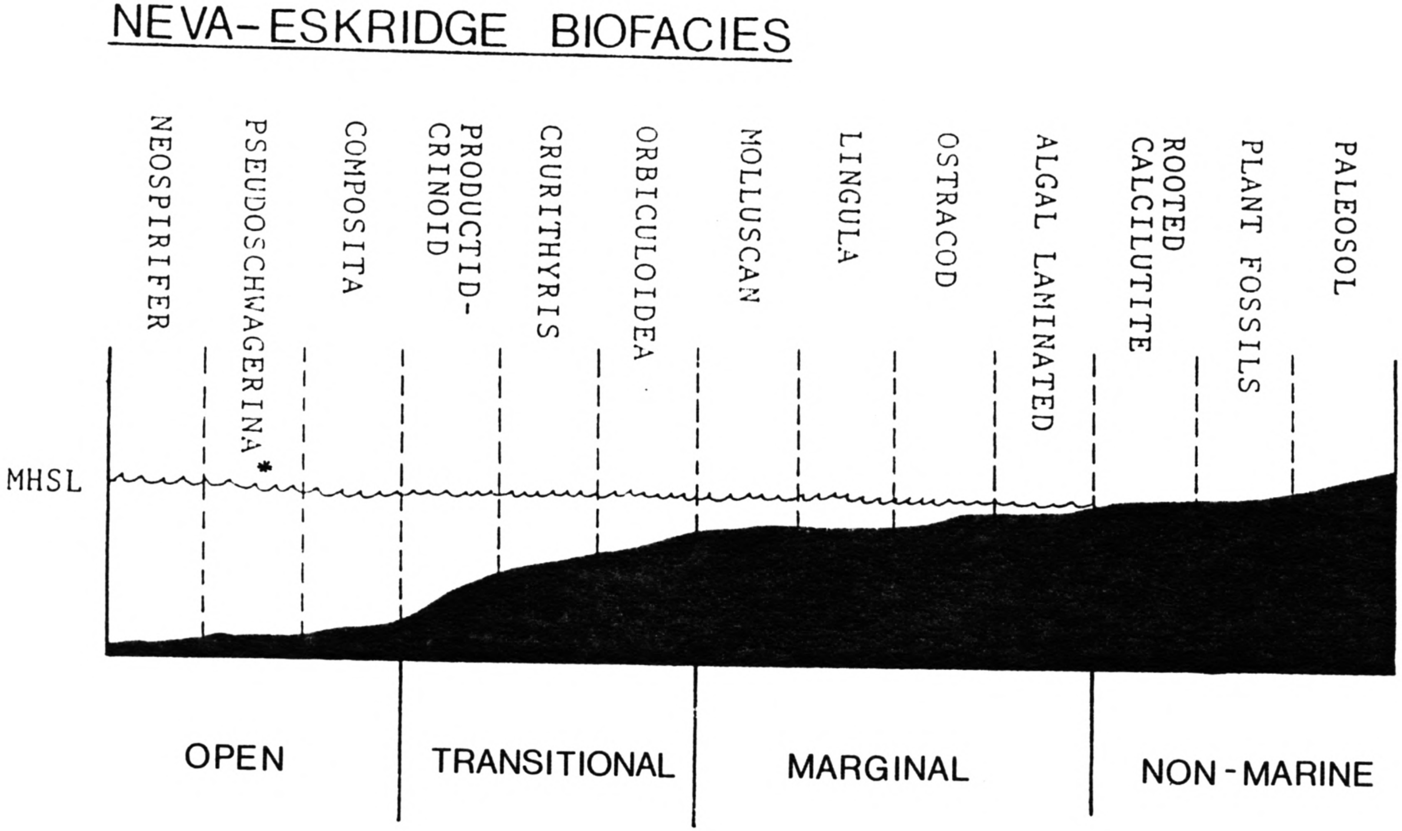


Figure 17. Neva-Eskridge biofacies scheme for onshore to offshore paleoenvironmental changes (* Read Leptotriticites for Psuedoschwagerina).

	Neospirifer Biofacies	Leptotriticites Biofacies	Composita Biofacies
Neospirifer	A	-	-
Composita	C	C	A
Neochonetes	C	S	C
Derbyia	S	F	F
Juresania	S	S	S
Linoproductus	S	S	S
Reticulatia	S	S	S
Quadrochonetes	F	F	F
Lissochonetes	F	F	F
Crurithyris	F	F	S
Hustedia	-	F	S
Wellerella	-	F	F
Ditomopyge	F	F	F
Leptotriticites	-	A	-
Crinoids	S	C	A
Echinoids	S	C	A
Bryozoans	S	S	S
Horn Corals	-	F	F
Aviculopecten	F	F	-
Nuculopsis	-	-	-
Septimyalina	-	-	-
Aviculopinna	-	-	-
Permophorus	-	-	-
Wilkingia	-	-	-
Bellerophon	-	-	-
High Spired Gastropods	-	-	-
Scaphopods	-	-	-
Ostracods	-	-	-
Orbiculoidea	-	-	-
Lingula	-	-	-
Shark Teeth	-	-	-
Osagia	-	F	-
Stromatolites	-	-	-
Phylloid Algae	-	-	F
Plant Fossils	-	-	-
Root Traces	-	-	-

Table 1. Distribution and relative abundance of the fauna within the Neva-Eskridge biofacies for the open marine paleoenvironment (A--Abundant; C--Common; S--Scattered; F--Few).

diverse stenotopic faunal assemblage. This paleoenvironment would correspond with Moore's (1964) Tarkio (Triticites) assemblage, and Elias's (1937) fusulinid and calcareous brachiopod zones.

The Leptotriticites biofacies derives its name from the dominant fusulinid genus found within the Neva-Eskridge fifth-order T-R unit. Lesser numbers of other fusulinids may occur within the Neva-Eskridge transgressive hemicycle but were not noted in this study.

The transitional marine paleoenvironment consists of the Productid-Crinoid, Crurithyris, and Orbiculoidea biofacies (Table 2). These faunal assemblages represent transitional environmental conditions between open marine and the more restricted marginal marine paleoenvironments. This paleoenvironment is similiar to Moore's (1964) Speiser-type (Derbyia) assemblage, and his Red Eagle-type (Orbiculoidea-Lingula) assemblage. Elias's (1937) mixed fauna zone would also be a similar paleoenvironment.

The marginal marine paleoenvironment is represented by the Molluscan, Lingula, Ostracod, and Algal (Stromatolitic) biofacies (Table 3). These biofacies are representative of eurytopic biotic assemblages which develop at or near shoreline in semi-restricted to restricted marine conditions. This paleoenvironment is comparable with Moore's (1964) Ozawkie-type (Knightites), and Morrill-type (Osagia) assemblages and with Elias's (1937) molluscan and Lingula

	Productid-Crinoid Biofacies	*Crurithyris* Biofacies	*Orbiculoidea* Biofacies
Neospirifer	-	-	-
Composita	-	-	-
Neochonetes	F	F	-
Derbyia	S	-	-
Juresania	C	S	-
Linoproductus	C	S	-
Reticulatia	C	S	F
Quadrochonetes	F	-	-
Lissochonetes	F	-	F
Crurithyris	F	A	S
Hustedia	-	-	-
Wellerella	-	F	F
Ditomopyge	-	-	-
Leptotriticites	-	-	-
Crinoids	A	S	F
Echinoids	C	F	-
Bryozoans	F	F	-
Horn Corals	F	-	-
Aviculopecten	F	-	-
Nuculopsis	-	-	F
Septimyalina	-	-	-
Aviculopinna	F	-	-
Permophorus	-	-	-
Wilkingia	-	-	-
Bellerophon	-	-	-
High Spired Gastropds	-	-	-
Scaphopods	-	-	-
Ostracods	-	-	-
Orbiculoidea	-	S	A
Lingula	-	F	S
Shark Teeth	-	-	-
Osagia	-	-	-
Stromatolites	-	-	-
Phylloid Algae	-	-	-
Plant Fossils	-	-	-
Root Traces	-	-	-

Table 2. Distribution and relative abundance of the fauna within the Neva-Eskridge biofacies for the transitional marine paleoenvironment (A--Abundant; C--Common; S--Scattered; F--Few).

	Molluscan Biofacies	*Lingula* Biofacies	Ostracod Biofacies	Algal Biofacies
Neospirifer	-	-	-	-
Composita	-	-	-	-
Neochonetes	-	-	-	-
Derbyia	S	-	-	-
Juresania	F	-	-	-
Linoproductus	F	-	-	-
Reticulatia	F	-	-	-
Quadrochonetes	-	-	-	-
Lissochonetes	-	-	-	-
Crurithyris	-	-	-	-
Hustedia	-	-	-	-
Wellerella	-	-	-	-
Ditomopyge	-	-	-	-
Leptotriticites	-	-	-	-
Crinoids	-	-	-	-
Echinoids	-	-	-	-
Bryozoans	-	-	-	-
Horn Corals	-	-	-	-
Aviculopecten	A	F	-	-
Nuculopsis	A	F	-	-
Septimyalina	A	-	-	-
Aviculopinna	S	-	-	-
Permophorus	S	-	-	-
Wilkingia	S	-	-	-
Bellerophon	C	-	-	-
High Spired Gastropods	C	-	F	S
Scaphopods	F	-	-	-
Ostracods	S	F	A	F
Orbiculoidea	-	S	-	-
Lingula	-	A	-	-
Shark Teeth	F	F	-	-
Osagia	S	-	F	F
Stromatolites	-	-	-	A
Phylloid Algae	-	-	F	S
Plant Fossils	-	-	-	-
Root Traces	-	-	-	F

Table 3. Distribution and relative abundance of the fauna of the Neva-Eskridge biofacies for the marginal marine paleoenvironment (A--Abundant; C--Common; S--Scattered; F--Few).

zones.

The non-marine paleoenvironment is represented by the Rooted Calcilutite, Plant Fossil, and Paleosol biofacies (Table 4) and is indicative of deposition in supratidal to terrestrial environments. This paleoenvironment is similiar to Moore's (1964) various non-marine assemblages, and to Elias's green and red shale zones.

The rooted calcilutite facies is interpreted to represent deposition in a supratidal paleoenvironment. The presence of very few marine skeletal fragments combined with the persistent occurrence of plant root traces within a calcareous matrix suggests a harsh supratidal environment. Esteban and Klappa (1983) noted that root molds and/or borings are cylindrical pores left after root decay. They suggested that the preservation of root molds provided useful evidence in interpreting very shallow marine sequences.

Those rocks which are dominated by plant fossil biofacies were generally brown to black mudstones. Most of these mudstones are suggested to have been deposited in low energy lagoonal environments due to the preservation of the fragile plant fossils in a clay matrix.

Rocks interpreted to be paleosols were identified using characteristics outlined by Schutter and Heckel (1985), and Retallack (1988). They suggested that Carboniferous paleosols exhibited a blocky fabric, leached clay profiles,

	Rooted Calcilutite Biofacies	Plant Fossils Biofacies	Paleosol Biofacies
Neospirifer	-	-	-
Composita	-	-	-
Neochonetes	-	-	-
Derbyia	-	-	-
Juresania	-	-	-
Linoproductus	-	-	-
Reticulatia	-	-	-
Quadrochonetes	-	-	-
Lissochonetes	-	-	-
Crurithyris	-	-	-
Hustedia	-	-	-
Wellerella	-	-	-
Ditomopyge	-	-	-
Leptotriticites	-	-	-
Crinoids	-	-	-
Echinoids	-	-	-
Bryozoans	-	-	-
Horn Corals	-	-	-
Aviculopecten	-	-	-
Nuculopsis	-	-	-
Septimyalina	-	-	-
Aviculopinna	-	-	-
Permophorus	-	-	-
Wilkingia	-	-	-
Bellerophon	-	-	-
High Spired Gastropods	F	-	-
Scaphopods	-	-	-
Ostracods	S	-	-
Orbiculoidea	-	-	-
Lingula	-	-	-
Shark Teeth	F	-	-
Osagia	F	-	-
Stromatolites	S	-	-
Phylloid Algae	S	-	-
Plant Fossils	F	A	S
Root Traces	A	S	A

Table 4. Distribution and relative abundance of the fauna of the Neva-Eskridge biofacies for the non-marine paleoenvironment (A--Abundant; C--Common; S--Scattered; F--Few).

caliche horizons, slickensides, root traces, and sometimes red color. Schutter and Heckel reported that most of their soil profiles resembled vertisols, which develop under semi-arid conditions.

The non-fossiliferous mudrock facies is used for those units in which biotic components were absent. The mudrocks vary from mudstones to claystones. This lithofacies is interpreted to represent continental deposition such as that which occurs on alluvial plains.

HIERARCHAL GENETIC STRATIGRAPHY OF THE NEVA-ESKRIDGE 5TH-ORDER T-R UNIT

Hierarchal genetic stratigraphy uses small correlative genetic packages (commonly, and in this case 6th-order T-R units) defineable at the outcrop scale and groups them into larger deepening-shallowing sequences (5th-order T-R units). All lithologic and biotic changes found in the field are checked for lateral continuity by examination of the unit at other localities. Three sections labeled A,B, and C (Fig. 18) have been selected for the completeness of exposure and geographic location to demonstrate how the 6th-order T-R units are defined and how the hierarchy is constructed.

Section A is located in the NW 1/4, NE 1/4, sec. 1, T. 6 S., R. 12 E., in extreme northwest Jackson County, Kansas (see Appendix B, Locality #20). Section B is located in the SW 1/4, SE 1/4, sec. 13, T. 7 S., R. 11 E., in northeast Pottawatomie County, Kansas (see Appendix B, Locality #19). The third section, labeled C, is located in the NE 1/4, SW 1/4, sec. 12, T. 12 S., R. 10 E., in central Wabaunsee County, Kansas (see Appendix B, Locality #23).

These sections will also demonstrate how the analysis of lithologies, sedimentary structures, and fossils were used to define biofacies and their implications for specific paleoenvironments. Each transgressive surface is labeled

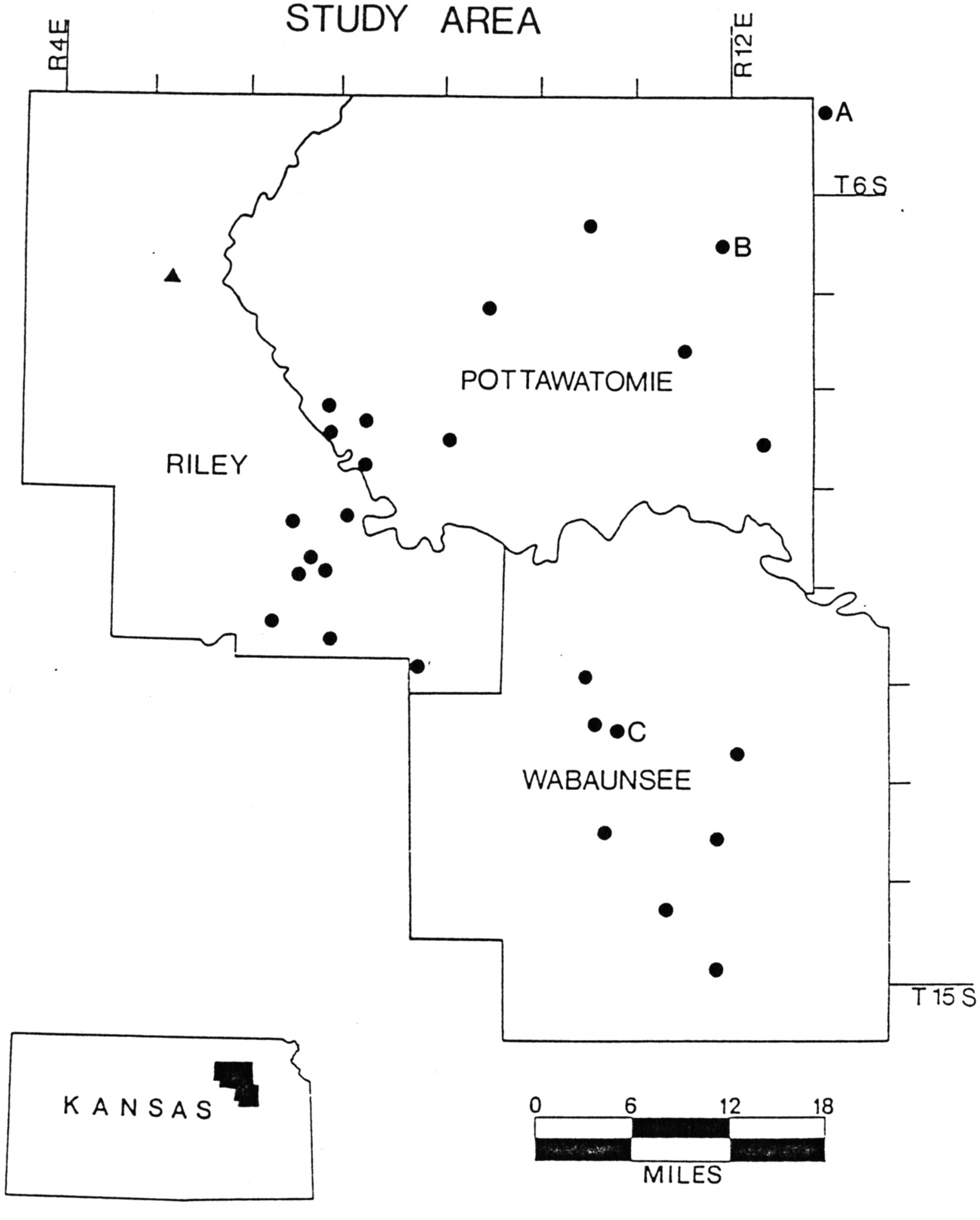


Figure 18. Location map of selected sections A (#20), B (#19), and C (#23).

with two capital letters and a corresponding number in upward order of occurrence from 1 to 11 which represent the 11 6th-order transgressive surfaces found within the Neva-Eskridge 5th-order T-R unit. The first capital letter refers to the name of of the fifth-order T-R unit in question, such as B (for the underlying Burr fifth-order T-R unit), N (for Neva-Eskridge fifth-order T-R unit), and C (for the overlying Cottonwood fifth-order T-R unit). The capital T represents the transgressive surface that was defined in the field. A complete description of all measured sections and the core are given in Appendix B.

Northwest Jackson County Section (A)

Based upon evidence from field and laboratory study the interval labeled section A was divided into 11 6th-order T-R units (Fig. 19). These 11 6th-order T-R units form a net deepening-shallowing sequence referred to here as the Neva-Eskridge 5th-order T-R unit.

The uppermost facies of the Salem Point Shale is recorded as unit 1 and represents the top of the underlying Burr 5th-order T-R unit's regressive hemicycle. Here unit 1 is a dark green, crumbly mudstone which is interpreted to represent deposition under terrestrial conditions.

The base of the Neva Limestone is defined in unit 2. At

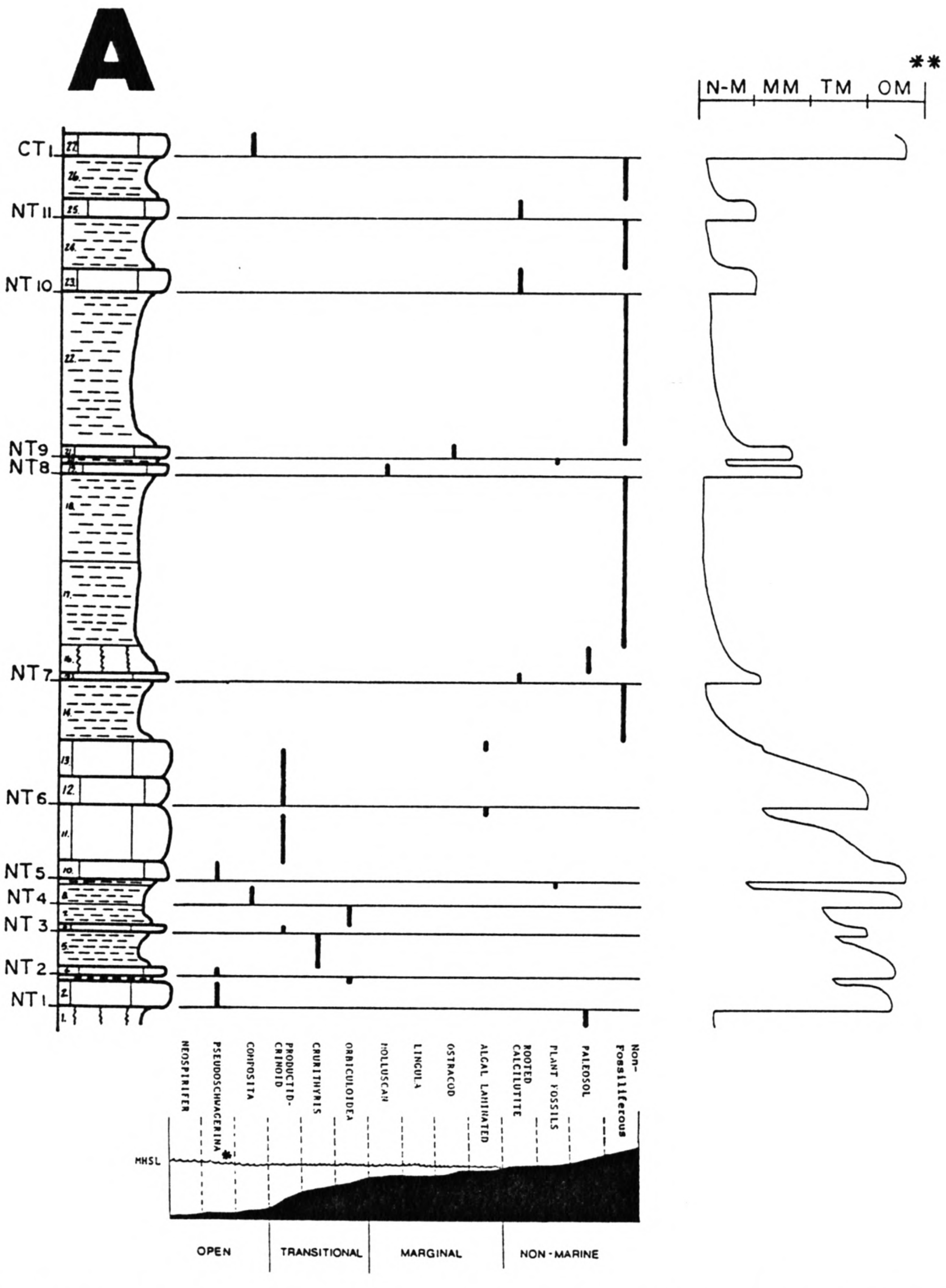


Figure 19. Diagram of section A (locality #20) showing biotic contents and relative sea level curve (** N-M=non-marine, MM=marginal marine, TM=transitional marine, OM=open marine; * Read <u>Leptotriticites</u> for <u>Psuedoschwagerina</u>; 1 inch=10 feet).

the base of unit 2 is the transgressive surface T_1 which represents the start of a net deepening trend or transgressive hemicycle. Unit 2 is an 18-inch (0.46 m) thick medium calcilutite containing coated grains, productids, and crinoids at the base and common fusulinids towards the middle of the unit. This Leptotriticites zone is interpreted to represent deposition under open marine conditions, and the scattered Crurithyris specimens found at the top of the unit may indicate a gradual restriction of marine conditions. Unit 3 is a 1-inch (0.03 m) thick, black mudstone and specimens of Orbiculoidea are common. This eurytopic biofacies represents the most restricted, regressive paleoenvironment of NT_1.

The second transgressive surface encountered (NT_2) is found at the base of unit 4. This unit is a 5-inch (0.13 m) thick coarse calcilutite with common fusulinids and is interpreted to represent a return to relatively open marine conditions. Scattered specimens of Crurithyris occur near the top of the unit with Lingula and probably again represents a gradual restriction of marine conditions. The overlying unit (5) is a 23-inch (0.58 m) thick, black, fissile, mudstone in which Orbiculoidea is common, and Crurithyris, and Lingula are scattered, and is interpreted as representing the maximum regressive facies of NT_2.

The base of unit 6 represents transgressive surface NTT_3 and is a 3-inch (0.08 m) medium calcilutite containing a productid-crinoid biofacies indicating relatively more open marine conditions than underlying unit 5. Unit 7 is a 12-inch (0.30 m) black, platy, mudstone containing common specimens of Orbiculoidea, and scattered specimens of Crurithyris, and Lingula, and is interpreted as the regressive apex of 6th-order T-R Unit 3.

The fourth transgressive surface (NT_4) occurs at the base of unit 8. This unit is a 12-inch (0.30 m) brown, mudstone with a diverse stenotopic biota in which Composita and Wellerella are common and is interpreted as having been deposited in an open marine paleoenvironment. Unit 9 is a 2-inch (0.05 m) brown-green mudstone containing scattered plant fossils and interpreted to represent a non-marine environment of deposition.

The base of unit 10 represents NT_5 and is described as a 10-inch (0.25 m) thick calcilutite containing scattered fusulinids and is interpreted as deposition in an open marine paleoenvironment. Unit 11 is a 35-inch (0.89 m) thick fine calcilutite with a productid-crinoid biofacies. Gradual restriction of marine conditions is suggested by the occurrence of an algal laminated biofacies which is interpreted representing intertidal conditions at the top of unit 11.

The base of unit 12 represents transgressive surface 6 (NT_6). Unit 12 is an 18-inch (0.46 m) medium calcilutite with a productid-crinoid biofacies indicating a shallow subtidal paleoenvironment. The top of unit 13 corresponds to the top of the Neva-Eskridge transgressive hemicycle, whereas the base of unit 14 begins the Neva-Eskridge regressive hemicycle. Unit 13 is 23-inch (0.58 m) thick fine calcilutite with a productid-crinoid biofacies which shallows upward into an algal laminated biofacies that is interpreted as an intertidal paleoenvironment. Unit 14 is the lowest unit in the Eskridge Shale and is a 38-inch (0.96 m) thick, red mudstone with dessication cracks that suggest deposition in a supratidal to terrestrial paleoenvironment. Thus unit 14 is the regressive apex of 6th-order T-R unit 6.

The seventh transgressive surface (NT_7) encountered lies at the base of unit 15. This unit is a thin fine calcilutite with common plant roots and is interpreted as representing deposition in intertidal to supratidal paleoenvironment. As sea level dropped, unit 16 was deposited as a deep red, crumbly mudstone with common clay films, root traces, and caliche nodules, and is interpreted to represent a paleosol. This time of soil development is widely correlative over the study area and probably represents the regressive apex of the Neva-Eskridge 5th-order T-R Unit. Elias (1937) also believed that this "red bed" was the regressive apex and thus the top of the Neva cyclothem. However, because the hierarchal method of T-R unit stratigraphy is based upon net transgression, the top of the Neva-Eskridge 5th-order T-R unit lies at the base of the Cottonwood Limestone which represents the next major net transgression of the sequence. Units 17 and 18 are thick light green, semi-indurated, non-fossiliferous mudstones interpreted as continental deposits.

The base of unit 19 represents the eighth transgressive surface (NT_8) encountered. This unit is a 4-inch (0.10 m) fine calcilutite with an abundant molluscan and ostracod assemblage and is interpreted as representing deposition in a marginal marine paleoenvironment. The overlying unit 20 is a 2-inch (0.05 m) thick brown-green mudstone containing scattered plant fossils and is interpreted as representing a regressive non-marine paleoenvironment.

Transgressive surface NT_9 occurs at the base of unit 21. This unit is a 5-inch (0.13 m) thick fine calcarenite containing scattered specimens of Bellerophon and microgastropods, as well as algal laminations. This facies is interpreted as representing deposition in a nearshore paralic to marginal marine paleoenvironment. Unit 22 is a 100-inch (2.54 m) thick, red and green, semi-indurated mudstone interpreted to have been deposited in a non-marine paleoenvironment.

The base of unit 23 represents the tenth transgressive surface (NT_{10}) defined at this location. This unit is a 14-inch (0.36 m) fine calcilutite containing dessication cracks and a few root traces suggesting deposition in a supratidal paleoenvironment. As sea level dropped, unit 24 was deposited as a 33-inch (0.84 m) pale red to green mudstone interpreted to have been deposited in a continental paleoenvironment.

The eleventh and final transgressive surface (NT_{11}) within the Neva-Eskridge fifth-order T-R unit occurs at the base of unit 25. This unit is a 12-inch (0.30 m) fine calcilutite containing root traces and is interpreted to have been deposited in a supratidal paleoenvironment.

The base of unit 27 corresponds to the base of the Cottonwood Limestone and represents the first transgressive surface recognized in the overlying Cottonwood fifth-order T-R unit. Unit 27 is a 10-inch (0.25 m) fine calcarenite containing the Composita biofacies and is interpreted to represent a return to open marine conditions.

Northeastern Pottawatomie County Section (B)

Using field evidence and laboratory observations, study interval B was divided into nine sixth-order T-R units (Fig. 20). The sixth-order T-R units labeled 3 and 7 (in Fig. 19) are missing at this location and are interpreted as being either eroded penecontemporaneously before deposition of the overlying T-R unit or never deposited. Evidence for erosion at this locality include the siliceous limestone clasts which are common in unit 24 (NT_8) and are suggested to have

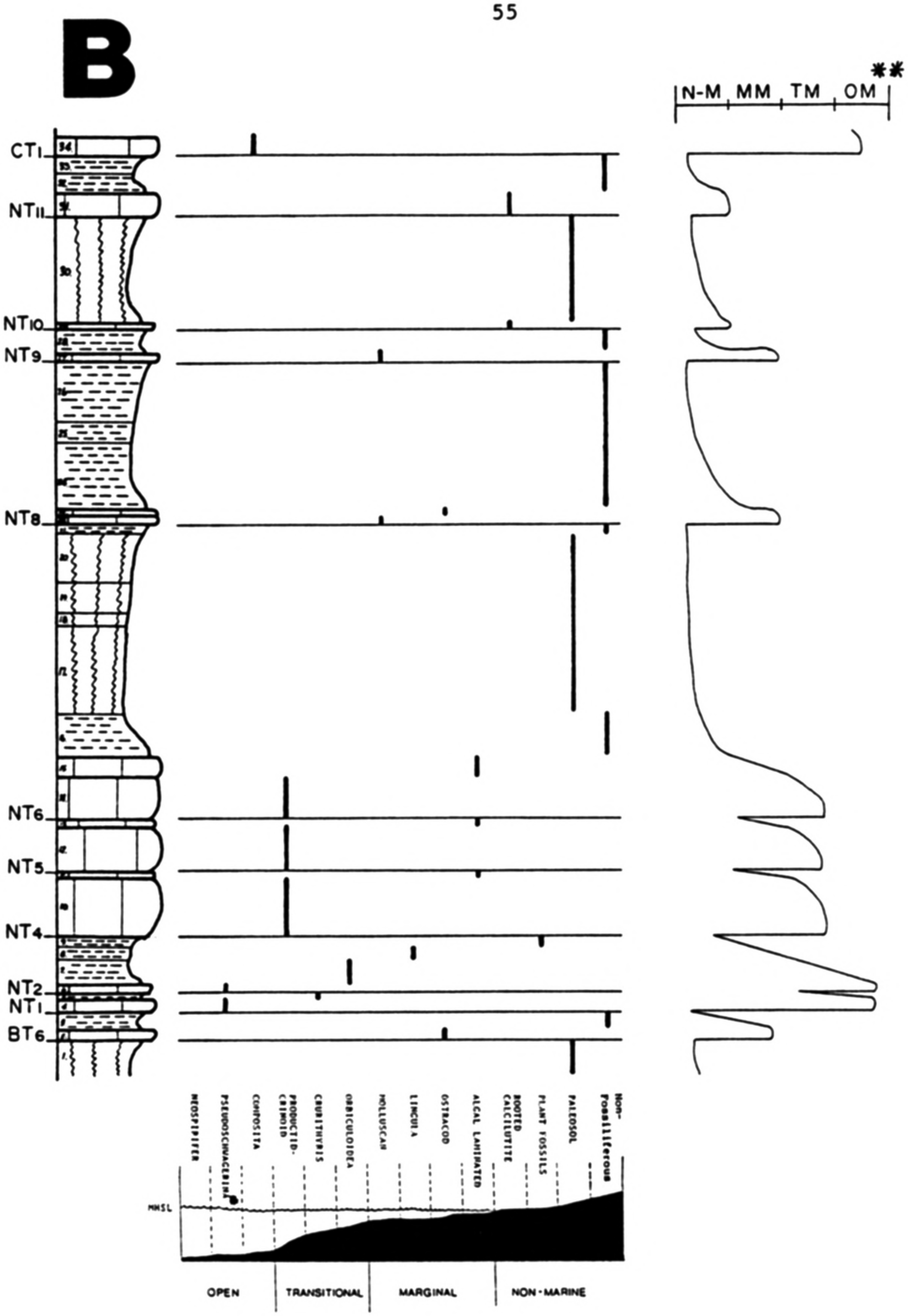


Figure 20. Diagram of section B (locality #19) showing biotic contents and relative sea level curve (* For explanation this, and other marked items, and scale, see Fig. 19, p. 49).

resulted from erosion of the underlying unit (23) in this area.

The first three units of section B, below transgressive surface NT_1, represent the regressive part of the last sixth-order T-R unit within the underlying Burr fifth-order T-R unit. While the uppermost unit 33 represents the basal transgressive surface (CT_1) of the overlying Cottonwood fifth-order T-R unit. The uppermost three facies of the Salem Point Shale are represented by units 1, 2, and 3. Unit 1 is a 24-inch (0.61 m) thick red to green mudstone containing caliche nodules and interpreted as a paleosol (a non-marine paleoenvironment). The base of unit 2 marks the final transgression of the Burr 5th order T-R unit (BT_6). Unit 2 is a 6-inch (0.15 m) thick fine calcilutite with a few ostracods and is indicative of a marginal marine paleoenvironment. As sea level regressed, unit 3 was deposited as an 11-inch (0.28 m) brown, non-fossiliferous mudstone which represents deposition in a non-marine paleoenvironment.

The first Neva-Eskridge 6th-order T-R unit begins at the base of unit 4 (NT_1). This unit is a 10-inch (0.28 m) thick coarse calcilutite with abundant shell fragments and scattered fusulinids and bryozoans, and is interpreted as representing deposition under open marine conditions. The overlying unit 5 is a 2-inch (0.05 m) thick brown mudstone containing scattered specimens of <u>Crurithyris</u> and is interpreted as representing a shallow subtidal paleoenvironment.

A return to open marine conditions is interpreted to have occurred at the base of unit 6, transgressive surface NT_2. This unit is a 4-inch (0.10 m) thick fine calcarenite containing abundant fusulinids and scattered crinoids and skeletal fragments. As the sea regressed unit 7 was deposited as a 16-inch (0.41 m) brown mudstone containing abundant specimens of Orbiculoidea and scattered specimens of Crurithyris. The sixth-order T-R unit NT_3 of location A was not recognized at this location and either was not deposited or was eroded before deposition of units 8 and 9. Evidence for erosion, such as the presence of an erosional surface is lacking at this locality. Unit 8 is an 8-inch (0.20 m) black mudstone containing scattered specimens of Lingula, Crurithyris, and Orbiculoidea and is interpreted as representing deposition in a lower intertidal marine paleoenvironment. Unit 9 is a 6-inch (0.15 m) green mottled black mudstone containing scattered plant fossils which suggest a non-marine paleoenvironment.

The fourth sixth-order T-R unit (NT_4) begins at the base of unit 10. This unit is a 32-inch (0.81 m) fine calcilutite containing a productid-crinoid biofacies suggesting deposition in a shallow subtidal paleoenvironment. As sea level dropped unit 11 was deposited as a 3-inch (0.08 m) algal-laminated fine calcilutite which is interpreted as an intertidal paleoenvironment.

Transgressive surface NT_5 is encountered at the base of unit 12. This unit is a 30-inch (0.76 m) medium calcilutite containing a productid-crinoid biofacies and represents a return to shallow subtidal conditions. As the sea regressed over the area unit 13 was deposited as a 5-inch (0.13 m) algal-laminated medium calcilutite suggesting intertidal conditions and represents the regressive apex of sixth-order T-R unit 5 (NT_5).

The sixth-order T-R unit labeled NT_6 starts at the base of unit 14. This unit is a 29-inch (0.74 m) medium calcilutite containing a productid-crinoid biofacies, suggesting a return of shallow subtidal conditions. The occurrence of unit 15, a 13-inch (0.33 m) medium calcilutite containing algal laminations at the top suggests an intertidal environment, and thus a lowering of sea level. The base of the Eskridge Shale is defined at the bottom of unit 16. This unit is a 30-inch (0.76 m) light green crumbly non-fossiliferous mudstone and suggests continental deposition. Units 17, 18 ,19 and 20 cumulatively represent 122-inches (3.10 m) of mudstones divided on the basis of color but all containing clay films and root traces and are interpreted as paleosol. Unit 21 is a 6-inch (0.15 m) green-gray non-fossiliferous mudstone which is interpreted to have been deposited in a non-marine paleoenvironment. While the transgressive part of NT_7 is not recognizable here, the paleosol which represents the regressive apex of NT_7 is present here as elsewhere. Soil development at this locality may explain the absence of the transgressive surface (limestone unit 15 in Fig. 19) of NT_7.

The eighth sixth-order T-R unit (NT_8) begins at the base of unit 22. This unit is a 4-inch (0.10 m) fine calcilutite containing a molluscan biofacies suggesting a marginal marine paleoenvironment. Unit 23 is a 1-inch (0.03 m) fine calcarenite containing common ostracods and microgastropods and is also interpreted as a marginal marine, possibly lower intertidal paleoenvironment. Unit 24 is a thick 47-inch (1.19 m) dark green sandy mudstone with common angular, siliceous limestone clasts that are interpreted as reworked rocks deposited in a non-marine environment such as an alluvial plain. Both unit 25, a 14-inch (0.36 m) light green mudstone containing root traces, and unit 26, a 40-inch (1.02 m) pale red to green varigated mudstone are interpreted as non-marine deposits.

The ninth sixth-order T-R unit (NT_9) begins at the base of unit 27 where a 5-inch (0.13 m) medium calcilutite containing a molluscan biofacies occurs. This unit is interpreted as representing deposition in a marginal marine paleoenvironment. Unit 28 is a 17-inch (0.43 m) light green mottled black, non-fossiliferous mudstone which is interpreted to have been deposited in a non-marine environment and represents the regressive apex of sixth-order T-R unit 9.

Transgressive surface NT_{10} is encountered at the base of unit 29. This unit is a 2-inch (0.06 m) algal-laminated, fine calcilutite containing dessication cracks and interpreted as a supratidal paleoenvironment. As sea level regressed unit 30 was deposited, a 72-inch (1.83 m) pale red and light green, crumbly mudstone containing root traces and clay films, a probable paleosol.

The eleventh sixth-order T-R unit (NT_{11}) starts at the base of unit 31. This unit is a 16-inch (0.41 m) fine calcilutite containing root traces and is interpreted to have been deposited in a supratidal paleoenvironment. Overlying unit 31 is a 13-inch (0.41 m) pale red, crumbly mudstone (unit 32) containing root traces and interpreted as a return to non-marine conditions, such as an alluvial plain. Unit 33 is the last unit of the Eskridge Shale encountered at location B and is a 12-inch (0.30 m) light green, crumbly semi-indurated mudstone suggesting continued non-marine conditions.

The base of unit 34, the base of the Cottonwood Limestone, and consequently the base of the Cottonwood fifth-order T-R unit, is an 11-inch (0.28 m) coarse calcilutite containing a <u>Composita</u> biofacies and thus represents deposition in an open marine paleoenvironment.

In summary, the nine sixth-order T-R units defined at section B appear, overall, to be shallower than those defined at section A. This may be due to topographical differences which were present within the study area during the time of deposition of the Neva-Eskridge fifth-order T-R unit. The inferred topographical differences are important in the interpretation of the paleogeography and will be discussed in a later section.

Central Wabaunsee County Section (C)

The interval of location C, was divided into 11 sixth-order T-R units (Fig. 21) which form the net deepening-shallowing sequence referred to here as the Neva-Eskridge fifth-order T-R unit. The first rocks encountered occur below transgressive surface NT_1 represent a regressive phase of the final sixth-order T-R unit (BT_6) within the underlying Burr fifth-order T-R unit. Conversely, the uppermost unit 39 corresponds to the basal transgressive surface (CT_1) of the overlying Cottonwood fifth-order T-R unit.

The uppermost facies of the Salem Point Shale, referred to as unit 1, is an 11-inch (0.28 m) dark green to brown, crumbly, indurated mudstone. This unit is interpreted as having been deposited in a non-marine paleoenvironment.

The Neva-Eskridge fifth-order T-R unit begins at the base of unit 2 and therefore represents the base of sixth-order T-R unit NT_1. This unit is a 16-inch (0.41 m) coarse

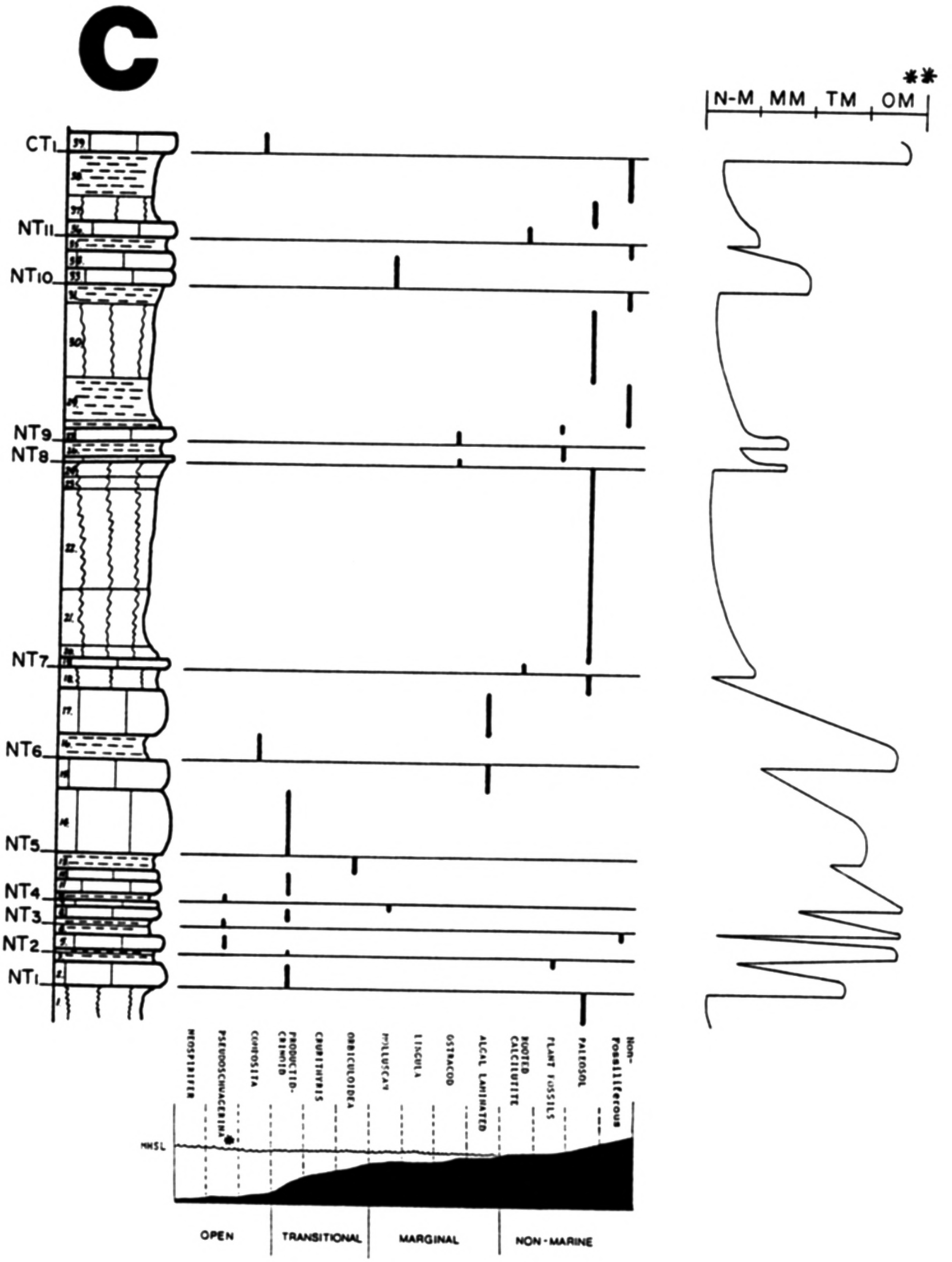


Figure 21. Diagram of section C (locality #23) showing biotic contents and relative sea level curve (* For explanation this, other marked items, and scale, see Fig. 19, p. 49).

calcilutite containing a productid-crinoid biofacies and is interpreted as a shallow subtidal paleoenvironment. Unit 3 is a 3-inch (0.08 m) brown mudstone containing common Orbiculoidea shell fragments and plant fossils and is interpreted as a marginal marine paleoenvironment.

The second sixth-order T-R unit (NT_2) begins at the base of unit 4 and is 5-inches (0.13 m) of green-gray mudstone with a diverse stenotopic assemblage. The biota indicate the Composita biofacies and deposition in a relative open marine environment. Unit 5 represents a continuation of open marine conditions as is reflected by 4-inches (0.10 m) of medium calcilutite containing the Leptotriticites biofacies. As the sea regressed unit 6 was deposited as a 5-inch (0.13 m) olive to dark green, non-fossiliferous mudstone, interpreted as a non-marine deposit.

The third sixth-order T-R unit (NT_3) begins at the base of unit 7. This unit is a 2-inch (0.05 m) olive green mudstone containing the Leptotriticites biofacies and thus represents a return of relative open marine conditions. These conditions were maintained as unit 8, which also contains the Leptotriticites biofacies, was deposited. Unit 9 is interpreted as the regressive apex of NT_3 and contains an algal laminated biofacies which was probably deposited in an intertidal paleoenvironment.

The fourth sixth-order T-R unit (NT_4) begins at the base of unit 10. This unit is a 3 inch (0.08 m) light green mudstone containing the Leptotriticites biofacies and is interpreted as representing deposition in an open marine paleoenvironment. Overlying units 11 and 12 also contain the Leptotriticites biofacies and thus open marine conditions continued. As sea level fell unit 13 was deposited as a 14-inch (0.36 m) brown mudstone containing scattered specimens of Orbiculoidea and Crurithyris and represents deposition in a marginal marine paleoenvironment.

The fifth sixth-order T-R unit (NT_5) starts at the base of unit 14. This unit is a 42-inch (1.07 m) medium calcilutite containing the productid-crinoid biofacies and is interpreted as representing deposition under shallow subtidal conditions. Unit 15 is a 23-inch (0.58 m) fine calcilutite containing a dominant algal-laminated biofacies indicating deposition in an intertidal paleoenvironment. It also represents the regressive apex of NT_5.

Sixth-order unit NT_6 begins at the base of unit 16. This unit is a 15-inch (0.38 m) green-gray mudstone containing the Composita biofacies and is interpreted as having been deposited in an open marine paleoenvironment. This unit represents the transgressive apex of the Neva-Eskridge fifth-order T-R unit and as such is the top of the Neva-Eskridge transgressive hemicycle. The overlying unit (17) is a 29 inch (0.74 m) coarse calcilutite with an algal laminated biofacies, representing an intertidal paleoenvironment. Concordantly, unit 17 represents the base of the Neva-Eskridge regressive hemicycle. Unit 18 is a 17-inch (0.43 m) light green, non-fossiliferous mudstone which is interpreted as having been deposited in a non-marine paleoenvironment and as such represents the regressive apex of NT_6.

The seventh T-R unit (NT_7) begins at the base of unit 19, and is a 4-inch (0.10 m) fine calcilutite commonly root mottled and interpreted as representing a supratidal paleoenvironment. Unit 20 is an 8-inch (0.20 m) light green, non-fossiliferous, calcareous mudstone suggesting a non-marine paleoenvironment. Units 21, 22, and 23 are red to brown mudstones cumulatively 116-inches (2.95 m) thick, which contain nodular caliche, microslickensides, and clay films, and thus suggest paleosol development. Unit 24 is an 8-inch (0.20 m) dark green, semi-indurated mudstone which is also interpreted as a terrestrial deposit.

The eighth sixth-order T-R unit (NT_8) starts at the base of unit 25. This unit is a 1-inch (0.03 m) medium calcilutite containing abundant ostracods and is interpreted to have been deposited in a marginal marine paleo-environment. The overlying unit (26) is an 11-inch (0.28 m) olive green mudstone with scattered ostracods and plant fossils which become dominant near the top of the unit. This unit is interpreted as representing a gradual restriction of marine influence culminating in a more marginal marine paleoenvironment, the regressive apex of NT_8.

The ninth sixth-order T-R unit (NT_9) begins at the base of unit 27 and is a 9-inch (0.23 m) medium calcilutite with scattered ostracods, microgastropods, and algal laminations. The evidence suggests that it was deposited in a marginal marine (intertidal) paleoenvironment. As sea level fell a 1-inch (0.03 m) black, coaly mudstone containing well preserved plant fossils was deposited. This unit is interpreted as a coal smut deposited in a low energy swamp-like paleoenvironment. The overlying unit (29) is a 32-inch (0.81 m) dark green, mottled black mudstone that is interpreted to have been deposited in a terrestrial paleoenvironment. Units 30 and 31 are cumulatively 47-inch (1.19 m) thick, red to green non-fossiliferous mudstones formed in a terrestrial paleoenvironment. The final bed of the regressive part of NT_9, unit 32, is a 16-inch (0.41 m) light green, non-fossiliferous mudstone which is interpreted to represent continental deposition.

The tenth sixth-order T-R unit (NT_{10}) occurs at the base of unit 33. This unit is an 8-inch (0.20 m) fine calcilutite containing few skeletal fragments and interpreted as having been deposited in an intertidal paleoenvironment. As sea level continued to rise, unit 34 was deposited, a 13-inch (0.33 m) medium calcilutite containing the molluscan biofacies, a marginal marine paleoenvironment. Unit 35, a 33 inch (0.84 m) light green, non-fossiliferous mudstone which is interpreted as having been deposited in a non-marine paleoenvironment and represents the regressive apex of NT_{10}.

The eleventh sixth-order T-R unit (NT_{11}) begins at the base of unit 36. This unit is a 7-inch (0.18 m) fine calcilutite with abundant plant roots and scattered productid spines and is interpreted as having been deposited in an intertidal to supratidal paleoenvironment. Unit 37 is a 15-inch (0.38 m) brown-red, crumbly, non-fossiliferous mudstone which is interpreted to be a terrestrial deposit. The last bed observed within the Eskridge Shale is unit 38, a 33 inch (0.84 m) light green nonfossiliferous mudstone reflecting a non-marine paleoenvironment. Concurrently, this unit also represents the top of the Neva-Eskridge regressive hemicycle.

The base of unit 39 is the base of the Cottonwood Limestone, and thus the base of the Cottonwood fifth-order T-R unit. Here this unit is a 12-inch (0.30 m) medium calcilutite containing the Composita biofacies and represents a return to open marine conditions in the area.

Correlation Methods and Results

The methods used to correlate the sixth-order transgressive surfaces and thus the sixth-order T-R units entailed a rigorous location by location comparison of all genetic surfaces and marker beds. The datum used was the base of the Neva Limestone (NT_1) because it marks the initial transgression over the area and signifies initial development of the Neva-Eskridge T-R unit. Other major marker beds found everywhere within the study area include the algal-laminated top of the Neva Limestone found within unit NT_6, the red paleosol which forms the regressive apex of NT_7, and the basal unit of the Cottonwood Limestone. Minor marker beds were used locally. As the transgressive surfaces were "stepped out" from location to location across the study area, subtle to extreme changes in minor marker beds were then recognized and noted. As a check of these methods, the relative number of sixth-order T-R units and the general shape of the sea level curves were then compared. The eleven sixth-order T-R units defined within the Neva-Eskridge fifth-order T-R unit were mostly correlative over the study area with few exceptions.

These methods were utilized to correlate among all the measured sections within the study area. This correlation of allocyclic sixth-order T-R units will allow for definition of paleogeographic changes on a sixth-order scale.

Two cross-sections were drawn to illustrate lateral relationships of the full Neva-Eskridge fifth-order T-R unit. The cross-sections, which include all the complete measured sections, are drawn along two lines (Fig. 22). The first line of cross-section is drawn parallel to the axis of the Nemaha Anticline, and includes localities # 20, 19, 5, 23, and 31. This line of cross-section (A-A') incorporates the three previously discussed detailed sections A (#20), B (#19), and C (#23) to illustrate how the sixth-order T-R units are correlated. While the second line of cross-section is drawn perpendicular to the first line, and includes localities # 23, 5, 1, 8, 6, 10, and 28 (core).

The line of cross-section A-A', drawn parallel to the axis of the Nemaha Anticline (Fig. 23) illustrates correlation of the eleven sixth-order T-R units over a horizontal distance of approximately 90 miles.

Locality #20 displays the eleven sixth-order T-R units of the Neva-Eskridge fifth-order T-R unit. When compared to locality #19, which occurs 10 miles to the southwest, sixth-order T-R unit NT_3 pinches out. In its place lies a conspicuously thicker interval (NT_2), which contains scattered plant fossils in the top 6 inches (0.15 m). This subtle change suggests that the transgressive surface NT_3 is not recognizable at this locality either because it was never deposited or was quickly eroded after deposition. The presence of the plant fossil biofacies indicates that a

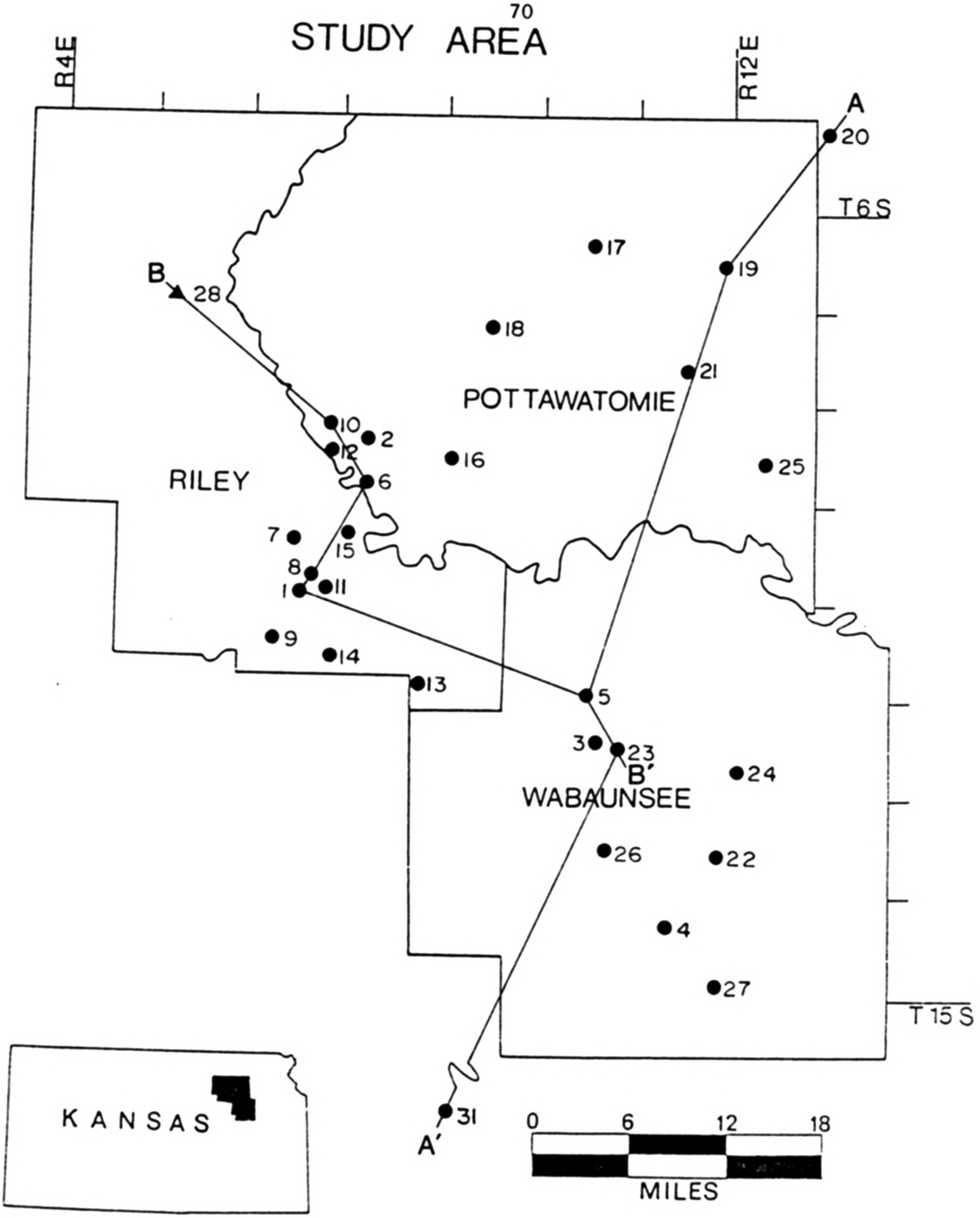


Figure 22. Location map for correlated cross-sections A-A'(localities # 20, 19, 5, 23, and 31), and B-B'(localities # 28, 10, 6, 8, 1, 5, and 23).

topographic anomaly may have occurred here. The transgressive surface NT_7, which is generally a rooted calcilutite, is also absent at locality #19 whereas the prominent overlying paleosol occurs here. Further evidence for a topographic anomaly includes a thickening of NT_8 over this relatively short distance. Included within the regressive part of NT_8 is a 47-inch (1.19 m) thick, sandy mudstone containing siliceous, angular limestone clasts (up to 10 mm) which may have been the result of local erosion and deposition of the underlying limestone units which form the transgressive part of NT_8. A thick paleosol also occurs in the regressive part of NT_{10}, whereas it does not occur at locality #20.

Locality #5 which occurs approximately 30 miles southeast of locality #19, more closely resembles locality #20 in that all eleven sixth-order T-R units are present. In addition to the presence of NT_3 and the transgressive surface of NT_7 at locality #5, a thickening of NT_9 occurs as does an overall thickening of the fifth-order unit.

Locality #23, which lies approximately four miles southeast of locality #5, shows an overall similiar pattern with all eleven sixth-order T-R units present. Several sixth-order T-R units are thinner at this locality and consequently comprise an overall thinner fifth-order T-R unit than that found at locality #5.

Locality #31 is in Chase County, Kansas, approximately

46 miles southwest of locality #23 and is the type locality of the Neva Limestone Member. Between these localities the marker beds were useful in correlating eight of the eleven sixth-order transgressive surfaces. Sixth-order T-R units NT_5 and NT_{11} pinch out at this locality and the transgressive surface of NT_7 is present. The non-deposition of these units may also be due to a topographic anomaly which existed in this area.

The line of cross-section B-B', drawn perpendicular to the axis of the Nemaha Anticline (Fig. 23) illustrates the correlation of the eleven sixth-order T-R units over a horizontal distance of approximately 42 miles.

Locality #28 (core) exhibits 10 of the 11 sixth-order T-R units of the Neva-Eskridge fifth-order T-R unit. Sixth-order T-R unit NT_3 is again missing and may not have been deposited.

Locality #10 occurs approximately 13 miles southeast of locality #28 and displays similiar characteristics as once again sixth-order T-R unit NT_3 is absent. Evidence for an autogenic event is present within NT_8 as a thin 4-inch (0.10 m) fine calcilutite containing <u>Aviculopecten</u> occurs in the regressive part of NT_8 and may indicate a local inundation at this time.

Locality #6 lies approximately 4.5 miles southeast of locality #10 and is also very similiar except for the presence of NT_3. At this locality sixth-order T-R unit NT_3

consists of a medium dololutite at its base overlain by a thin dolomitic sandstone and non-fossiliferous mudstones. The occurrence of NT_3 may signify a topographic irregularity present in this area.

Locality #8 is approximately seven miles southwest of locality #6 and exhibits an overall similiar fifth-order thickness but again NT_3 pinches out.

Locality #1 occurs approximately one mile southwest of locality #8 and displays an abrupt thinning of the Neva-Eskridge fifth-order T-R unit. At this locality sixth-order T-R unit NT_4 is a dololutite (unit 33) which represents a transgression over the underlying non-fossiliferous mudstone. Abundant root mottling and small geodes occur at the top of the dololutite and suggests a regressive facies below the overlying transgressive surface NT_5.

Locality #5 is 20 miles southeast of locality #1 and contains all eleven sixth-order T-R units within the Neva-Eskridge fifth-order T-R unit. The presence of NT_3 plus thickening in sixth-order units NT_6, NT_9, and NT_{11} creates an overall fifth-order thickening in this area.

Locality #23 is approximately four miles southeast of locality #5 and displays all eleven sixth-order T-R units within the Neva-Eskridge fifth-order T-R unit.

In summary, many subtle changes are observable in cross-section, most notably the presence or absence of sixth-order T-R unit NT_3 and transgressive surface NT_7. Those localities where these units were missing were characteristically thinner on a fifth-order scale and contained biotic and lithologic evidence of deposition on topographic highs.

Berendsen and Doveton (1988) in their mapping of the St. Peter Sandstone, revealed annular anomalies associated with structurally high features on the Nemaha Anticline where the St. Peter is absent. They attributed these absences to non-deposition rather than later erosional removal. It is plausible that a combination of the two factors of non-deposition and erosion are primarily responsible for the subtle changes observed in the Neva-Eskridge interval.

Neva-Eskridge Fifth-Order T-R Unit

The Neva-Eskridge fifth-order T-R unit section extends from the base of the Neva Limestone Member to the top of the Eskridge Shale and represents one net deepening-shallowing sequence (Fig. 24), one cyclothem. As Busch and West (1987) have suggested, fifth-order T-R units represent intervals of about 300,000 to 500,000 years, each of the 11 sixth-order T-R units within the Neva-Eskridge fifth-order T-R unit represents an average of from 27,300 to 45,500 years.

Bogina, (1988) suggested that the Neva-Eskridge fifth-order T-R unit ranges in thickness from 33.5 to 51.5 feet (10.2 to 15.7 meters) within the study area. The 11 defined Neva-Eskridge sixth-order T-R units range in thickness from 1 to 16 feet (0.3 to 4.9 meters) and commonly reflect a shallowing upward sequence.

Rocks below NT_1 at all localities, contained evidence of deposition in a non-marine paleoenvironment. These include mudstones, interpreted as paleosols, and siltstones, interpreted as alluvial plain deposits. These non-marine sediments were deposited during maximum marine regression associated with the top of the underlying Burr fifth-order T-R unit.

The basal transgressive surface NT_1 represents the initial fifth-order transgression and is characterized by

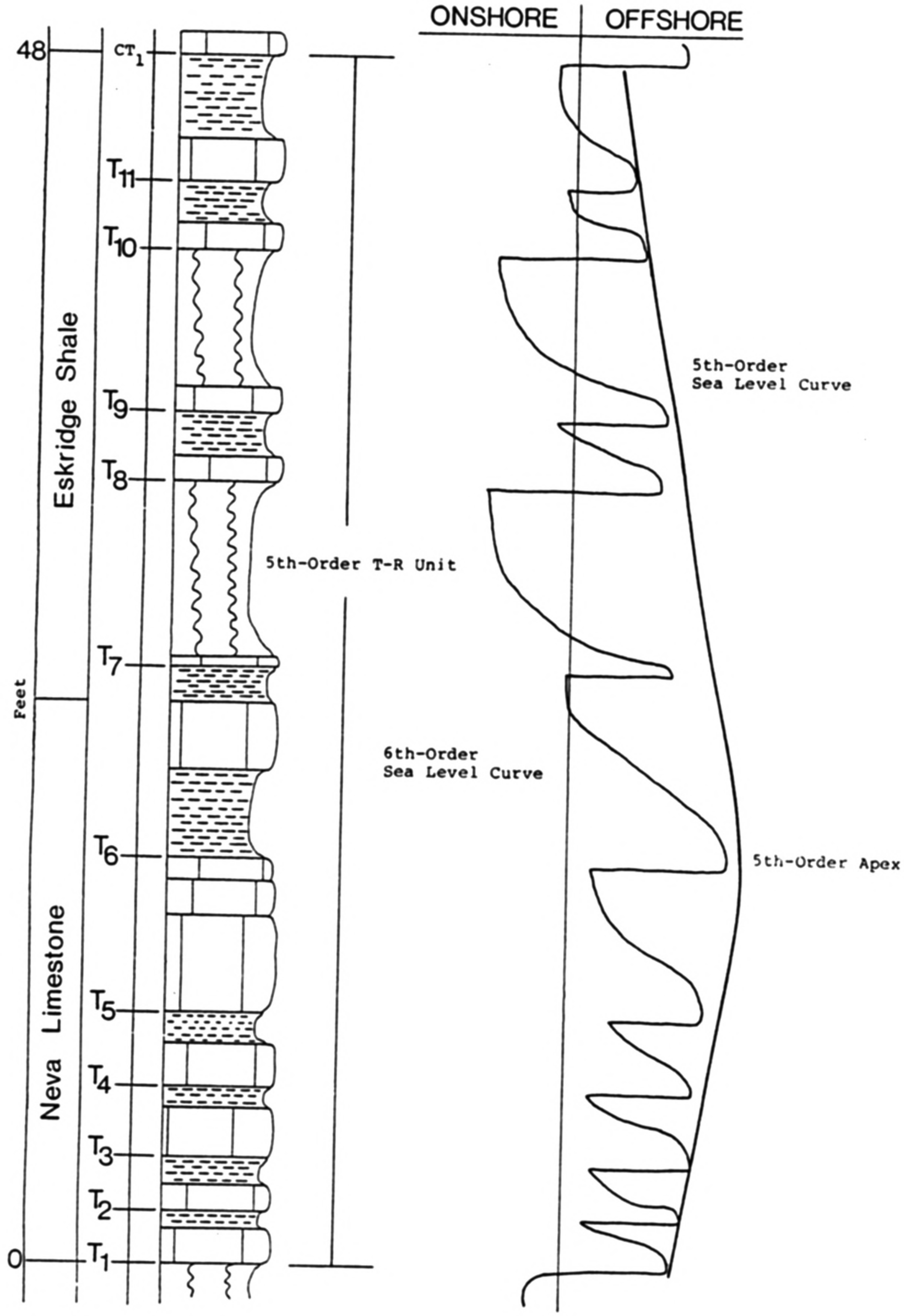


Figure 24. Generalized diagram of the Neva Limestone Member and Eskridge Shale with sea level curve.

coarse calcilutite containing a fairly diverse biota, frequently including fusulinids. This facies reflects open marine conditions over the area investigated.

Sixth-order T-R units NT_1 to NT_6 represent successively greater transgressions and comprise the Neva transgressive hemicycle. Sixth-order unit NT_6 is the transgressive apex of the Neva-Eskridge fifth-order T-R unit. Evidence for this interpretation includes the occurrence of an abundant, highly diverse stenotopic biota, the most open marine facies, of the Neva-Eskridge fifth-order T-R unit.

The Neva-Eskridge regressive hemicycle is represented by sixth-order T-R units NT_7 to NT_{11}. These five sixth-order T-R units consist predominantly of marginal marine limestone and paleosol couplets and form a net shallowing sequence to the base of the Cottonwood limestone.

Sixth-order T-R unit CT_1 represents the start of the overlying Cottonwood fifth-order T-R unit and a return to open marine conditions. Thus the transgressive surface CT_1 marks both the upper boundary of the Neva-Eskridge fifth-order T-R unit and the lower boundary of the Cottonwood fifth-order T-R unit.

NEVA-ESKRIDGE SIXTH-ORDER PALEOGEOGRAPHY

Lithologic and Biotic Trends

Based on the previously presented information detailed litho- and biofacies maps were drawn at times of maximum transgression for each of the 11 defined Neva-Eskridge sixth-order T-R units. The transgressive apices of each sixth-order T-R unit provide a time line for that unit and maps drawn at that surface should reflect the existing paleogeography of the area. Thus paleobathymetric changes can be deduced from the litho- and biofacies existing during eustatic sea level rise.

The litho- and biofacies maps are in color to aid recognition of relationships, both optically and temporally. Lithofacies maps define the carbonate units (aqua) and mudstone units (green). Biofacies maps define the major paleoenvironments used in this study. These include the open marine paleoenvironment (violet), the transitional marine paleoenvironment (aqua), the marginal marine paleo-environment (green), and the non-marine paleoenvironment (yellow).

Identification of recurrent facies changes within the study area are used to develop a composite paleogeographic map for the Neva-Eskridge fifth-order T-R unit. Isopach maps drawn for the Neva transgressive hemicycle and the Neva-Eskridge regressive hemicycle should help delineate sea floor topography. Relating these topographic features to the structure of the area might suggest that sedimentation was structurally controlled.

Maximum transgression for sixth-order T-R unit NT_1 is everywhere recognized by a carbonate lithofacies (Fig. 25) which ranges from a coarser calcarenite in the western half of the study area to a finer calcilutite eastward. The biofacies developed at the transgressive apex for NT_1 (Fig. 26) was transitional, as illustrated by the shallow subtidal Productid-Crinoid biofacies in the north-central part and the transitional biofacies in the southern third of the area. These transitional biofacies are separated by a prominent fusulinid biofacies interpreted to represent open marine conditions.

Maximum transgressive lithofacies for sixth-order T-R unit NT_2 (Fig. 27) consists of mudstone deposited in the southwest quarter of the study area with persistent calcilutites present everywhere else. The transgressive biofacies developed over 90% of the area at NT_2 (Fig. 28) is a fusulinid biofacies. The transitional biofacies in the southern 10% of the study area contains a sparse assemblage of echinoids and the brachiopod Derbyia.

The lithofacies at the transgressive apex of sixth-order T-R unit NT_3 (Fig. 29) include persistent calcilutites in the eastern half of the area with mudstone deposited in the extreme southeastern part of the area. The

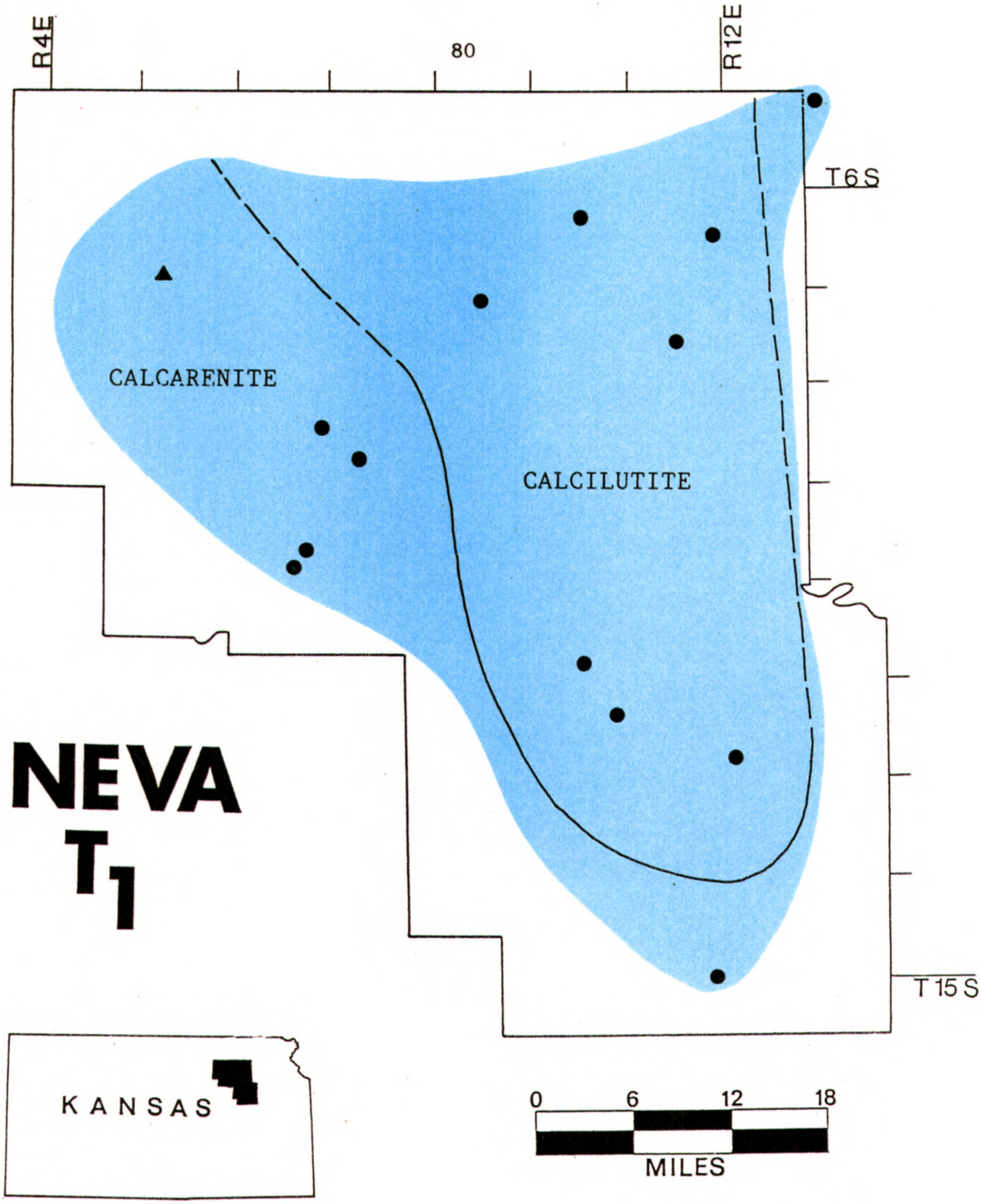


Figure 25. Paleogeographic map of lithofacies at the transgressive apex of NT_1 for the localities where NT_1 is present (for locality identification use overlay in pocket).

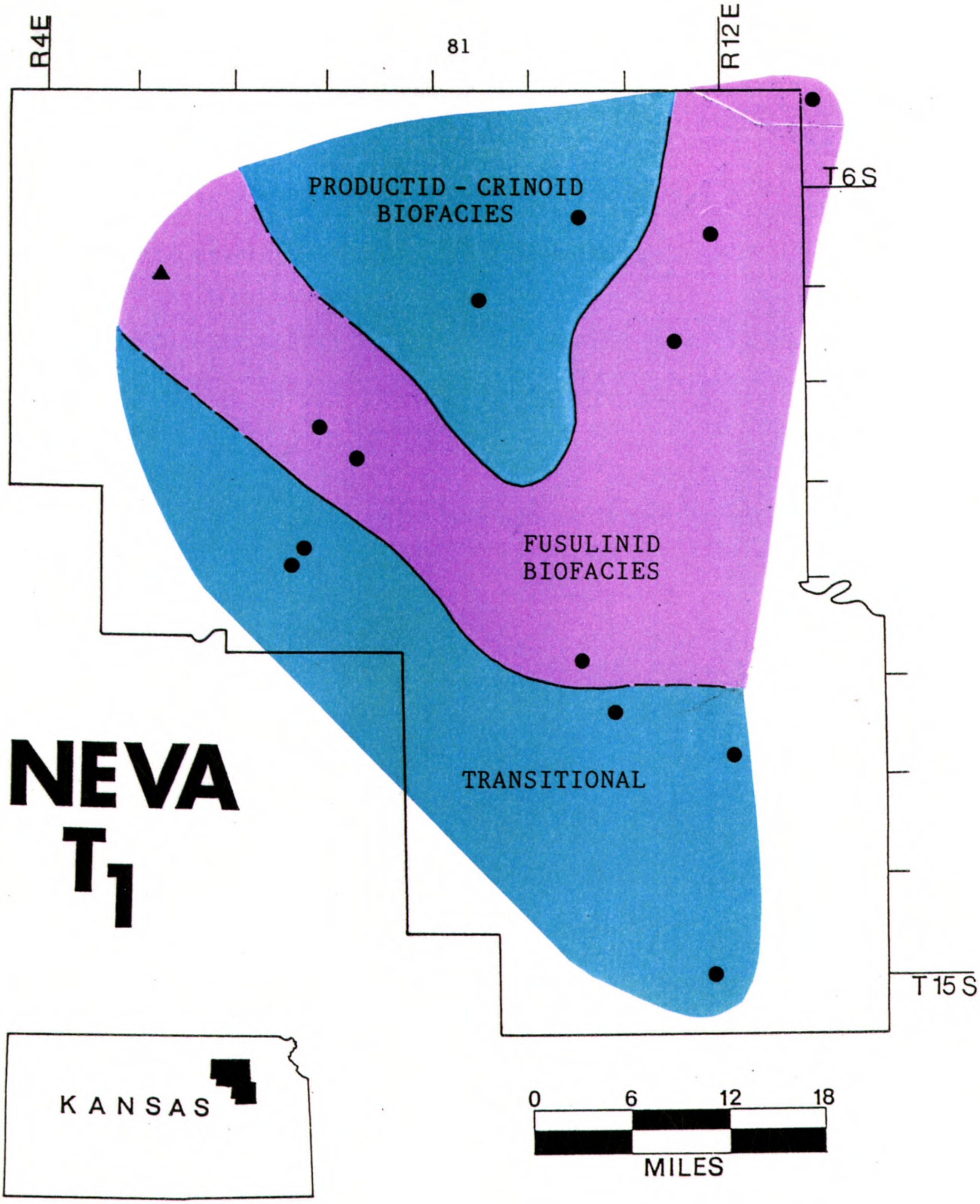


Figure 26. Paleogeographic map of biofacies at the transgressive apex of NT_1 for the localities where NT_1 is present (for locality identification use overlay in pocket).

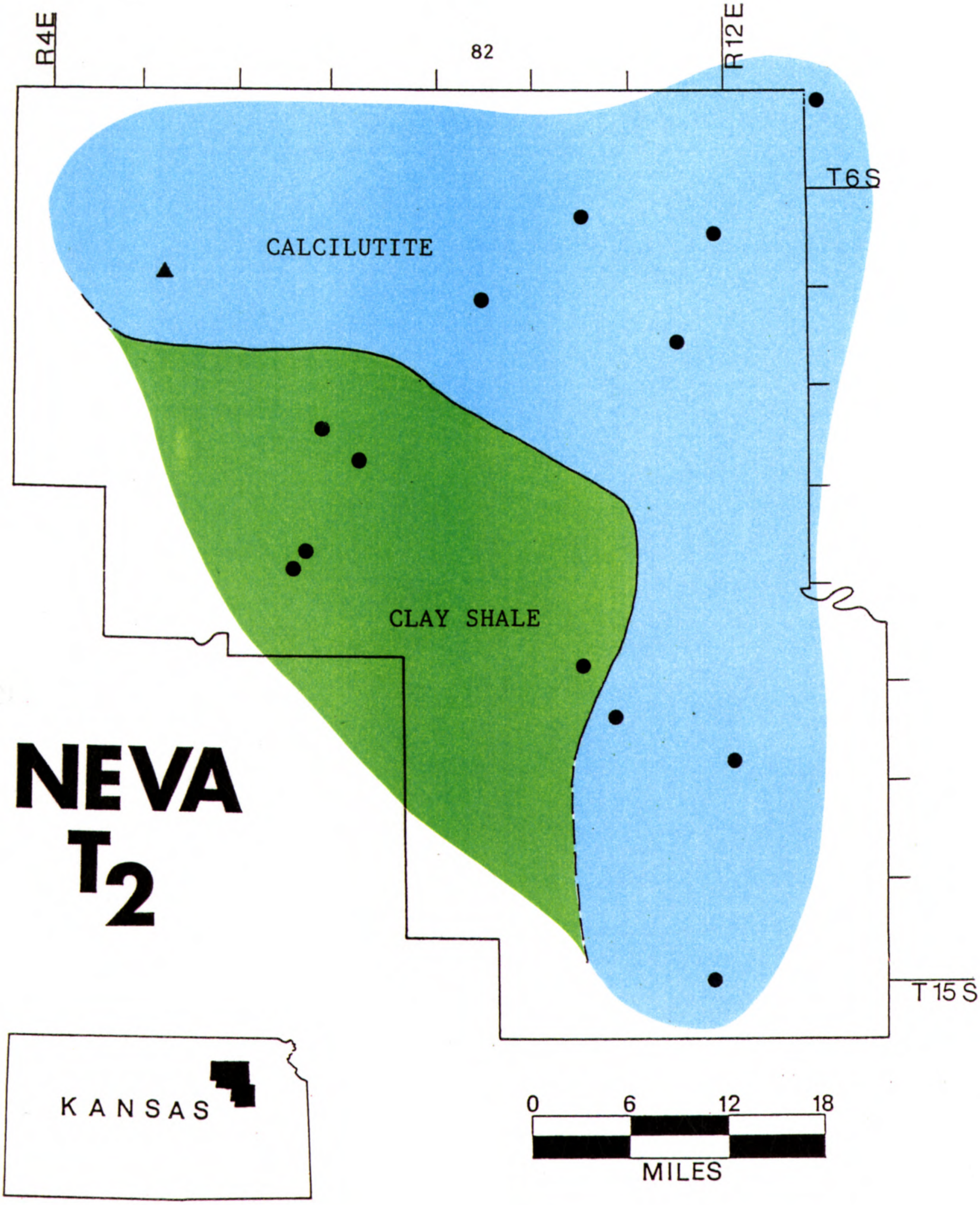


Figure 27. Paleogeographic map of lithofacies at the transgressive apex of NT_2 for the localities where NT_2 is present (for locality identification use overlay in pocket; for clay shale read mudstone).

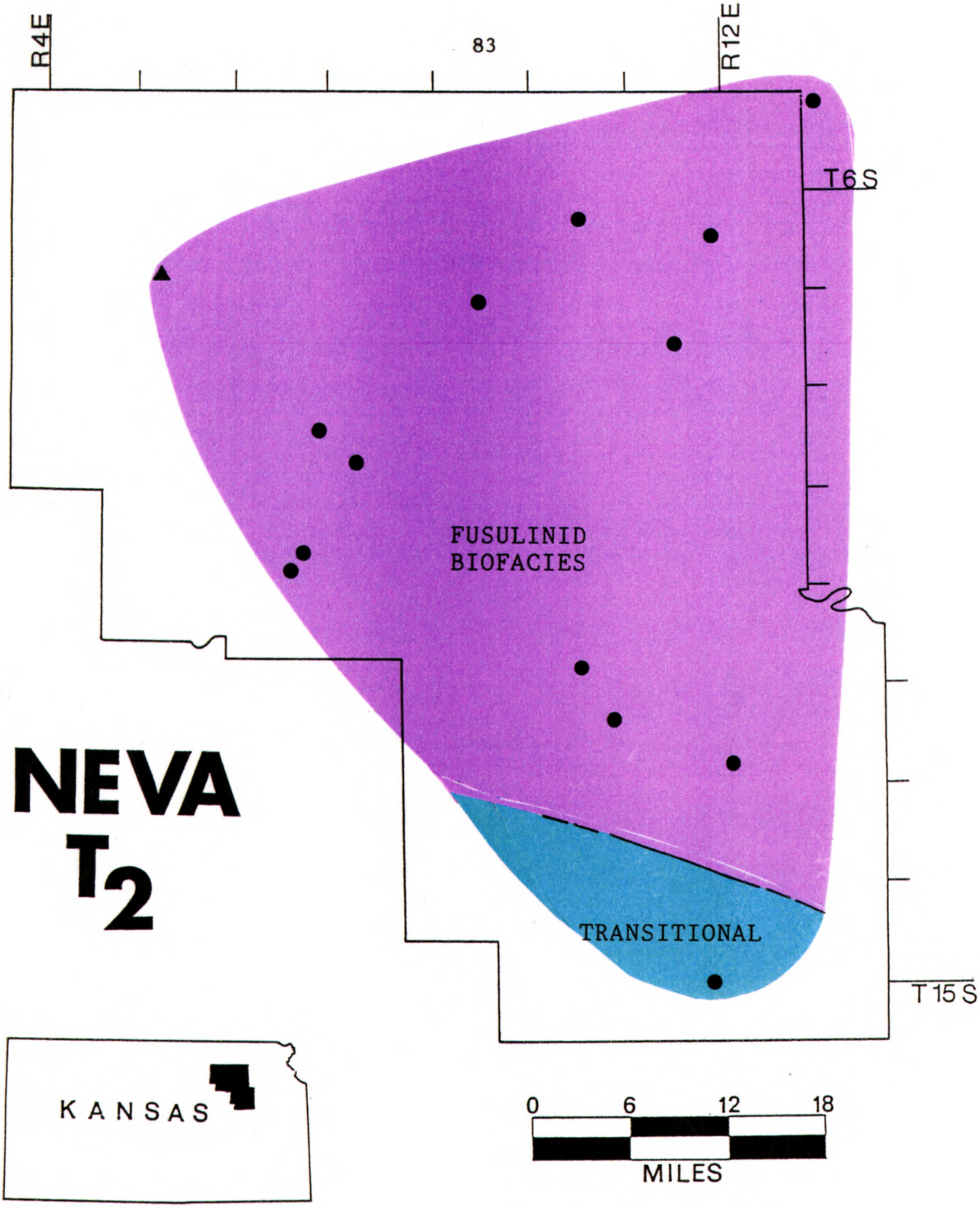


Figure 28. Paleogeographic map of biofacies at the transgressive apex of NT_2 for the localities where NT_2 is present (for locality identification use overlay in pocket).

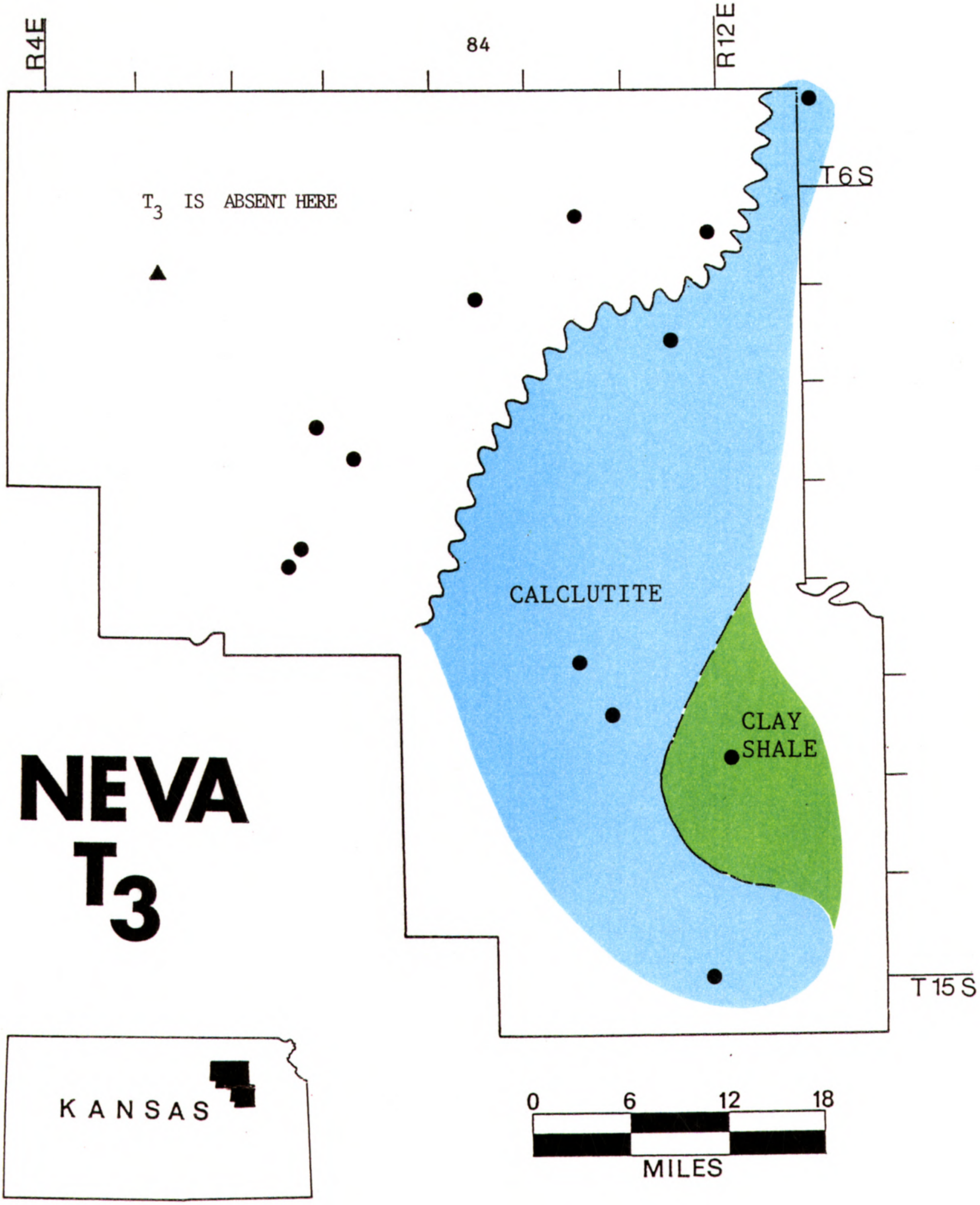


Figure 29. Paleogeographic map of lithofacies at the transgressive apex of NT_3 for the localities where NT_3 is present (for locality identification use overlay in pocket).

transgressive surface NT_3 is not present in the western half of the area and is interpreted to have been eroded during deposition of NT_4. The biofacies established at the transgressive apex of NT_3 (Fig. 30) reflects a transitional, shallow marine environment in the north-central to northeastern part of the area containing Crurithyris and productid-crinoid biofacies. The southeastern part of the area was an open marine environment reflected by a fusulinid and a Composita biofacies.

Lithofacies developed at the transgressive apex of sixth-order T-R unit NT_4 (Fig. 31) are a prominent calcareous shale in the north-central part of the area. The surrounding rocks were calcilutites at this time of maximum sea level rise. The fusulinid biofacies dominated at this time (Fig. 32) suggesting relative open marine conditions. The relatively shallow water productid-crinoid biofacies occurred in the northeastern and extreme southwestern portions of the area. This pattern is similar, in general, to that seen at the transgessive apex of NT_1 (Fig. 26) where shallower marine biofacies occur in the north-central and southwestern parts of the area.

Mudstone is the lithofacies present in the western half of the area during the transgressive apex of sixth-order T-R unit NT_5 (Fig. 33) while calcilutites were deposited in the eastern half. The biofacies deposited at maximum transgression for NT_5 (Fig. 34) is a mosaic with relative

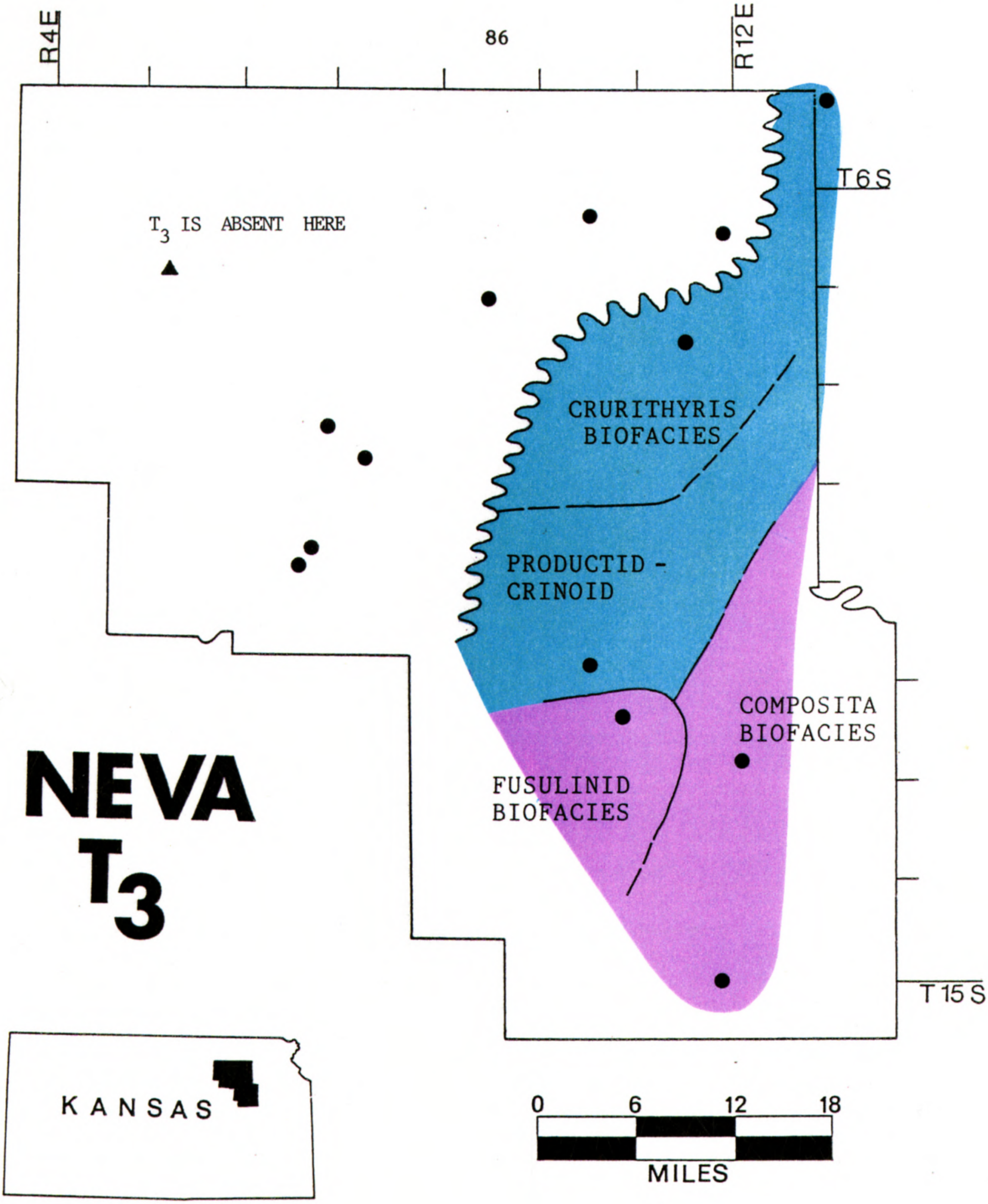


Figure 30. Paleogeographic map of biofacies at the transgressive apex of NT_3 for the localities where NT_3 is present (for locality identification use overlay in pocket).

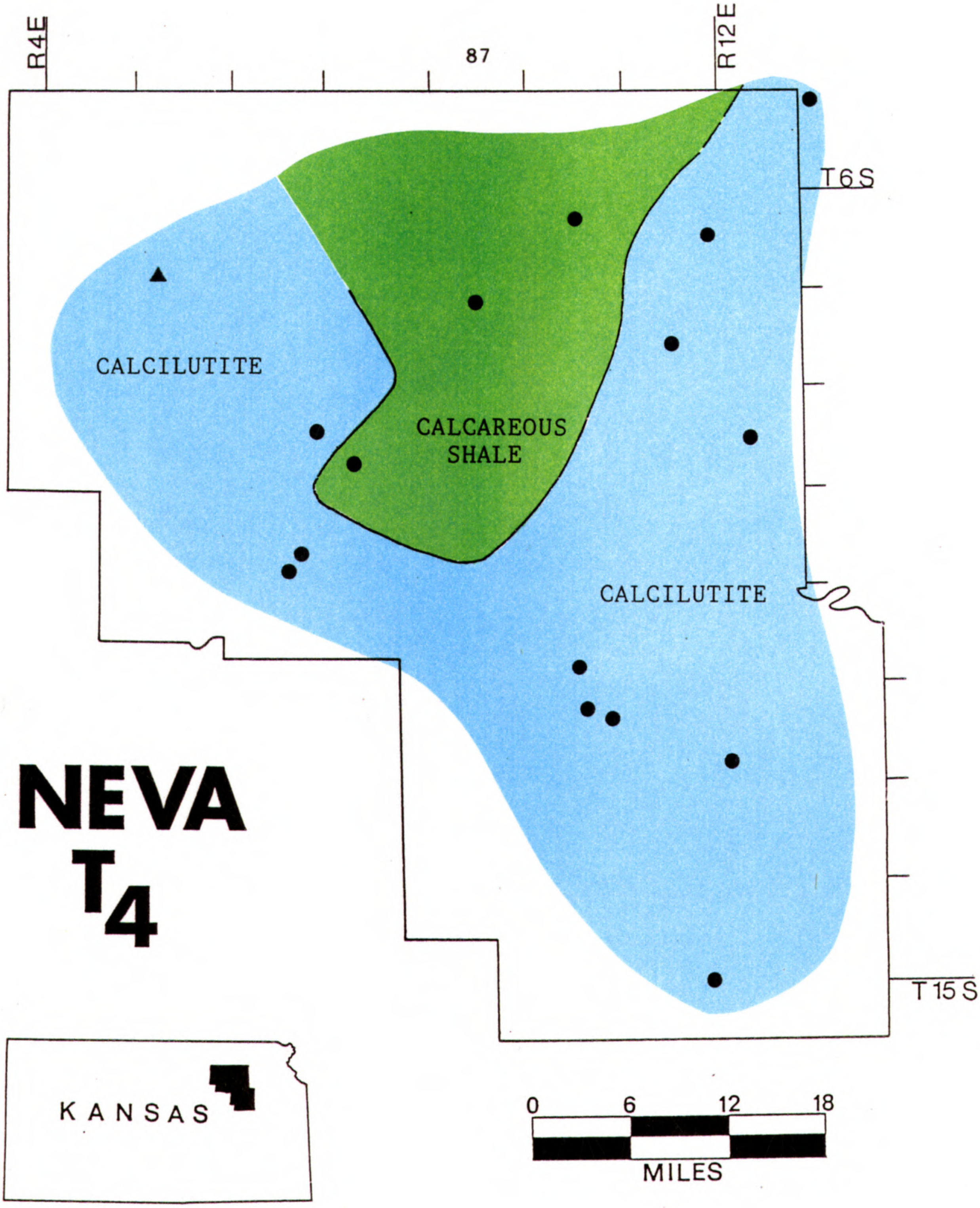


Figure 31. Paleogeographic map of lithofacies at the transgressive apex of NT_4 for the localities where NT_4 is present (for locality identification use overlay in pocket).

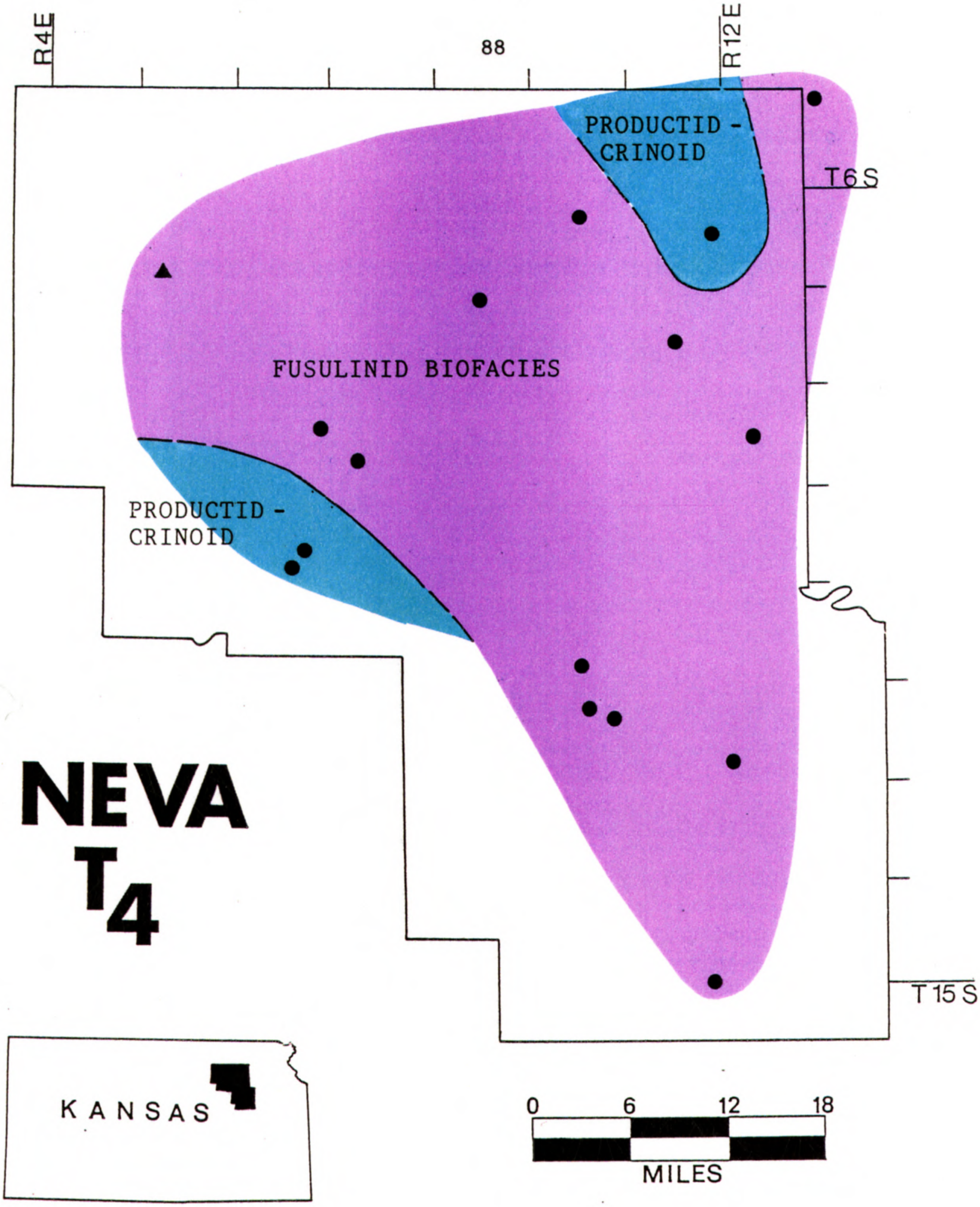


Figure 32. Paleogeographic map of biofacies at the transgressive apex of NT_4 for the localities where NT_4 is present (for locality identification use overlay in pocket).

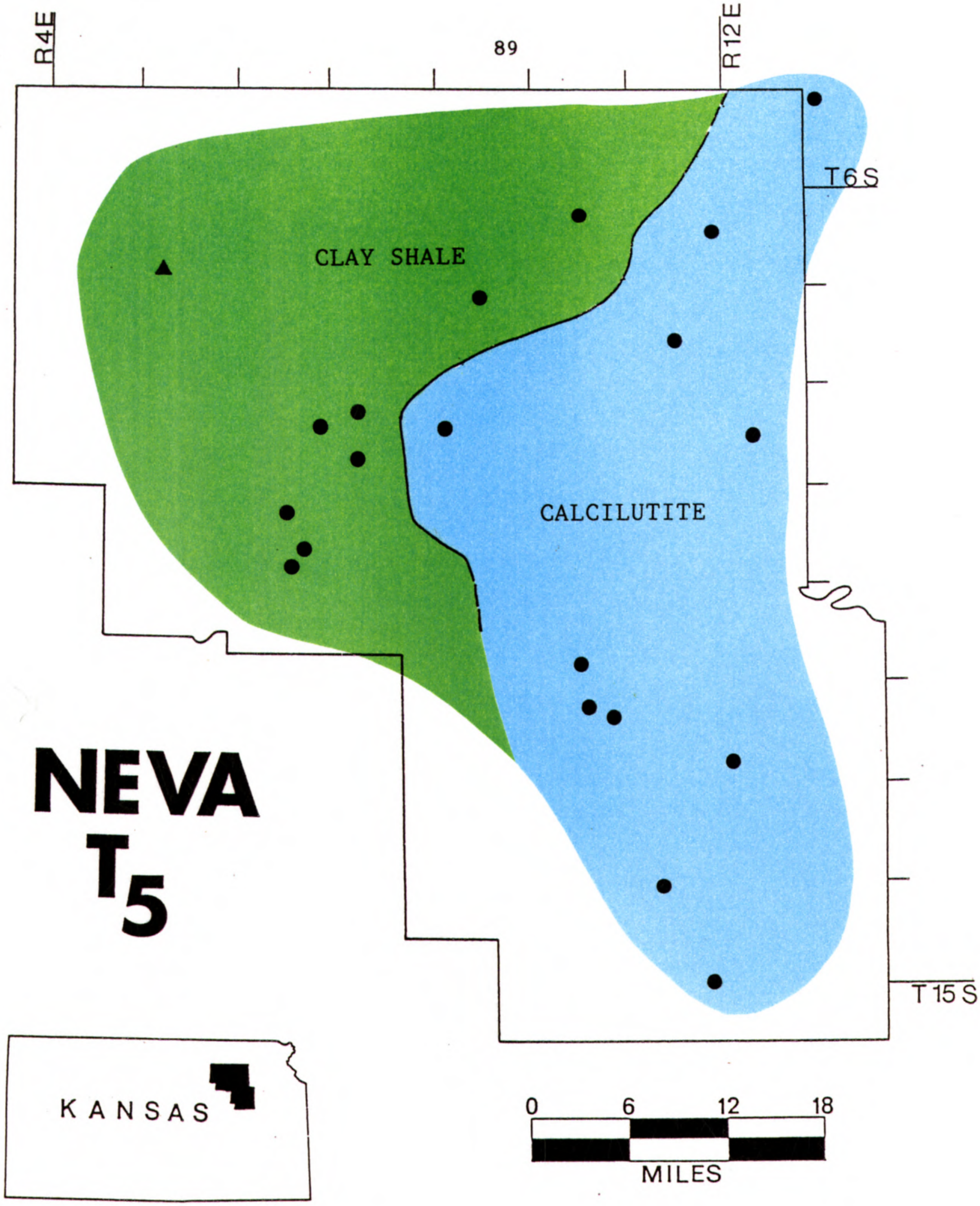


Figure 33. Paleogeographic map of lithofacies at the transgressive apex of NT_5 for the localities where NT_5 is present (for locality identification use overlay in pocket; for clay shale read mudstone).

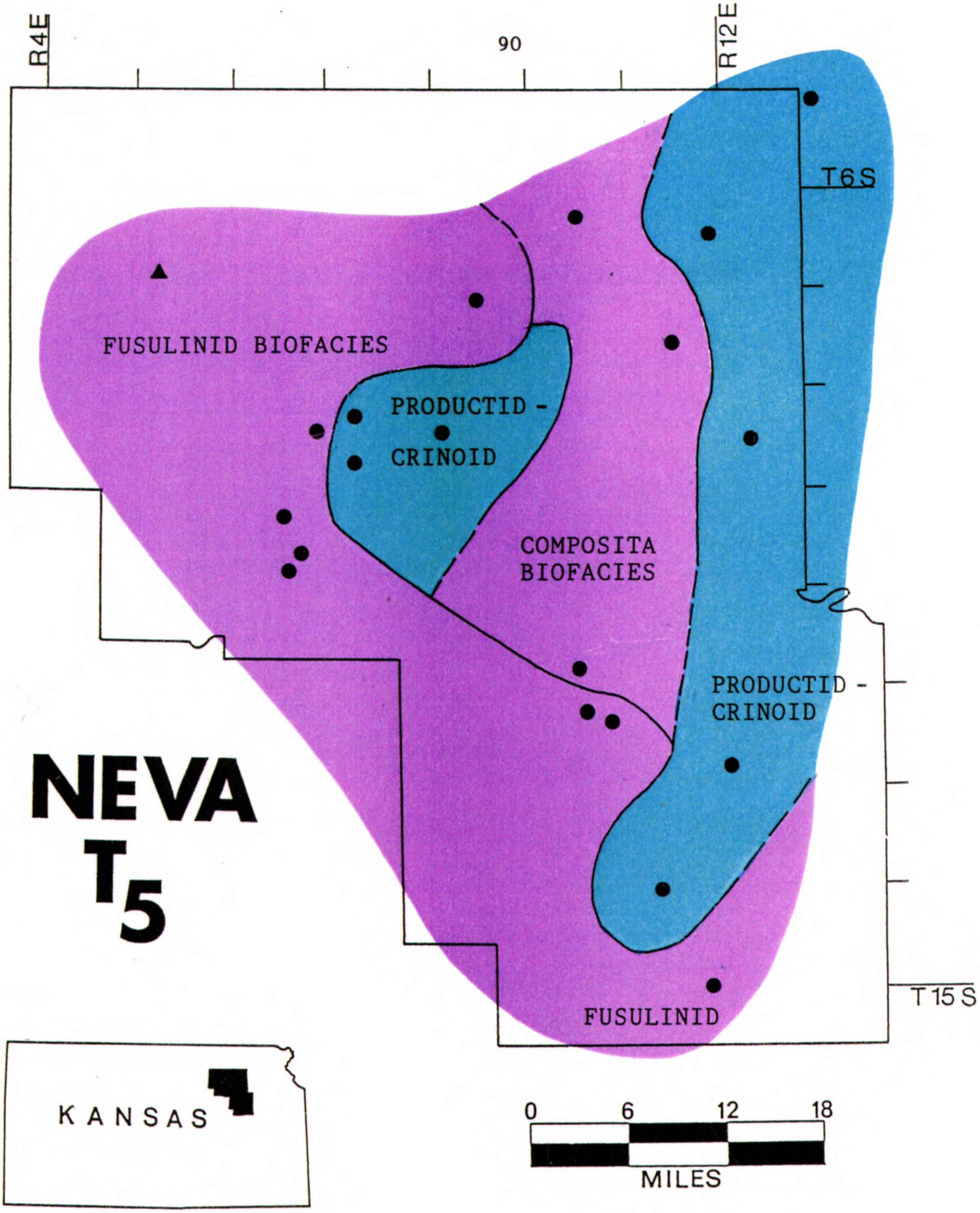


Figure 34. Paleogeographic map of biofacies at the transgressive apex of NT_5 for the localities where NT_5 is present (for locality identification use overlay in pocket).

open marine conditions as evidenced by the fusulinid and Composita biofacies dominant over the western two-thirds of the area. Relatively shallower, transitional marine, productid-crinoid biofacies dominated in the eastern third and is also present in the central part of the area.

During the transgressive apex of sixth-order T-R unit NT_6 (Fig. 35) calcilutite accumulated in the northeastern part of the area while calcareous shale was the dominant lithofacies in the remainder. Biofacies development at the transgressive apex of NT_6 (Fig. 36) was largely the Neospirifer and Composita biofacies (open marine) with the shallower marine, productid-crinoid facies restricted to the northern third of the area.

Calcilutites were deposited over most of the area with calcareous shale deposited only in the extreme southeastern part of the area during the maximum transgression of sixth-order T-R unit NT_7 (Fig. 37). Evidence for surface NT_7 is lacking at 5 localities in a small area near the center of the area and may have eroded during development of the overlying thick red paleosol. The predominant biofacies at this time (Fig. 38) was molluscan, interpreted as a marginal marine to intertidal environment. Nearly completely surrounding this molluscan biofacies is the rooted calcilutite biofacies suggesting a supratidal environment.

The lithofacies developed at the transgressive apex of sixth-order T-R unit NT_8 (Fig. 39) is everywhere

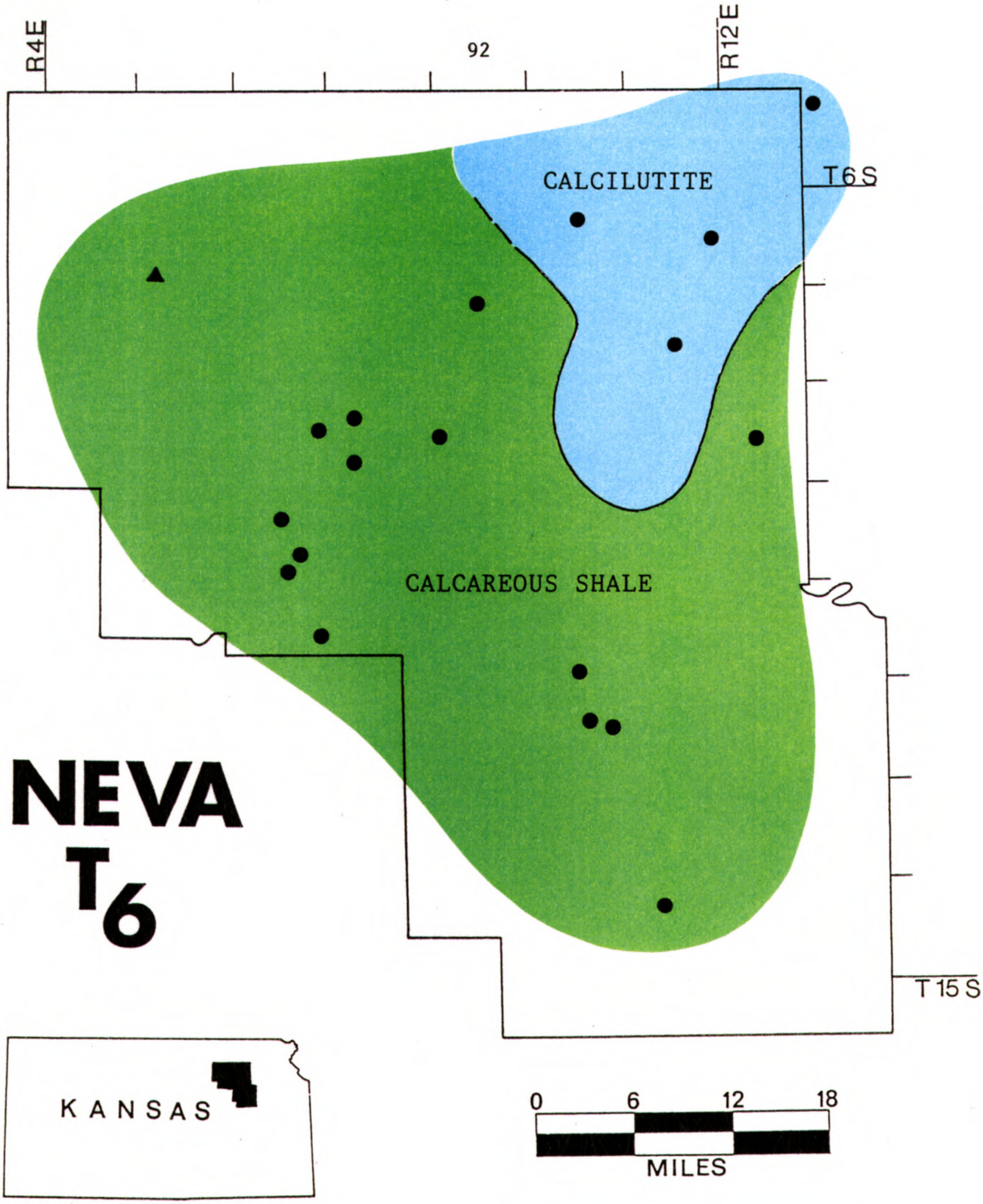


Figure 35. Paleogeographic map of lithofacies at the transgressive apex of NT_6 for the localities where NT_6 is present (for locality identification use overlay in pocket).

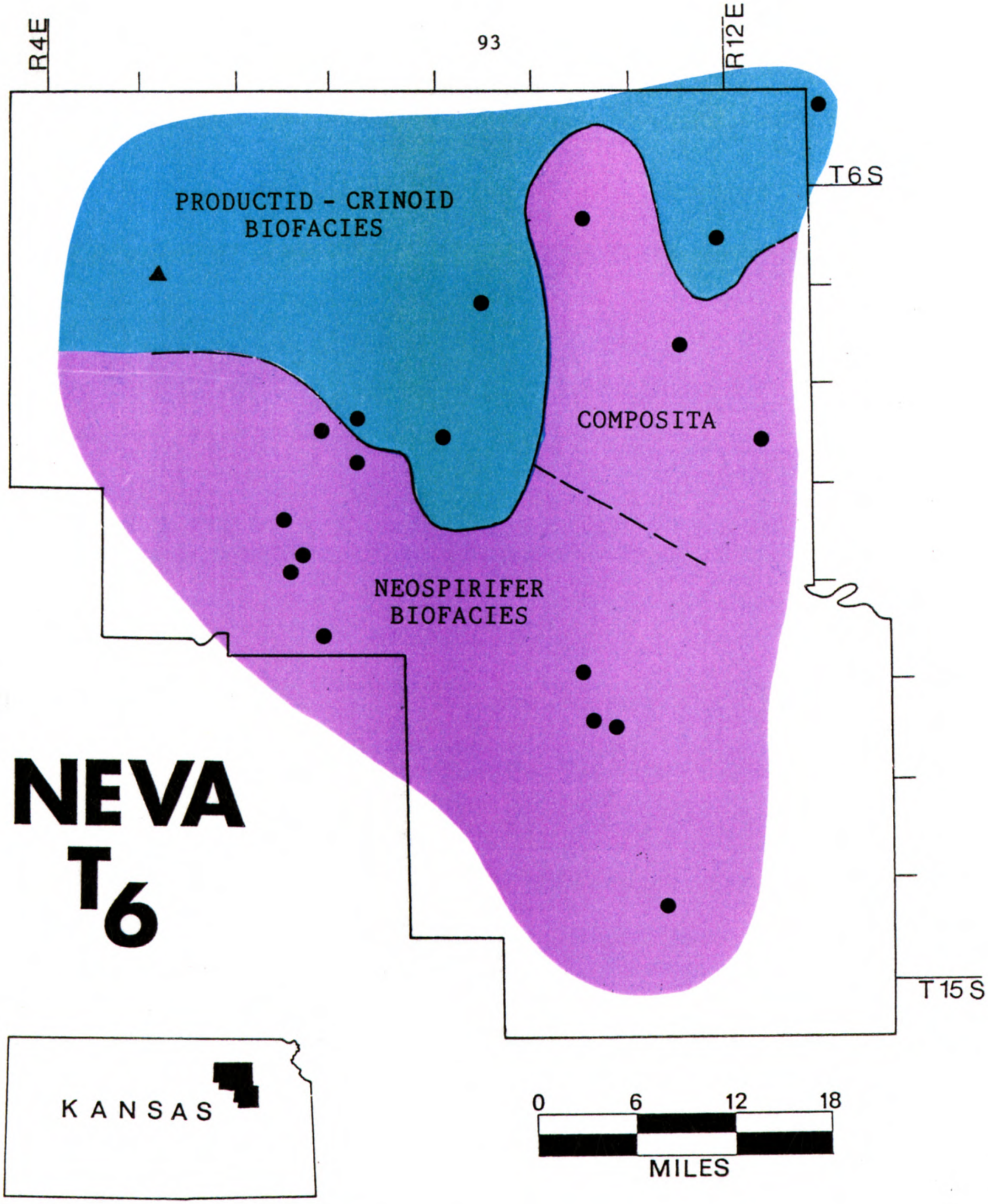


Figure 36. Paleogeographic map of biofacies at the transgressive apex of NT_6 for the localities where NT_6 is present (for locality identification use overlay in pocket).

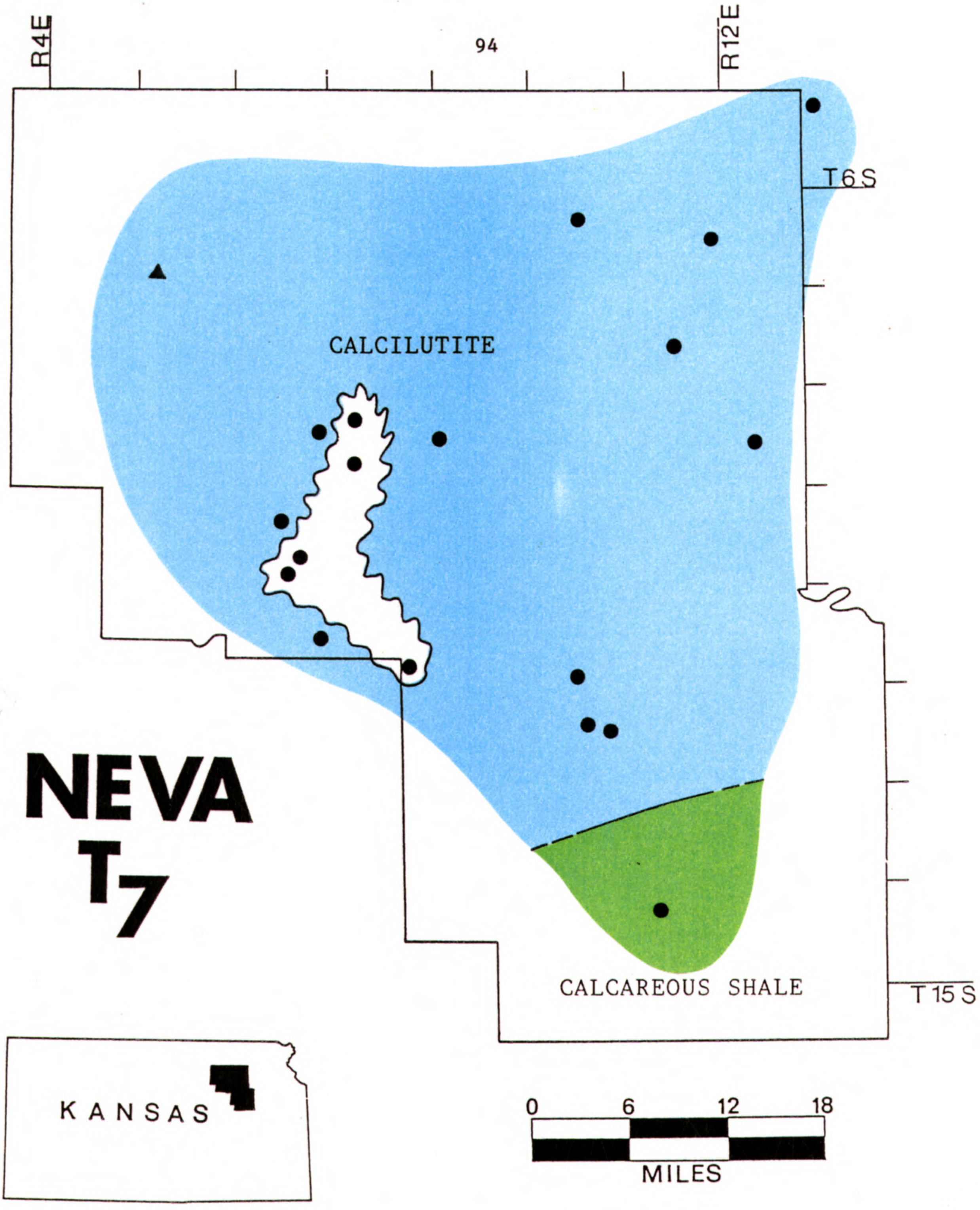


Figure 37. Paleogeographic map of lithofacies at the transgressive apex of NT_7 for the localities where NT_7 is present (for locality identification use overlay in pocket).

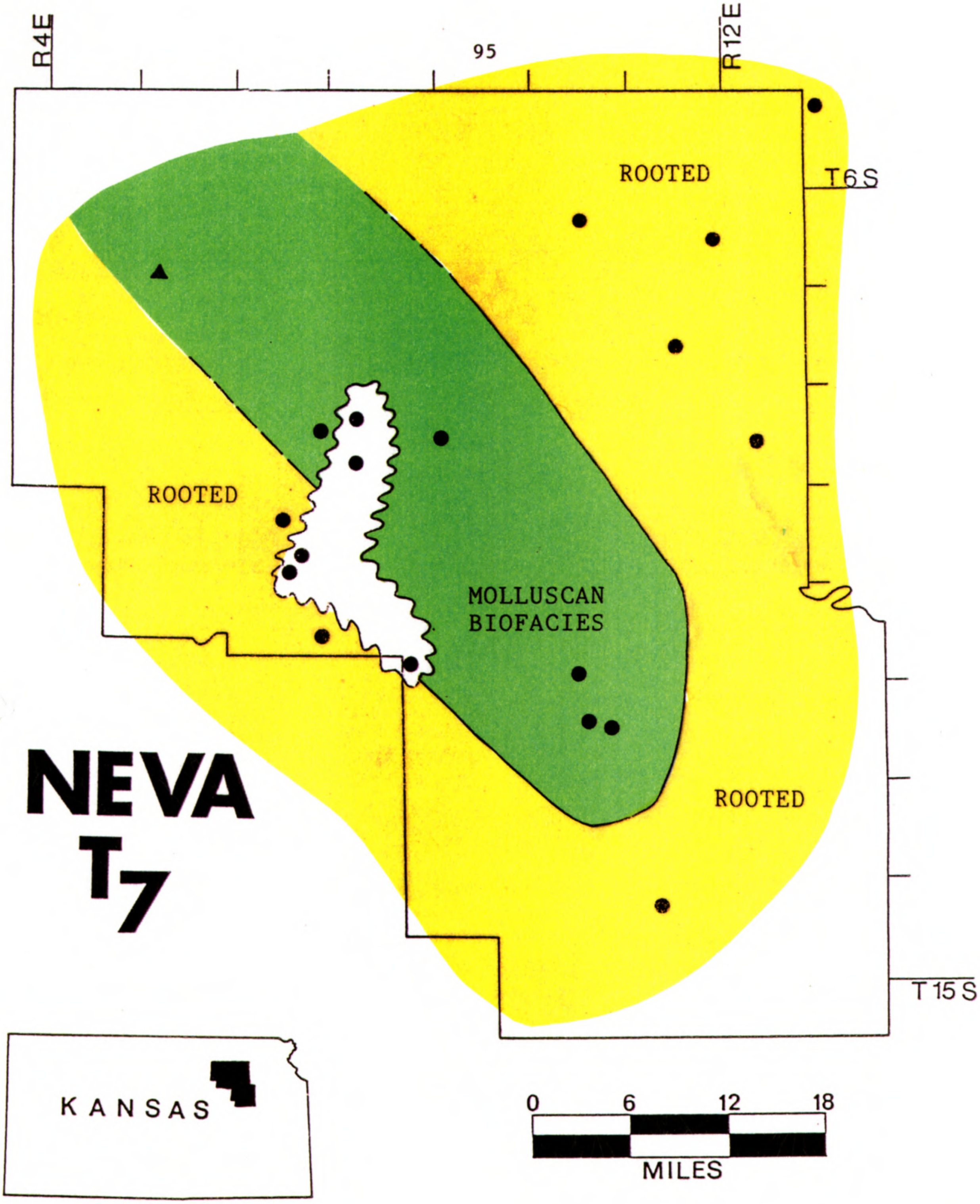


Figure 38. Paleogeographic map of biofacies at the transgressive apex of NT_7 for the localities where NT_7 is present (for locality identification use overlay in pocket).

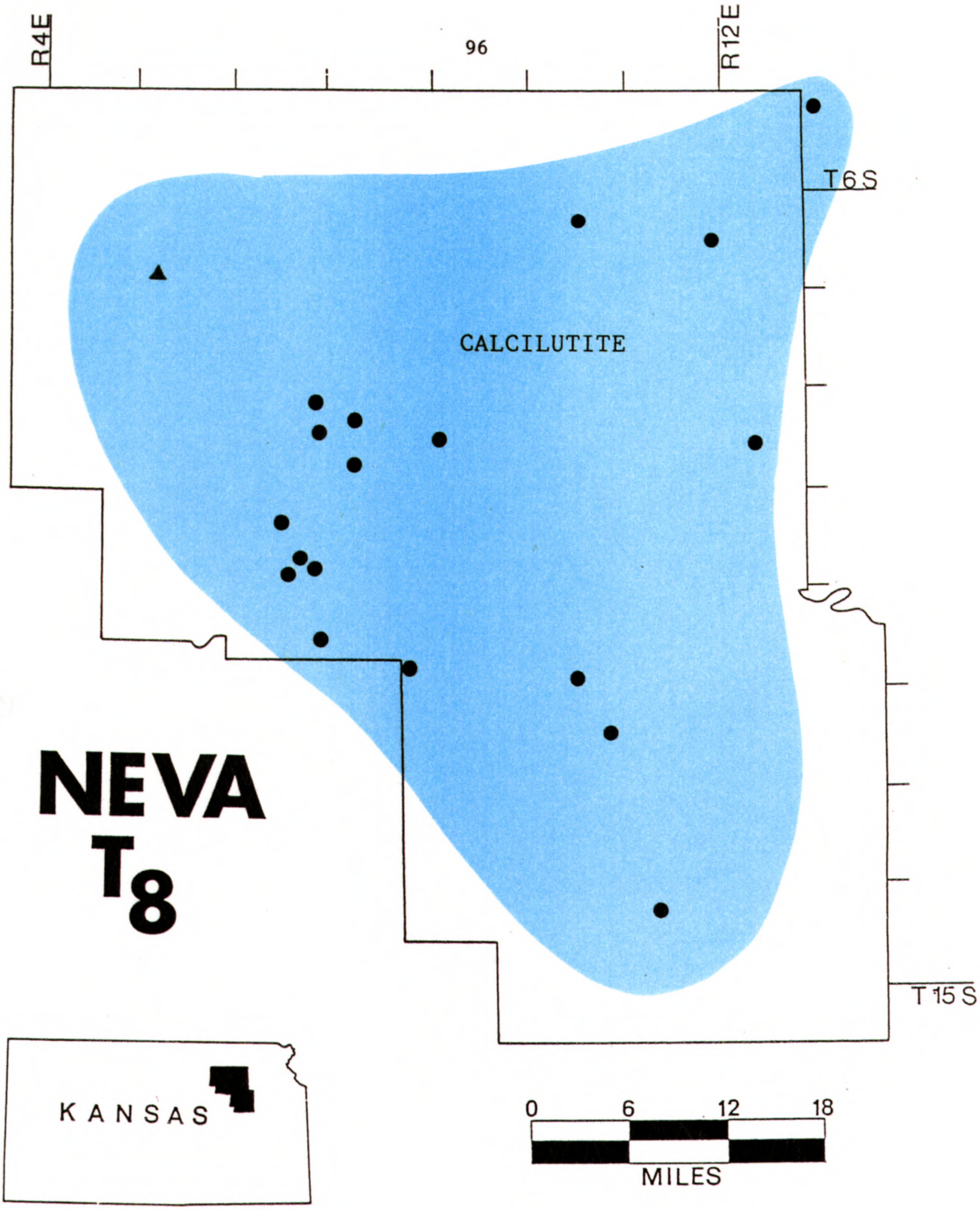


Figure 39. Paleogeographic map of lithofacies at the transgressive apex of NT_8 for the localities where NT_8 is present (for locality identification use overlay in pocket).

calcilutite. Whereas the biofacies are the same as in the underlying 6th-order T-R unit, the distribution is quite different (Fig. 40). The rooted calcilutite biofacies occurs in the northwest (loc. 28) and in the east (loc. 4 and 25).

Again as in the underlying 6th-order T-R unit, a calcilutite lithofacies covers the entire area during the transgressive apex of sixth-order T-R unit NT_9 (Fig. 41). The biofacies and their distribution are also similar to those occurring at the transgressive apex of NT_8 (Fig. 42). There is one basic difference, the rooted calcilutite biofacies is replaced by the algal-laminated biofacies in the south.

At the transgressive apex of sixth-order T-R unit NT_{10}, we see the same facies pattern with one exception, there is a very small area of calcarenite present in the southwestern part of the area (Fig. 43). Once again a molluscan biofacies (Fig. 44) was deposited over most of the area, and the algal-laminated biofacies occurred in the northeast part of the area, suggesting shallower (low intertidal to supratidal) conditions at this time.

Lithofacies and biofacies occurring during the transgressive apex of sixth-order T-R unit NT_{11} (Figs. 45 and 46) are basically the same as for the transgressive apices of sixth-order T-R units NT_7, NT_8, NT_9, and NT_{10} except that the ostracod biofacies occurs at one of the southernmost localities.

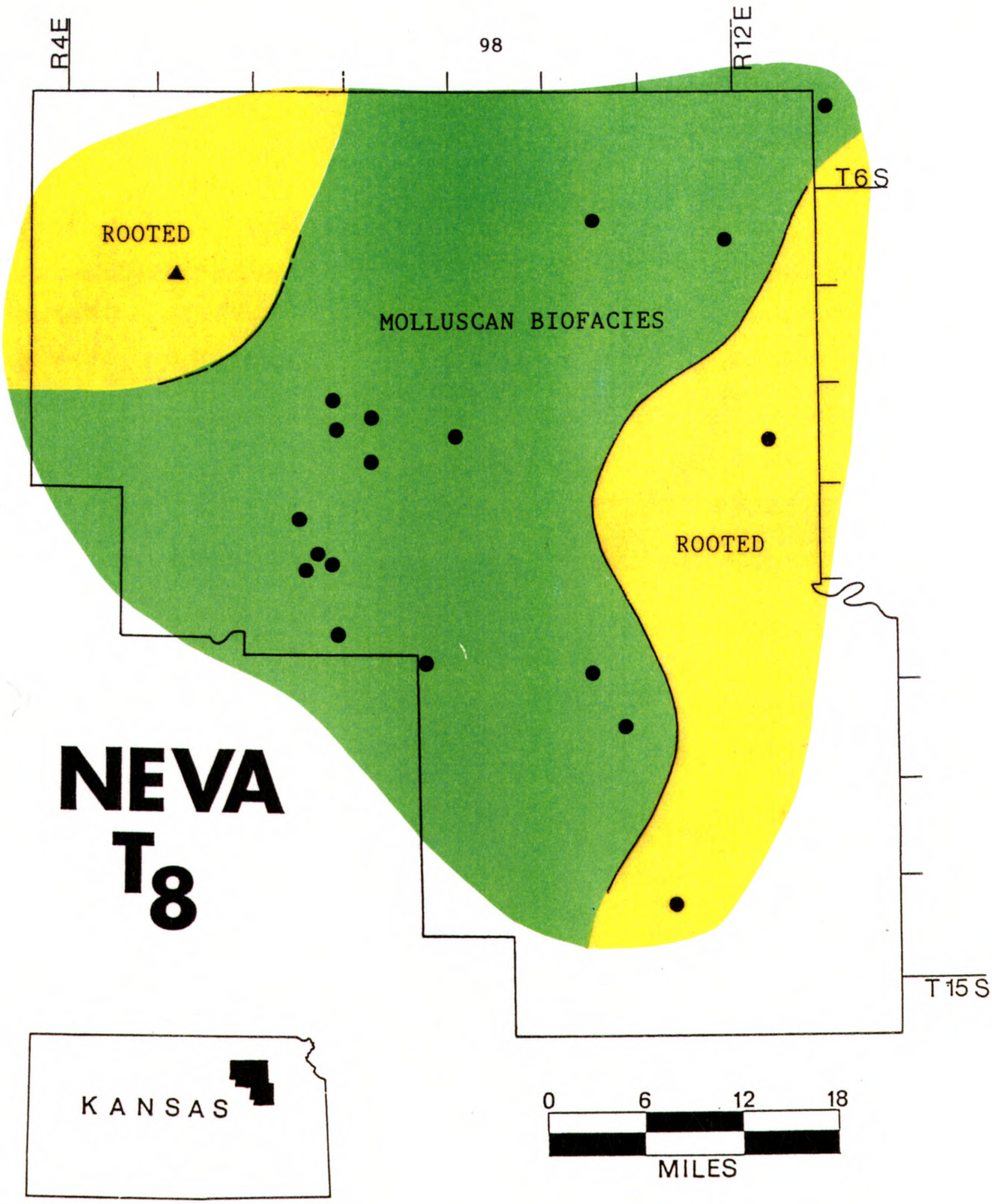


Figure 40. Paleogeographic map of biofacies at the transgressive apex of NT_8 for the localities where NT_8 is present (for locality identification use overlay in pocket).

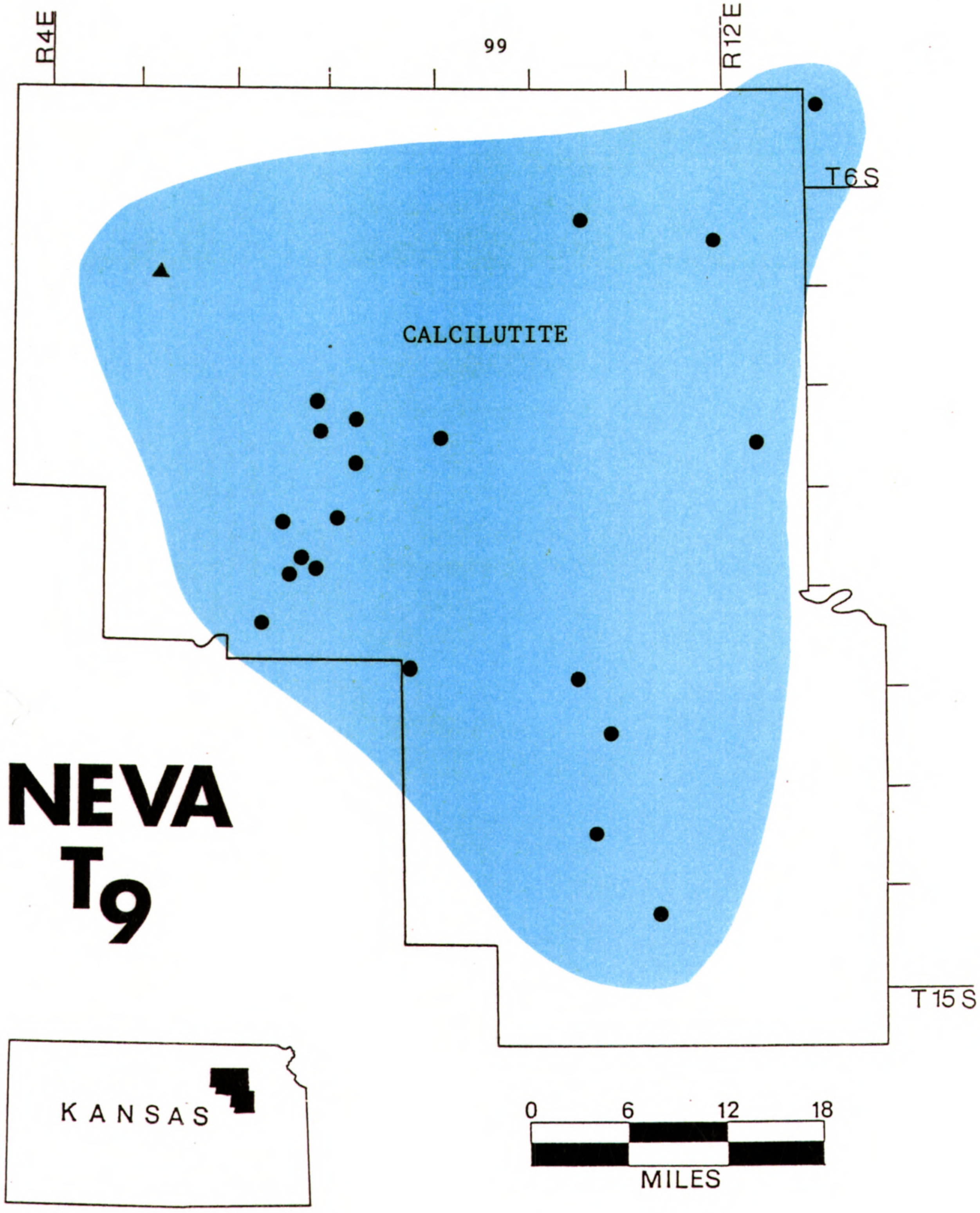


Figure 41. Paleogeographic map of lithofacies at the transgressive apex of NT_9 for the localities where NT_9 is present (for locality identification use overlay in pocket).

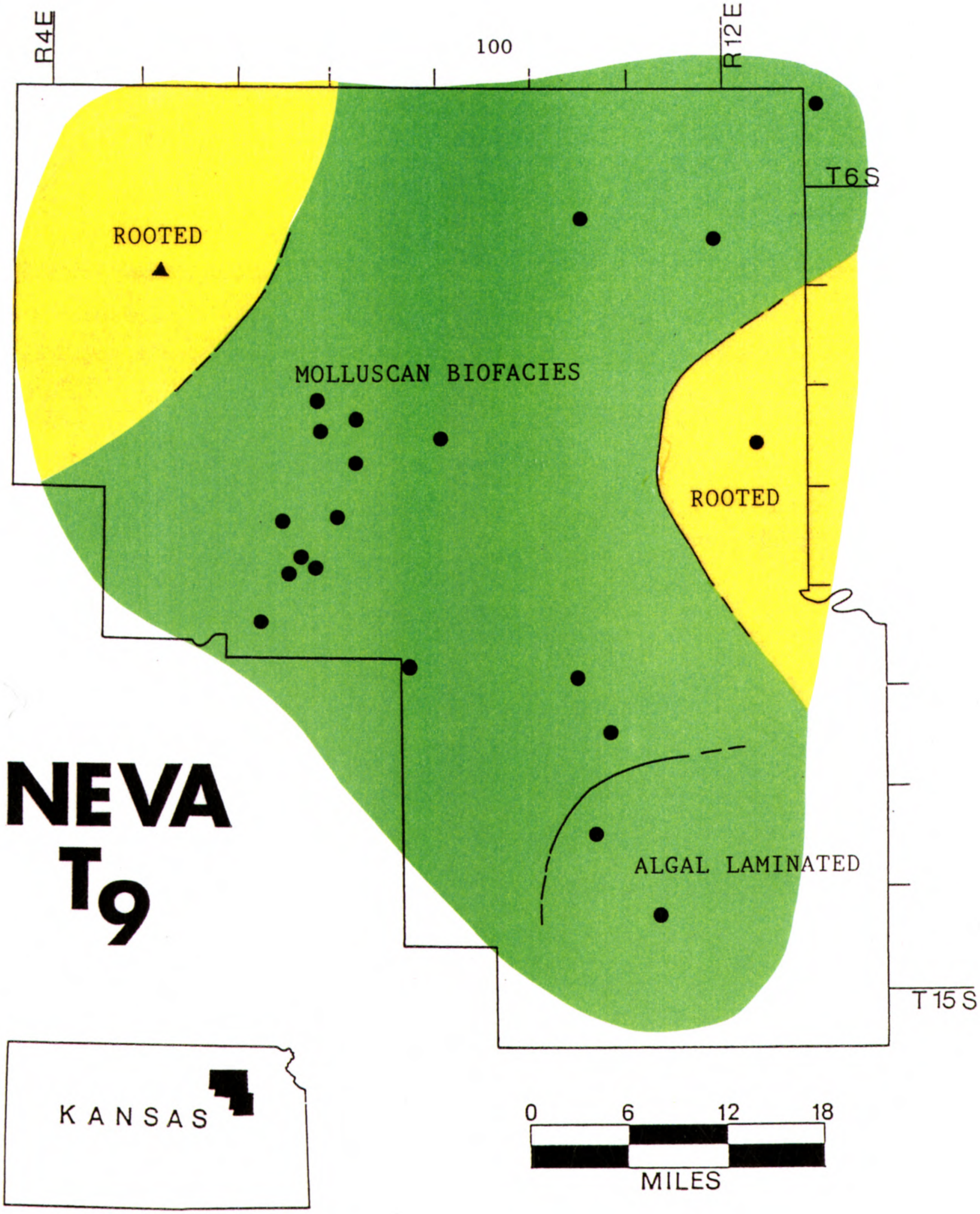


Figure 42. Paleogeographic map of biofacies at the transgressive apex of NT_9 for the localities where NT_9 is present (for locality identification use overlay in pocket).

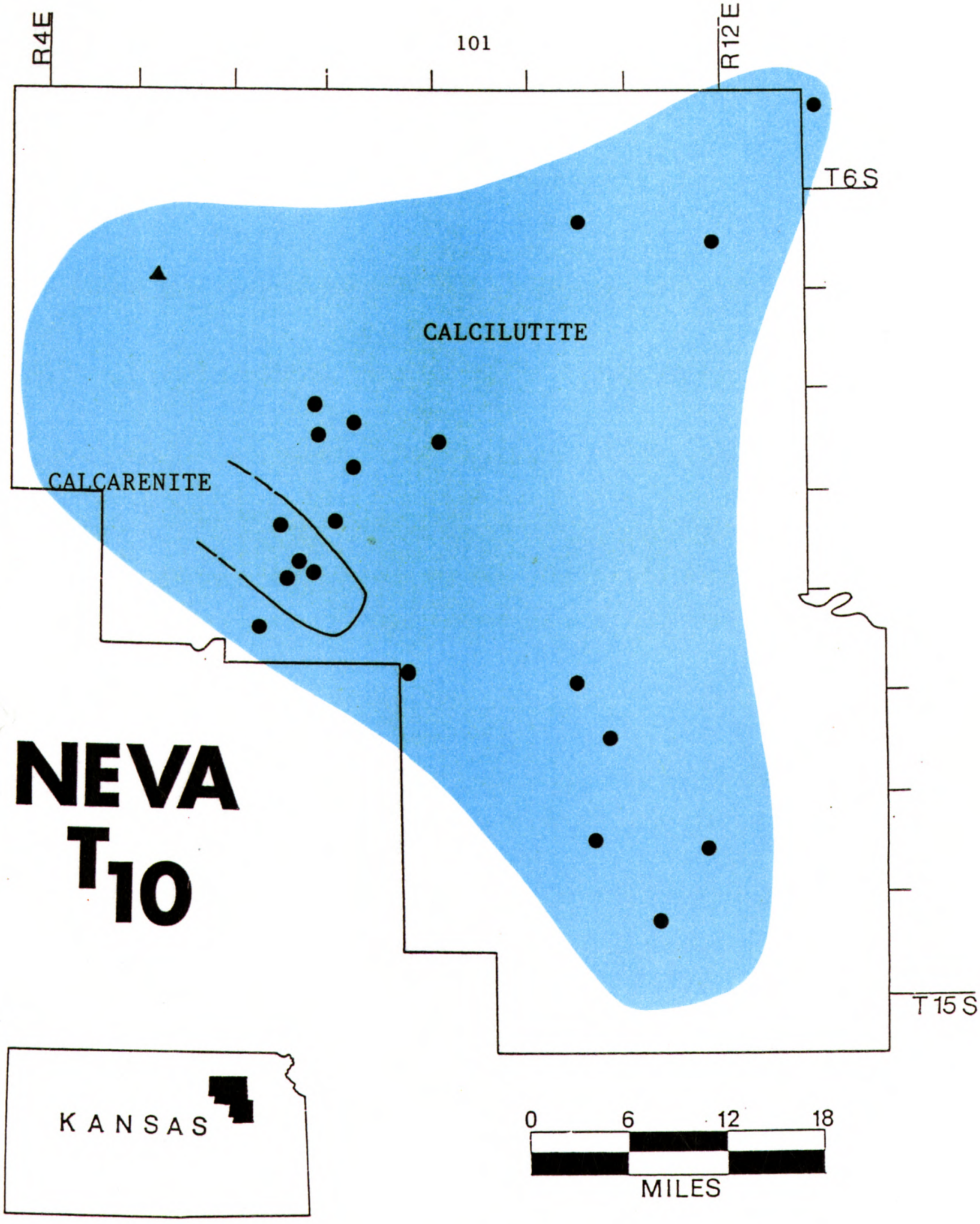


Figure 43. Paleogeographic map of lithofacies at the transgressive apex of NT_{10} for the localities where NT_{10} is present (for locality identification use overlay in pocket).

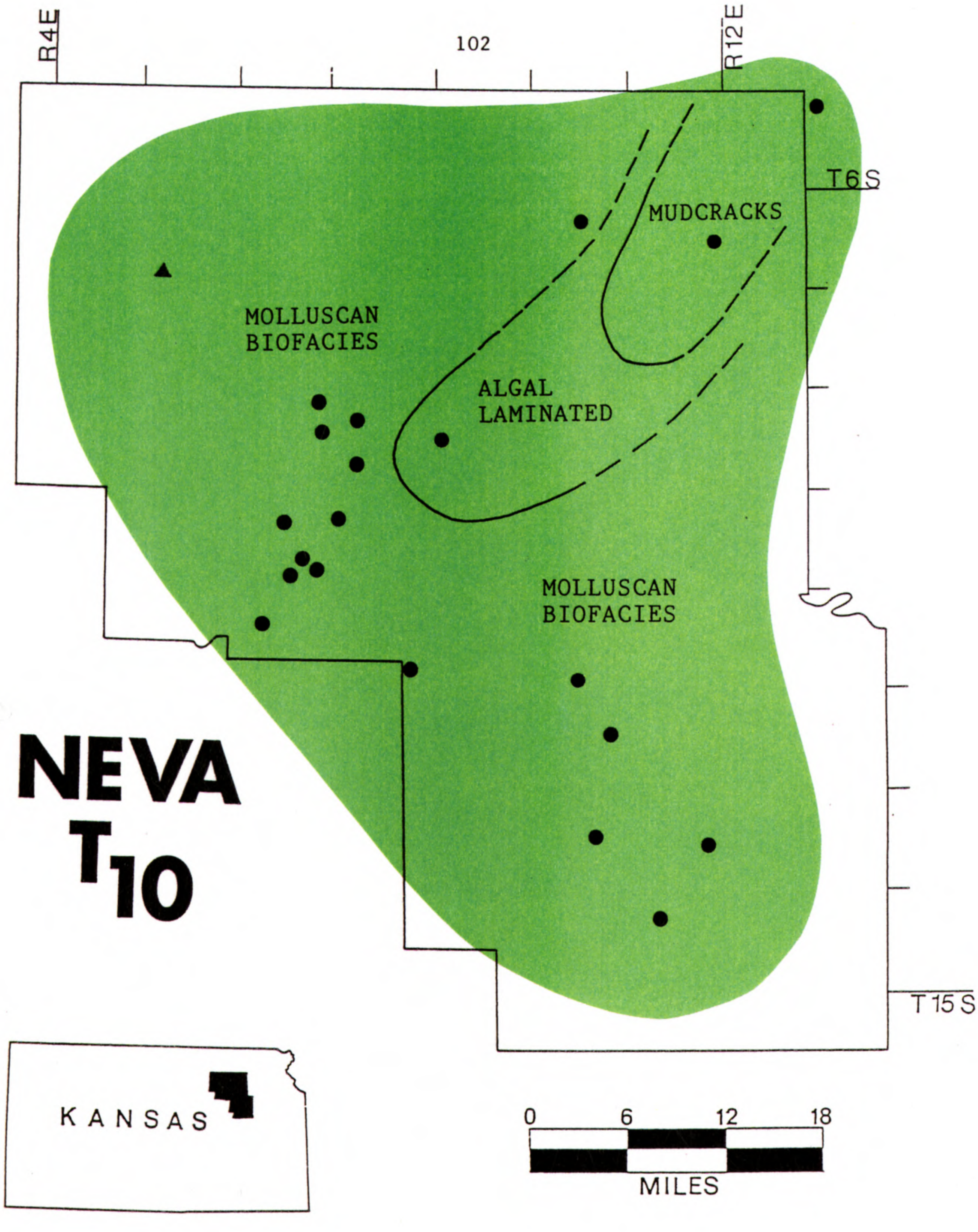


Figure 44. Paleogeographic map of biofacies at the transgressive apex of NT_{10} for the localities where NT_{10} is present (for locality identification use overlay in pocket).

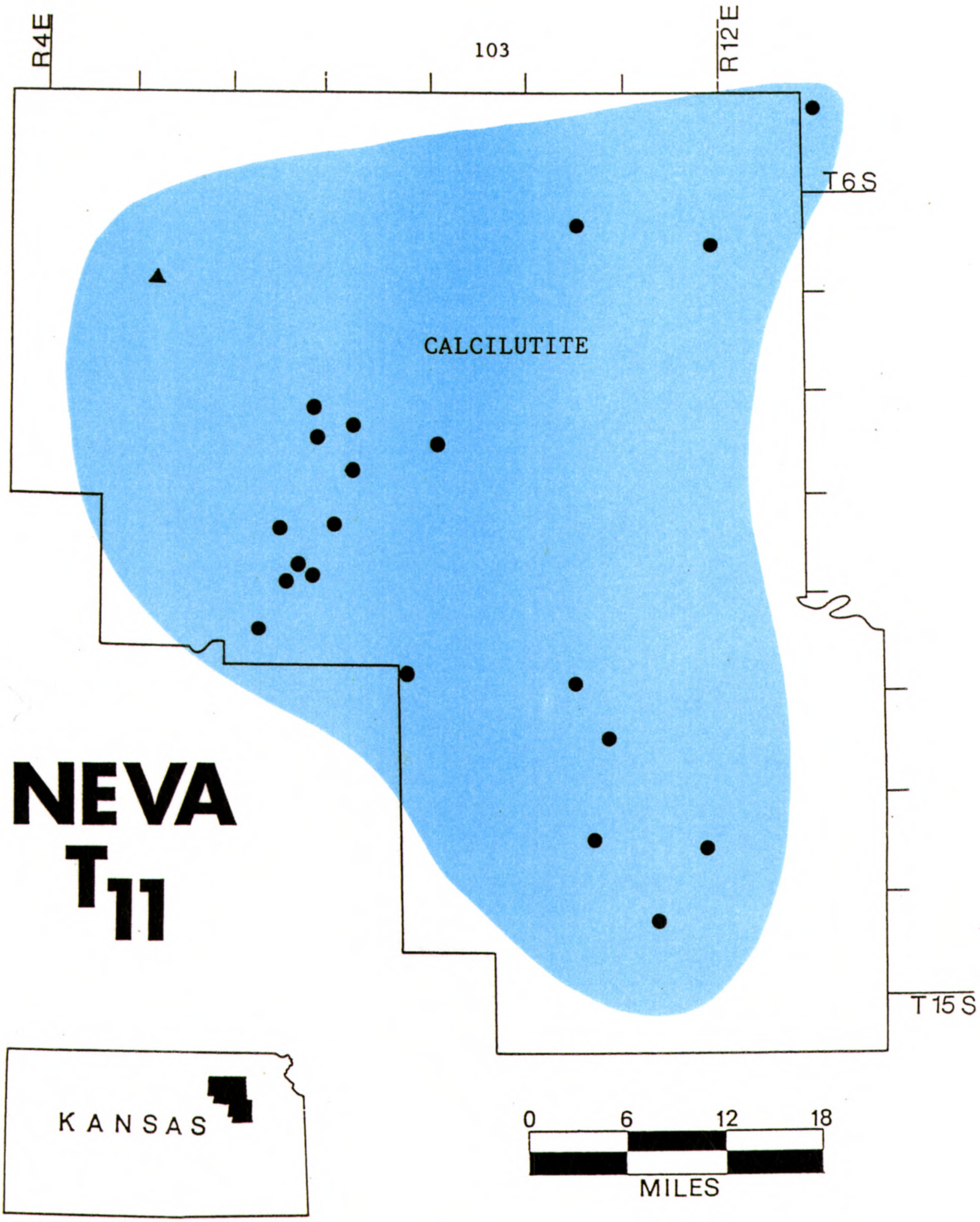


Figure 45. Paleogeographic map of lithofacies at the transgressive apex of NT_{11} for the localities where NT_{11} is present (for locality identification use overlay in pocket).

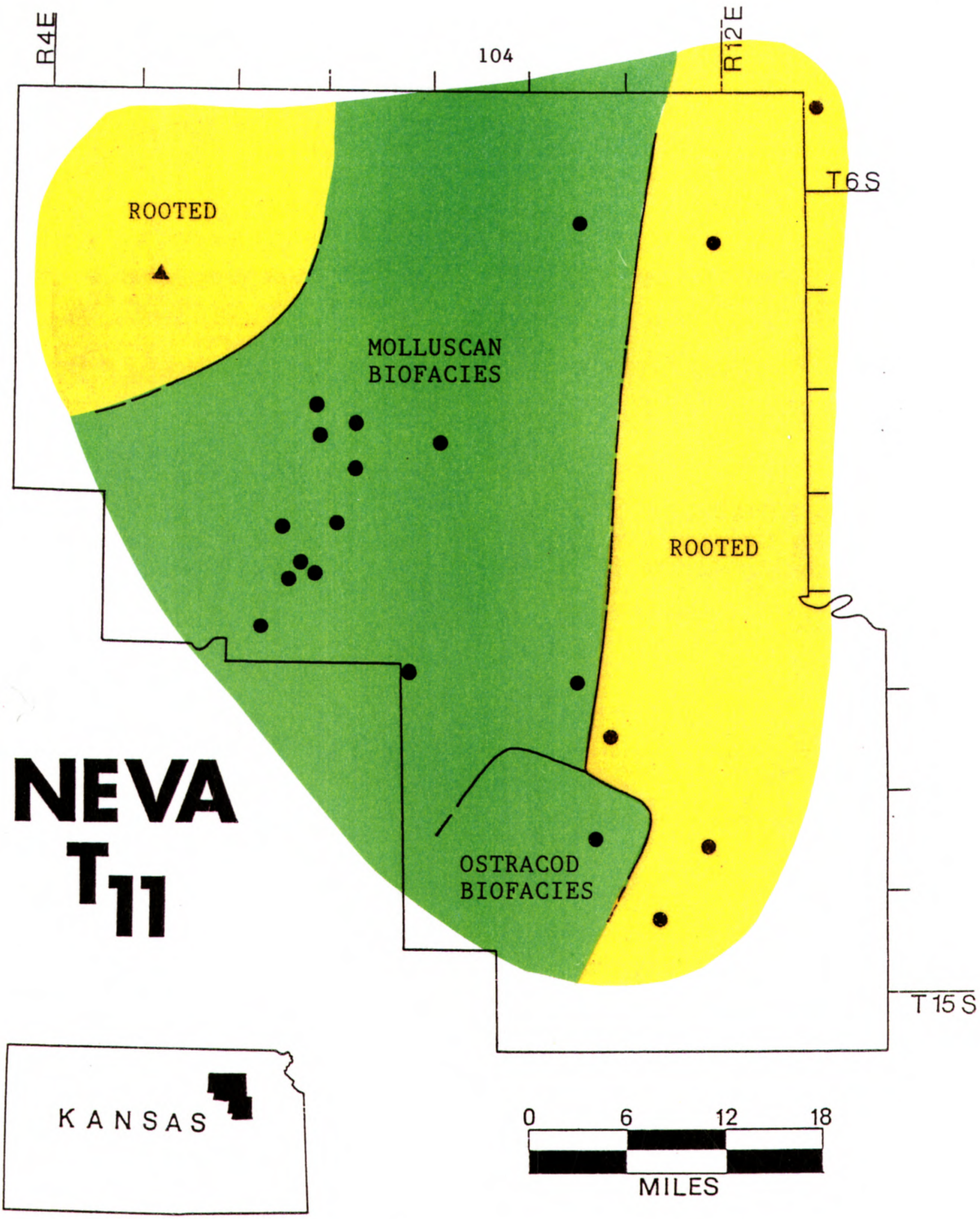


Figure 46. Paleogeographic map of biofacies at the transgressive apex of NT_{11} for the localities where NT_{11} is present (for locality identification use overlay in pocket).

The initial lithofacies deposited at the base of the Cottonwood fifth-order T-R unit (CT_1) everywhere within the area is as a calcarenite (Fig. 47), and the biofacies is the Composita biofacies (Fig. 48).

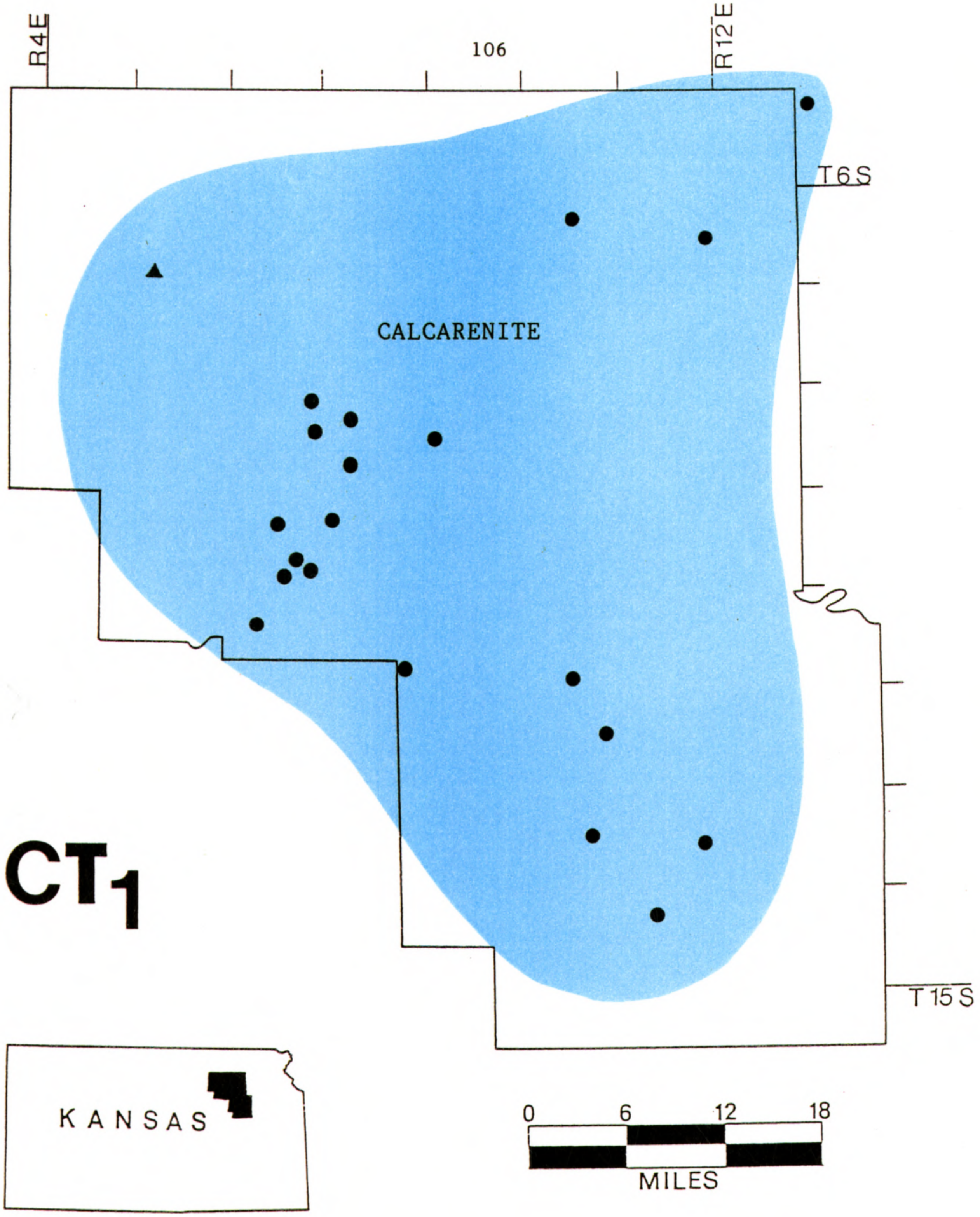


Figure 47. Paleogeographic map of lithofacies at the transgressive surface of CT_1 for the localities where CT_1 is present (for locality identification use overlay in pocket).

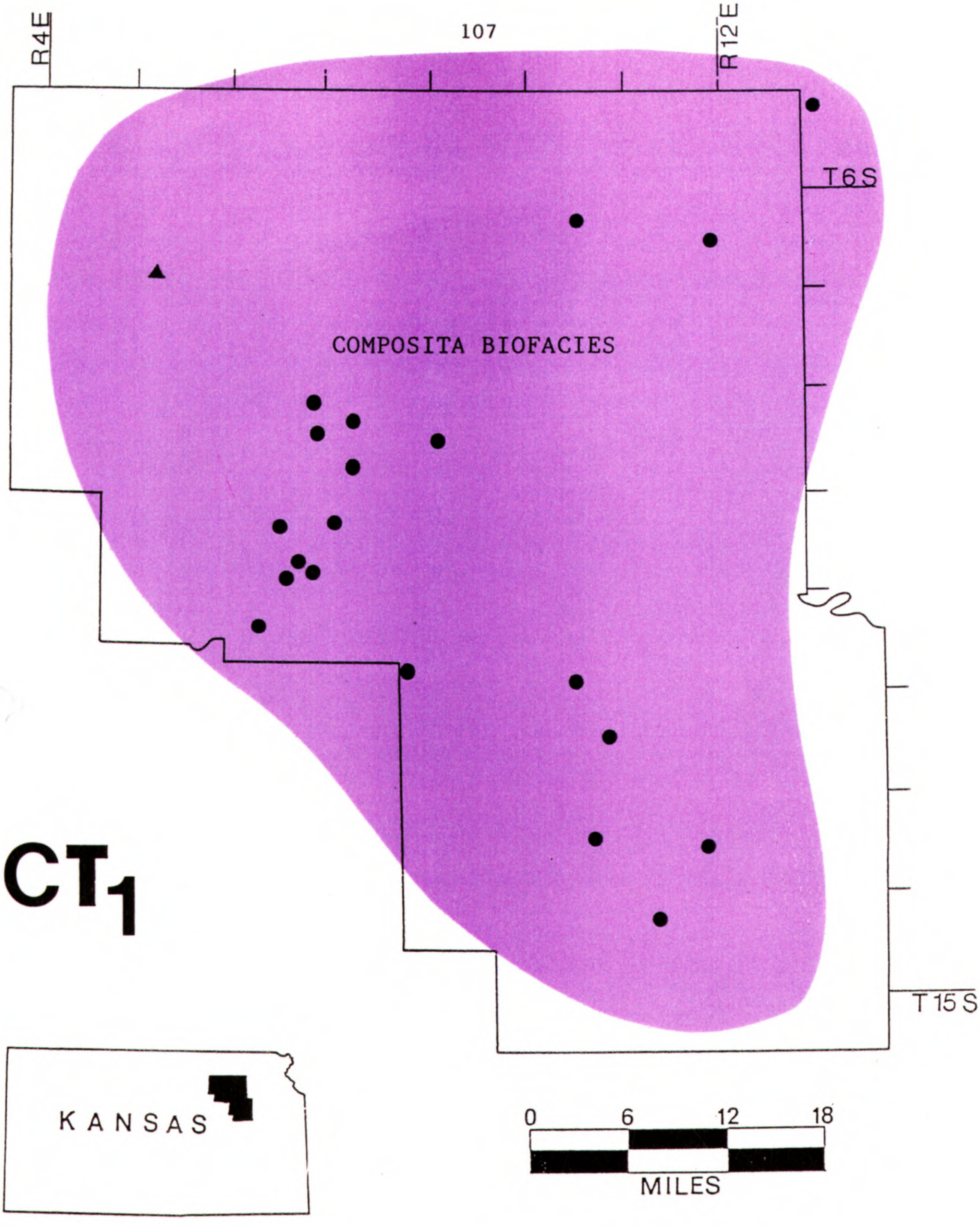


Figure 48. Paleogeographic map of biofacies at the transgressive surface of CT_1 for the localities where CT_1 is present (for locality identification use overlay in pocket).

Composite Paleogeographic Map

A composite paleogeographic map was constructed from the pattern of recurrent facies changes by comparing all the litho- and biofacies maps for all the sixth-order T-R units. These facies changes represent changing conditions within the area and suggest the site of topographic irregularities. Recurrent facies changes were compared with isopachous maps to determine the depositional influence of these irregularities. In addition, structure contour maps might indicate some relationship between the topographic irregularities and structural features that may have influenced the type and amount of sedimentation.

The composite paleogeographic map is a model for highlighting the overall paleogeography for the Neva-Eskridge fifth-order T-R unit (Fig. 49). The map exhibits three defineable topographic highs, suggesting less sediment accumulation and relatively shallower water conditions and biotas. The area around these topographic highs are interpreted as topographic lows, suggesting greater sediment accumulation as well as relatively more open marine conditions and biotas.

Evidence for the topographic high suggested for the central two thirds of Pottawatomie County includes the recurrent facies changes interpreted for sixth-order T-R

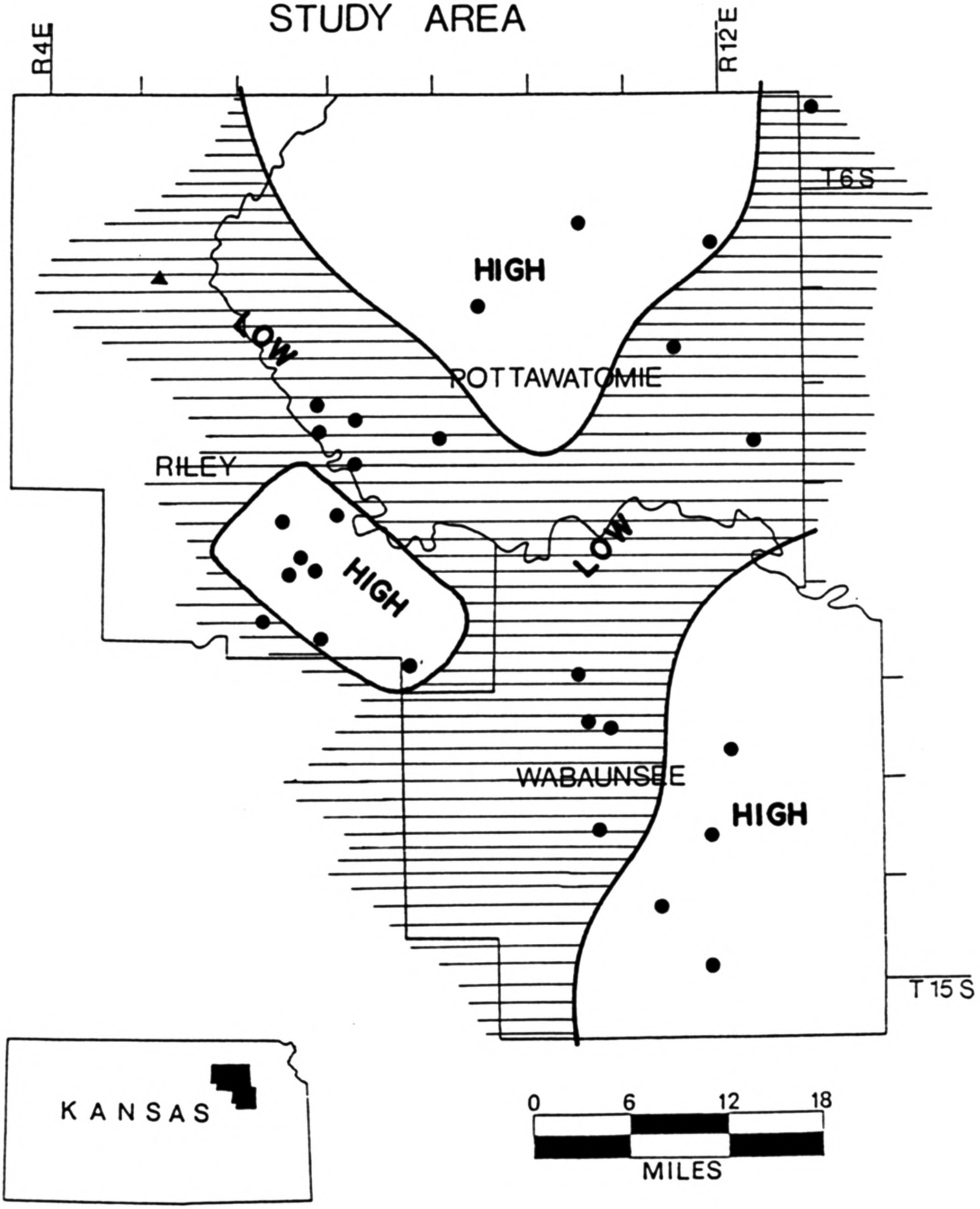


Figure 49. Composite paleogeographic map derived from sixth-order recurrent facies changes and illustrating the interpreted topographic irregularities (for locality identification use overlay in pocket).

units NT_1 (Fig. 26), NT_3 (Fig. 29 and 30), NT_4 (Fig. 31 and 32), NT_6 (Fig. 35 and 36), NT_{10} (Fig. 44). In each of these litho- and biofacies maps significant facies changes occur and consistently display relatively shallower facies for this area.

The topographic high inferred for southeastern Riley County is based on recurrent facies changes observed for sixth-order T-R units NT_1 (Fig. 26), NT_4 (Fig. 32), NT_7 (Fig. 37 and 38), and NT_{10} (Fig. 43). This recurrent facies pattern, while not as pronounced as the former, does, however, suggest shallower facies in this area.

In the eastern half of Wabaunsee County the inferred topographic high is based on recurrent facies changes observed for sixth-order T-R units NT_1 (Fig. 26), NT_2 (Fig. 28), NT_5 (Fig. 34), NT_7 (Fig. 38), NT_8 (Fig. 40), NT_9 (Fig. 42), NT_{11} (Fig. 46). The best expression of this topographic high occurs within the Neva-Eskridge regressive hemicycle (NT_7 to NT_{11}). This shallowing trend conforms with Wells (1950) observation that a persistent, land plant rich, black shale occurs within the Eskridge Shale (found within NT_9; see Appendix B Localities # 5, 23, 29, and 30). This coal smut occurs in southeast Morris County, northeast through central Wabaunsee County, to the eastern edge of Pottawatomie County. He suggested that the occurrence of the coal smut indicated the development of a shoreline facies along a NE-SW trending line. Wells identified this trend along the Nemaha Ridge and concluded that a causal relationship may have existed.

Topographic lows suggested to have occurred over the remaining areas are based on recurrent facies changes interpreted for sixth-order T-R units NT_1 (Fig. 26), NT_2 (Fig. 28), NT_4 (Fig. 31 and 32), NT_5 (Fig.34), NT_6 (Fig. 35 and 36), NT_7 (Fig. 38), NT_8 (Fig. 40), NT_9 (Fig. 42), NT_{10} (Fig. 44), and NT_{11} (Fig. 46). These litho- and biofacies maps consistently suggest that relatively more open marine conditions existed in these areas.

STRUCTURAL CONTROLS ON DEPOSITION

Structural Overview

The major structural feature within the study area is the Nemaha Anticline. When combined with its related minor structural features (Brownville Syncline, Alma-Davis Anticline, and Abilene Anticline) it forms the Nemaha Tectonic Zone (Berendsen and Blair, 1986). This zone is a major NE-SW trending system of folds and faults which extend through eastern Kansas. Blair and Berendsen (1988) describe the Nemaha Uplift in this area as an antiformal structure containing many individual domal culminations separated by synclinal troughs, sigmoidal anticlinal closures, and deep, rhomboidal shaped grabens.

Cole's (1976) structure contour map on the top of the Precambrian igneous sediments (Fig. 50) illustrates the structural features which occur in the area. Merriam (1963) suggested that the basement rock of the Nemaha Anticline is characterized by a series of knobs located along the crest of the structure. The structure contour map explicitly shows a structural high in north-central Pottawatomie County with an abrupt downdip boundary to the east where the Brownville Syncline lies and a gradual downdip grade to the west. A graben-like structure is definable in southeastern Riley and northwestern Wabaunsee Counties. Immediately to the south of this graben another structural high occurs in the form of an

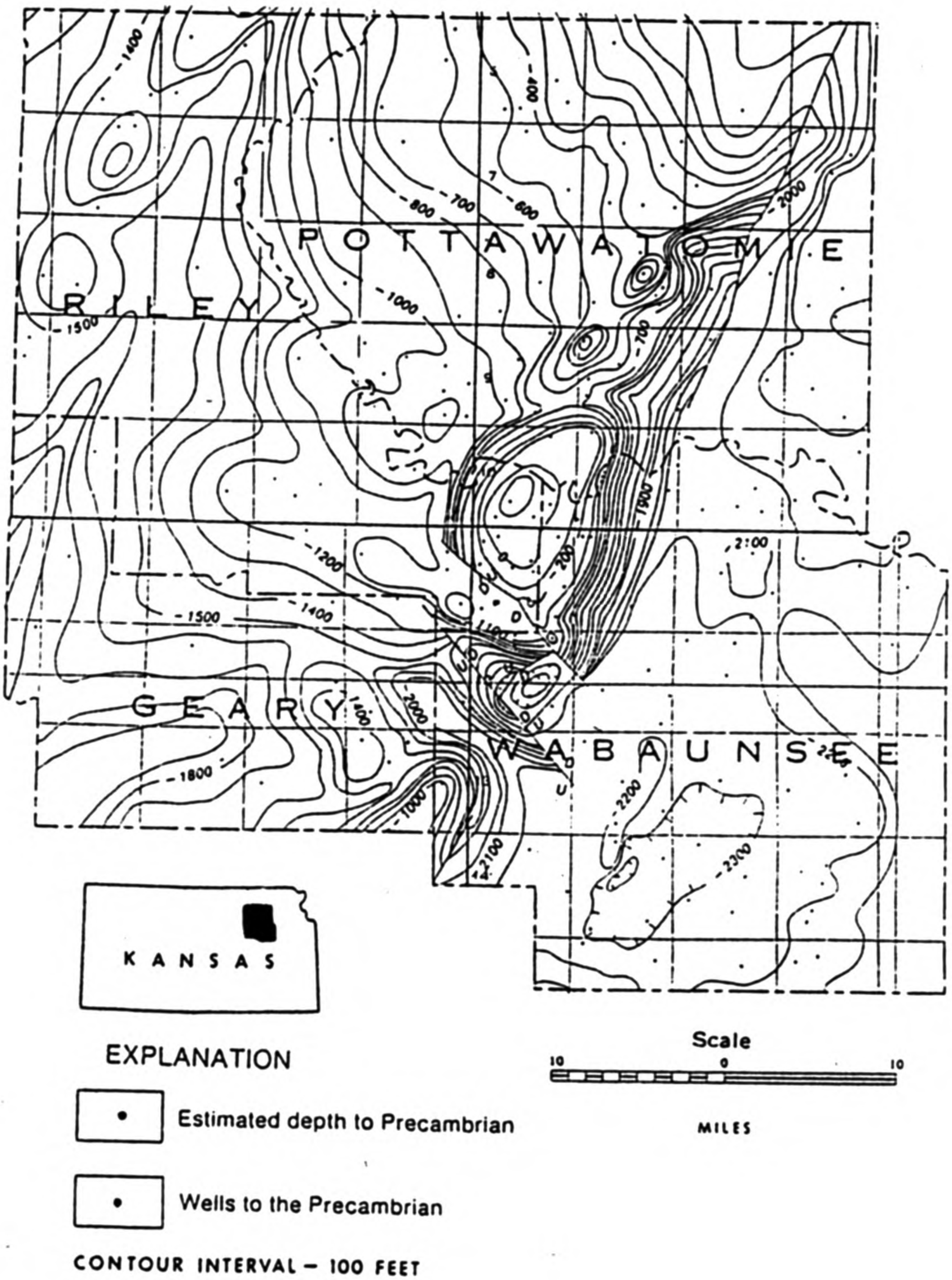


Figure 50. Structure contour map of the top of the Precambrian rocks for the area of investigation (from Cole, 1976).

upthrown block.

The expression of the Nemaha Tectonic Zone is also defineable in structure contour maps of overlying rock units. A structure contour map (Watney, 1979) drawn on the top of the Kansas City Group (Pennsylvanian) displays similar, though less pronounced characteristics (Fig. 51). Again the Nemaha Anticline is reflected by a broad structural high in central Pottawatomie County with an abrupt downdip boundary to the east, and a gradual downdip grade to the west. The graben-like feature located in southeastern Riley and northwestern Wabaunsee Counties, as well as the structural high located immediately south of there are also definable in this interval of geologically younger strata.

The age of the Nemaha Anticline has been defined as pre-Desmoinesian post-Mississippian based on upturned pre-Pennsylvanian strata, which have been truncated and overstepped by Pennsylvanian rocks along the flanks of the structure. At the crest of the Nemaha Anticline Pennsylvanian beds lie directly on Precambrian rocks (Merriam, 1963). The Nemaha Anticline is also recognizable in surface rocks of Permian age with expressed structural dips as high as five degrees. Shenkel (1959) suggested that intermittent minor deformation persisted throughout Pennsylvanian and Permian time as indicated by of minor unconformities in these sediments. Continuing minor deformation has occurred to the present time (Lee, 1954).

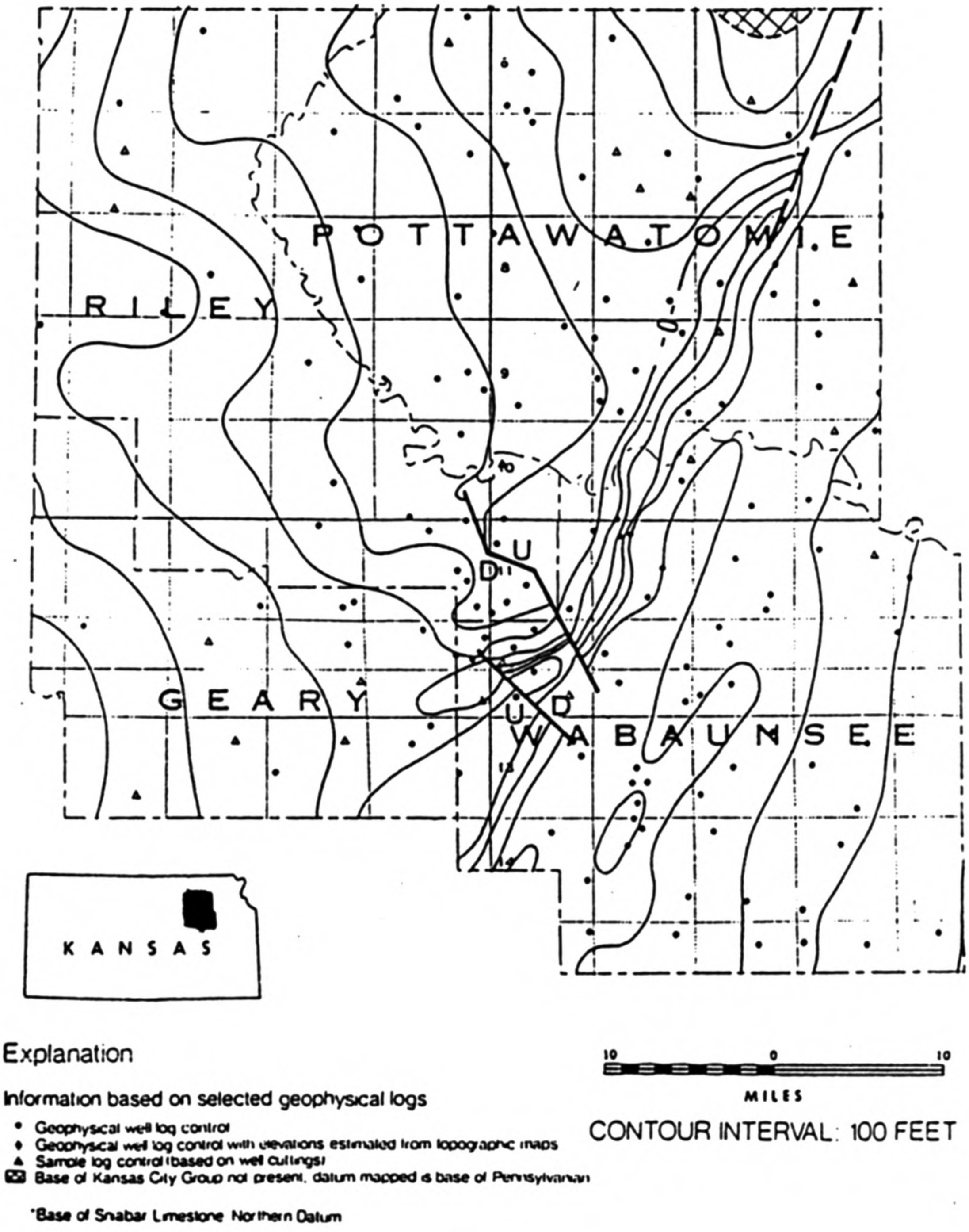


Figure 51. Structure contour map of the top of the Kansas City Group for the area of investigation (from Watney, 1979).

Isopach Maps

Isopach maps were drawn for three intervals chosen to define thickness relationships within the area. The Neva-Eskridge transgressive hemicycle isopach, which extends from the base of NT_1 to the top of the transgressive apex of NT_6, was chosen to illustrate the thickness relationships of sedimentation for the fifth-order transgressive sequence. The Neva-Eskridge regressive hemicycle isopach, which extends from the base of the initial regressive surface of NT_6 to the base of CT_1, was chosen to illustrate the thickness relationships of sedimentation for the fifth-order regressive sequence. The third isopach of the Neva-Eskridge fifth-order T-R unit, was drawn to depict any composite trends developed during this interval of sedimentation.

The isopach map of the Neva-Eskridge transgressive hemicycle (Fig. 52) shows the thinnest interval occurring in the north-central part of Pottawatomie County. A pronounced gradual thickening occurs to the southeast and southwest with the thickest interval in southwest Riley County. Thicknesses range from 353 cm (11.60 ft) for the former to 508 cm (16.67 ft) for the latter.

The isopach map of the Neva-Eskridge regressive hemicycle (Fig. 53) again shows the thinnest accumulations of sediments in north-central to central Pottawatomie

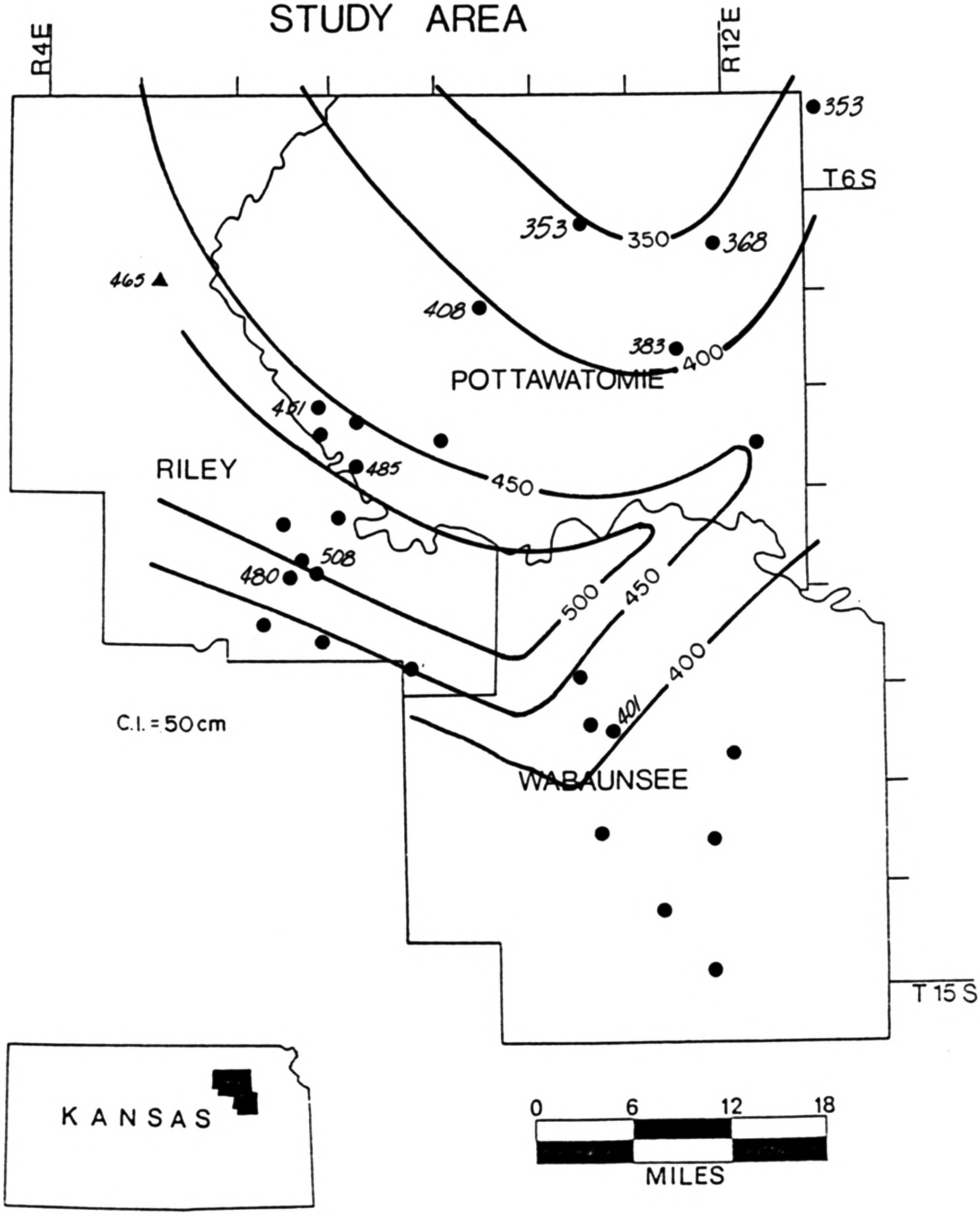


Figure 52. Isopach map of the Neva-Eskridge transgressive hemicycle using the localities where complete intervals are present (for locality identification use overlay in pocket).

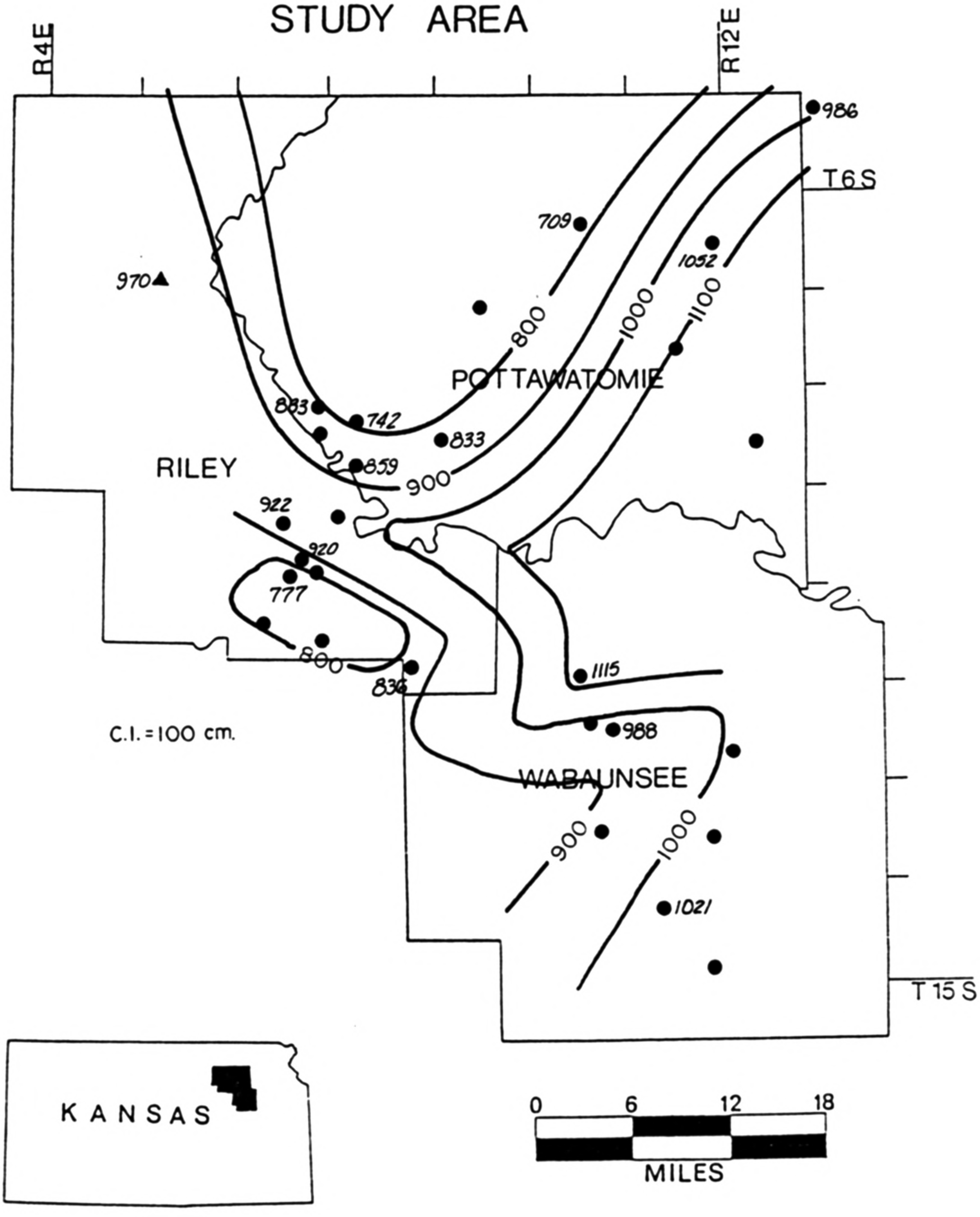


Figure 53. Isopach map of the Neva-Eskridge regressive hemicycle using the localities where complete intervals are present (for locality identification use overlay in pocket).

County. Abrupt thickening occurs to the east in eastern Pottawatomie County, and slightly more gradual thickening occurs to the west and southwest in Riley County. A thickening trend is also noted in southeast Riley County and north-central Wabaunsee County. Significant thinning also occurs immediately south of the former and west of the latter in extreme southeast Riley County.

The final isopach map, of the interval represented by the Neva-Eskridge fifth-order T-R unit (Fig. 54), illustrates the composite trends displayed in previous isopachs. Thus, the overall thinnest interval occurs in north-central Pottawatomie County. Gradual thickening occurs both in a southwesterly and a southeasterly direction until thinning occurs in extreme southeast Riley County and central Wabaunsee County.

Trends observed in these isopach maps conspicuously correspond to structure contour trends observed for underlying Precambrian and Pennsylvanian rocks (Fig. 50 and 51). The thinner isopach intervals appear to consistently overlie structural highs while the thicker isopach intervals appear to consistently overlie structural lows. Additionally, the Neva-Eskridge fifth-order composite paleogeographic map (Fig. 49) exhibits similiar patterns. Recurrent facies changes led to the definition of topographic irregularities within the area. It is suggested that shallower marine facies that were consistently

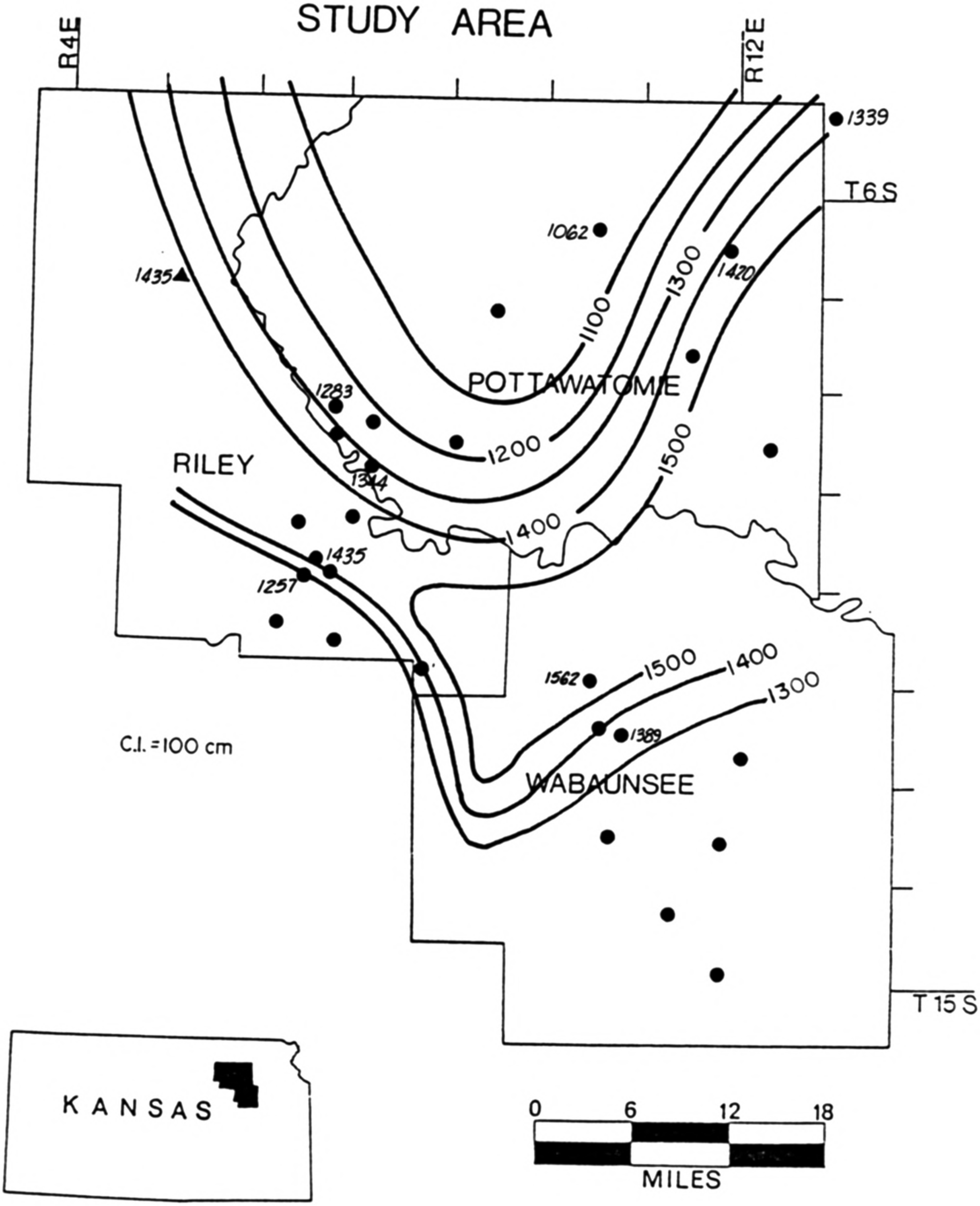


Figure 54. Isopach map of the Neva-Eskridge fifth-order T-R unit using the localities where complete intervals are present (for locality identification use overlay in pocket).

deposited on topographic highs are represented by thinner rock intervals. Relatively deeper marine facies that were consistently deposited in topographic lows are indicated by thicker rock intervals. This evidence suggests that depositional patterns were affected by existing topographic irregularities which appear to be directly related to the structural features of the area.

CONCLUSIONS

This study is a detailed analysis of the Neva Limestone Member of the Grenola Limestone and the Eskridge Shale in northeastern Kansas. A hierarchal genetic stratigraphic approach was employed in a successful effort to correlate sea level changes on a finer scale than has formerly been possible. Using the detailed study of the overlying and underlying members and formations, the Neva Limestone Member and Eskridge Shale were found to conform to one fifth-order transgressive-regressive unit (after Busch and Rollins, 1984). The Neva-Eskridge fifth-order T-R unit may represent an interval of about 300,000 to 500,000 years (Busch and Rollins, 1984) and ranges in thickness from 33.5 to 51.5 feet (10.2 to 15.7 meters) in the study area.

Within the Neva-Eskridge fifth-order T-R unit, eleven smaller sixth-order T-R units occur. These sixth-order T-R units may represent an average of 27,300 to 45,500 years (Busch and Rollins, 1984) and range in thickness from 1 to 16 feet (0.3 to 4.9 meters). The eleven sixth-order T-R units are correlative, with few exceptions over the study area. Sixth-order T-R units NT_1 to the transgressive apex of NT_6 form the transgressive hemicycle for the Neva-Eskridge fifth-order T-R unit. The regressive hemicycle begins with the regressive part of NT_6 and continues as an overall regressive sequence through NT_{11}.

Lithofacies and biofacies maps were constructed for times of maximum transgression in each sixth-order T-R unit of the Neva-Eskridge fifth-order T-R unit. These paleogeographic maps illustrate the development of the Neva-Eskridge fifth-order T-R unit as a sequence of sixth-order T-R units. After comparing all the litho- and biofacies maps, a composite paleogeographic map was constructed from the pattern of recurrent facies changes. These facies changes represent varying conditions within the area and suggest the site of topographic irregularities. Three topographic highs were defined which consistently displayed relatively shallower water conditions and biotas over these areas. Topographically lower areas were suggested where relatively more open marine conditions and biotas consistently occur.

Isopach maps drawn for the Neva-Eskridge fifth-order T-R unit exhibited distinct patterns of sedimentation. Those areas interpreted as topographic highs from paleogeographic data are invariably represented by thinner intervals of sedimentation. While those areas suggested to be topographic lows are consistently represented by thicker intervals of sedimentation. This evidence suggests that depositional patterns were affected by existing topographic irregularities.

As a check of the relationship between lithofacies and biofacies, and hence, paleogeographic maps and sedimentation, structure contour maps drawn for underlying formations were used. The maps suggest that several structural elements of the Nemaha Tectonic Zone are readily definable within the area of study. These structural features, both positive and negative, display many similarities to the topographic irregularities defined by paleogeographic and isopach mapping of the Neva-Eskridge fifth-order T-R unit. This relationship is suggested to be more than coincidental, and, as such, it can be concluded that depositional patterns within the Neva-Eskridge fifth-order T-R unit were influenced by existing structural elements.

The method of hierarchal genetic stratigraphy allows for detailed paleogeographic and isopach mapping. Because these maps can be used to define structural features, this stratigraphic method provides a useful tool for predicting structure where no structure contour maps exist.

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APPENDIX A

Classification Schemes

Grain-Size Scale for Carbonate Rocks

	Transported Constituents	Authigenic Constituents	
	Very coarse calcirudite	Extremely coarsely crystalline	
64 mm	Coarse calcirudite		
16 mm	Medium calcirudite		
4 mm	Fine calcirudite	Very coarsely crystalline	4 mm
1 mm	Coarse calcarenite	Coarsely crystalline	1 mm
0,5 mm	Medium calcarenite		
0,25 mm	Fine calcarenite	Medium crystalline	0,25 mm
0.125 mm.	Very fine calcarenite		
0.062 mm	Coarse calcilutite	Finely crystalline	0.062 mm
0.031 mm	Medium calcilutite		
0.016 mm	Fine calcilutite	Very finely crystalline	0.016 mm
0.008 mm	Very fine calcilutite		
0.004 mm		Aphanocrystalline	0.004 mm

Carbonate rocks contain both physically transported particles (oolites, intraclasts, fossils, and pellets) and chemically precipitated minerals (either as pore-filling cement, primary ooze, or as products of recrystallization and replacement). Therefore the size scale must be a double one, so that one can distinguish which constituent is being considered (e.g. calcirudites may be cemented with very finely crystalline dolomite, and finer calcarenites may be cemented with coarsely crystalline calcite).

The size scale for transported constituents uses the terms of Grabau but retains the finer divisions of Wentworth except in the calcirudite range; for dolomites of obviously allochemical origin, the terms *dolorudite, doloarenite,* and *dololutite* are substituted for those shown. The most common crystal size for dolomite appears to be between .062 and .25 mm, and for this reason that interval was chosen as the *medium crystalline* class (from Folk, 1962).

Dunham's (1962) classification of carbonate rocks

DEPOSITIONAL TEXTURE RECOGNIZABLE					DEPOSITIONAL TEXTURE NOT RECOGNIZABLE
Original Components Not Bound Together During Deposition				Original components were bound together during deposition... as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.	Crystalline Carbonate
Contains mud (particles of clay and fine silt size)			Lacks mud and is grain-supported		(Subdivide according to classifications designed to bear on physical texture or diagenesis.)
Mud-supported		Grain-supported			
Less than 10 percent grains	More than 10 percent grains				
Mudstone	Wackestone	Packstone	Grainstone	Boundstone	

TERMINOLOGY FOR DESCRIPTION OF SPLITTING AND STRATIFICATION

THICKNESS	SPLITTING i.e.,How does the rock split as it weathers?	STRATIFICATION i.e.How was the sediment originally stratified?	
	Massive splitting	Very Thick bedded	Bedding
100 cm			
	Blocky splitting**	Thick bedded	
30 cm			
	Slabby splitting	Medium bedded	
10 cm			
		Thin bedded	
3 cm			
		Very Thin bedded	
mm) 1 cm			
	Flaggy splitting	Thickly laminated	Lamination
5 mm			
	Platy splitting	Medium laminated	
1 mm			
	Fissile splitting	Thinly laminated	
0.5 mm			
	Papery splitting	Very Thinly laminated	

**"Blocky" is also used to describe nonstratified crumbly mudstones. To avoid confusion, one should use the description "crumbly mudstone" in such cases, rather than "blocky".

APPENDIX B

Measured Sections

Note: Read mudstone for clay shale; Leptotriticites for Psuedoschwagerina; gray for grey.

Locality #1

NE NW Sec.26, T.10S., R.7E., along Stagg Hill Road, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		54. Cottonwood limestone: medium calcarenite, wackestone to packstone; light grey, weathers yellow-gray; thick bedded; massive; with bedded chert nodules, abundant fusulinids, few Composita.	2	10	0.86
		53. Cottonwood limestone: fine calcarenite, wackestone; light grey, weathers yellow-gray; thick bedded; massive; with common crinoids, echinoids, brachiopod shell fragments.	2	3	0.69
		52. Cottonwood limestone: fine calcarenite, wackestone; grey, weathers yellow-gray, flaggy to slabby; with common shaly intraclasts, bivalves, microcrinoids, Planolites.	0	10	0.25
CT_1					
		51. Eskridge Shale: claystone; dark green, weathers olive, indurated.	2	9	0.84
		50. Eskridge Shale: fine calcilutite, mudstone; platy to slabby; argillaceous; with abundant root traces.	0	8	0.20
		49. Eskridge Shale: calcareous clay shale, mudstone; dark grey, weathers grey; nuculoids.	0	7	0.18
	NT_{11}				
		48. Eskridge Shale: claystone; green to red; crumbly; indurated.	3	6	1.17
		47. Eskridge Shale: medium calcilutite, wackestone; grey, weathers grey-green; massive; with scattered gastropods, productids, bivalves.	0	5	0.13
	NT_{10}				
		46. Eskridge Shale: claystone; red; crumbly; indurated.	1	7	0.48
		45. Eskridge Shale: claystone, green, weathers pale green; crumbly; indurated.	1	0	0.30
		44. Eskridge Shale: clay shale; red; platy; interbedded with fine calcilutite stringers, grey; platy; with common Aviculopectin; common plant fossils in mudstone.	0	5	0.13
	NT_9				
		43. Eskridge Shale: clay shale; green to red, weathers olive to pale red; with few Lingula, Aviculopectin.	3	1	0.94
		42. Eskridge Shale: clay shale; pale yellow to olive; platy; interbedded with thin beds of fine calcilutite, mudstone; pale green; platy; with scattered pectinids, nuculoids, Bellerophon gastropods.	0	10	0.25
	NT_8				
		41. Eskridge Shale: claystone; dark green fresh, weathers pale green (upper 24 inches, 0.61 m), to dark red fresh, weathers pale red; indurated; with caliche nodules abundant in lower 12 inches (0.30 m).	8	6	2.59
		40. Eskridge Shale: clay shale; green fresh, weathers pale green; flaggy; non-fossiliferous.	1	0	0.30
		39. Neva limestone: medium calcilutite, wackestone; grey fresh, weathers yellow-gray; slabby; algal laminated, with common crinoids, and brachiopod shell fragments.	0	10	0.25

Transgressive Surface	UNIT DESCRIPTIONS	Unit Thicknesses ft	in	m
	38. Neva limestone: calcareous shale; grey, weathers green; platy to fissile; with common echinoids, crinoids, bryozoans, productids, scattered Composita, few Neospirifer.	1	8	0.51
NT_6				
	37. Neva limestone: coarse calcilutite to fine calcarenite, wackestone; laminated; blocky; with scattered crinoids, brachiopod shell fragments.	5	6	1.68
	36. Neva limestone: medium calcilutite, wackestone; grey fresh, weathers yellow-gray; platy; with scattered crinoids.	0	2	0.05
	35. Neva limestone: calcareous shale; green fresh, weathers pale green; fissile; with common fusulinids, crinoids, scattered echinoids, Composita, Crurithyris, Orbiculoidea.	0	5	0.13
	34. Neva limestone: coarse calcilutite to fine calcarenite, wackestone; light grey fresh, weathers yellow-grey; slabby to blocky; vuggy; with scattered gypsum rosettes, microcrinoids, brachiopod and bivalve shell fragments.	4	9	1.45
NT_5				
	33. Neva limestone: fine dololutite, wackestone; grey-green, weathers orange-tan; slabby; with abundant root mottling, microgeodes at upper 5 in. (0.13 m), common crinoids at base.	1	2	0.36
NT_4				
	32. Neva limestone: clay shale, mudstone; grey-green fresh, weathers pale green; silty, indurated.	0	6	0.15
	31. Neva limestone: clay shale; grey-green fresh, weathers pale green; fissile; with common Orbiculoidea, Crurithyris, few Hustedia.	0	1	0.03
	30. Neva limestone: clay shale; green fresh, weathers pale green; fissile; with common fusulinids, crinoids, bryozoans, scattered Derbyia, Neochonetes.	0	2	0.05
NT_2				
	29. Neva limestone: clay shale; brown; platy; with common plant fossils.	0	2	0.05
	28. Neva limestone: fine calcilutite, wackestone; light gray fresh, weathers yellow-gray; massive; with common crinoids, coated grains, brachiopod shell fragments.	0	9	0.23
	27. Neva limestone: fine calcilutite, wackestone; light gray fresh, weathers yellow-gray; flaggy; with scattered brachiopod shell fragments.	0	5	0.13
NT_1				
	26. Salem Point shale: claystone; brown; crumbly; indurated.	1	6	0.46
	25. Salem Point shale: clay shale; brown to black; platy; with common plant fragments, few ostracods.	0	8	0.20
	24. Salem Point shale: fine calcilutite; tan; mudcracked; interbedded with calcareous green clay shale.	1	2	0.36
BT_6				
	23. Salem Point shale: claystone; brown to green; massive; crumbly.	2	4	0.71
	22. Burr limestone: medium calcilutite, wackestone; medium gray, weathers yellow-gray; slabby to blocky; with common skeletal fragments.	1	1	0.33
	21. Burr limestone: coarse calcilutite to fine calcarenite, wackestone; green-gray, weathers tan; flaggy; with scattered microgastropods, skeletal fragments.	0	4	0.10
	20. Burr limestone: coarse calcilutute to fine calcarenite, wackestone; green-gray, weathers tan; massive; with scattered microgastropods, skeletal fragments.	0	6	0.15
BT_5				

		UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		19. Burr limestone: fine calcilutite, mudstone; green-gray, weathers tan; flaggy; dolomitic; with scattered plant fossils.	0	5	0.13
		18. Burr limestone: fine calcilutite, mudstone; medium gray, weathers yellow-gray; flaggy; with scattered plant fossils and bivalves at basal 8 inches (0.20 m).	1	8	0.51
		17. Burr limestone: medium calcarenite, wackestone to packstone; brown-gray, weathers brown; slabby; with abundant microgastropods, bivalves, scattered intraclasts.	0	4	0.10
	BT_4				
		16. Burr limestone: clay shale; black, weathers green; platy; with scattered burrow or root mottling.	1	0	0.30
		15. Burr limestone: fine calcarenite, wackestone; light gray, weathers yellow-gray; flaggy; with scattered productids, bryozoans, bivalves, and algal biscuits.	0	3	0.08
		14. Burr limestone: medium calcarenite, wackestone; light gray, weathers tan; massive; with common crinoids, echinoids, microgastropods, bryozoans, scattered <u>Bellerophon</u>, <u>Aviculopectin</u>.	2	3	0.69
		13. Burr limestone: clay shale; black, weathers dark gray; fissile to platy; calcareous; with common ostracods, crinoids.	0	8	0.20
	BT_3				
		12. Burr limestone: clay shale; brown, weathers tan; platy; non-fossiliferous.	2	10	0.86
		11. Burr limestone: clay shale; green-gray, weathers pale green; platy to flaggy; calcareous; with scattered <u>Aviculopectin</u>, algal biscuits.	0	2	0.05
		10. Burr limestone: fine calcarenite, wackestone; medium gray, weathers yellow-grey; massive; with common crinoids, scattered ostracods, gastropods, intraclasts.	1	0	0.30
	BT_2				
		9. Legion shale: claystone; dark gray to olive to brown; varigated; crumbly; with scattered caliche nodules, up to 30 mm in diameter.	7	7	2.31
		8. Sallyards limestone: medium calcilutite, mudstone; gray-brown, weathers tan; slabby to blocky; with common roots, scattered skeletal fragments, and granular intraclasts.	1	9	0.53
		7. Sallyards limestone: fine calcilutite, mudstone; green-gray, weathers pale green; platy; silty; with few crinoids.	0	5	0.13
BT_1					
		6. Roca Shale: claystone; gray to dark green, crumbly; indurated.	2	6	0.76
		5. Roca Shale: fine calcilutite, mudstone; gray to brown; slabby; with common fenestral fabric, birdseye, scattered skeletal fragments.	0	3	0.08
	RE_6				
		4. Roca Shale: clay shale; green, red, brown, and gray; varigated; slightly indurated; non-fossiliferous.	1	6	0.46
		3. Roca Shale: clay shale; olive to green; platy; slighly silty; non-fossiliferous.	2	5	0.74
		2. Howe limestone: fine calcarenite, wackestone; medium gray, weathers yellow-gray; slabby to blocky; with common crinoids, coated grains, skeletal fragments, scattered fusulinids in basal 4 inches (0.10 m).	2	1	0.64
		1. Howe limestone: clay shale; green-gray, weathers pale olive; fissile to platy; calcareous; with common fusulinids.	0	3	0.08
	RE_5				

Locality #2

SW SW Sec. 8, T. 9 S., R. 8 E., along Hi-way 13, one mile east of Tuttle Creek Spillway, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		27. Florena shale: clay shale; dark gray; fissile; calcareous; with abundant Neochonetes, common bryozoans (ramose, encrusting, fenestrate), Derbyia, echinoids, scattered Ditomopyge.	4	0+	1.22
		26. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, scattered productids; nodular chert bed 12 inches (0.30 m) above base.	2	10	0.86
		25. Cottonwood limestone: medium calcarenite, wackestone; medium gray, weathers yellow-gray; massive; with common shell fragments, crinoids, echinoids, scattered Composita, few horn corals; two prominent nodular chert beds at 14 (0.36 m) and 24 inches (0.61 m) above base.	2	10	0.86
		24. Cottonwood limestone: medium calcilutite, wackestone; light gray; slabby; argillaceous; with common skeletal fragments.	0	6	0.15
CT_1					
		23. Eskridge Shale: clay shale; pale green; fissile to platy; non-fossiliferous.	3	1	0.94
		22. Eskridge Shale: fine calcilutite, mudstone; gray; blocky; algal laminated; with common skeletal fragments, scattered plant roots at top.	1	1	0.33
	NT_{11}				
		21. Eskridge Shale: claystone; brown; crumbly; indurated.	1	5	0.43
		20. Eskridge Shale: fine calcilutite, wackestone; light gray; flaggy; with scattered productids.	0	3	0.08
		19. Eskridge Shale: clay shale; pale olive green; platy to flaggy; with common intraclasts, scattered Aviculopecten, productids.	0	7	0.18
	NT_{10}				
		18. Eskridge Shale: claystone; brown; crumbly; indurated.	3	2	0.97
		17. Eskridge Shale: clay shale; pale red ; flaggy; few Lingula in basal one-half.	2	7	0.79
		16. Eskridge Shale: fine calcilutite; mudstone; green-gray; platy; with scattered skeletal fragments.	0	1	0.03
	NT_9				
		15. Eskridge Shale: clay shale; olive green; flaggy; sparsely fossiliferous.	1	4	0.41
		14. Eskridge Shale: fine calcilutite, mudstone to wackestone; green-gray; with common granular intraclasts, Aviculopecten, Nuculopsis, productids, few gastropods.	0	11	0.28
	NT_8				
		13. Eskridge Shale: claystone; brown; crumbly; indurated; with scattered plant fragments.	0	6	0.15
		12. Eskridge Shale: claystone; red; crumbly; indurated.	5	10	1.78
		11. Eskridge Shale: claystone; green; crumbly; indurated.	0	7	0.18
		10. Eskridge Shale: claystone; red; crumbly; indurated; with scattered plant roots.	1	5	0.43

	UNIT DESCRIPTIONS	Unit Thicknesses ft	in	m
	Transgressive Surface ——			
	9. Eskridge Shale: claystone; pale green; flaggy; semi-indurated.	0	6	0.15
	8. Neva limestone: fine calcarenite; pale green to brown; massive; algal laminated at top 5 inches (0.13 m) with hemispheroidal stromatolites, common nuculoid bivalves.	1	0	0.30
	7. Neva limestone: fine calcarenite, wackestone; gray, weathers pale green; massive; argillaceous; with common echinoids, crinoids, productids, scattered Neochonetes at base; scattered large subhorizontal burrows.	1	6	0.46
	6. Neva limestone: clay shale; pale olive green; platy to flaggy; calcareous; with common skeletal fragments.	0	6	0.15
	5. Neva limestone: fine calcarenite, wackestone; green-gray; flaggy; argillaceous; with common crinoids, echinoids, shell fragments, scattered Ditomopyge.	0	8	0.20
NT_6				
	4. Neva limestone: coarse calcilutite, wackestone; medium gray; massive; with common crinoids, scattered echinoids, productids.	2	8	0.81
	3. Neva limestone: clay shale; olive green; fissile to platy; calcareous; with common echinoids, scattered crinoids, shell fragments.	0	3	0.08
	2. Neva limestone: medium calcilutite, wackestone; light gray; blocky; laminated; scattered crinoids, shell fragments.	1	0	0.30
	1. Neva limestone: coarse calcilutite, wackestone; medium gray, weathers pale orange; slabby; with common crinoids, shell fragments; common thin olive green shale partings.	2	0+	0.61

Locality #3

SW NE Sec. 11, T. 12 S., R. 10 E., along bluff northeast of Mill Creek, Wabaunsee County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		14. Eskridge Shale: fine calcilutite; mudstone; light gray; flaggy; with scattered trace fossils.	0	5+	0.13+
	NT_8				
		13. Eskridge Shale: claystone; olive green; crumbly; indurated.	5	0	1.52
		12. Eskridge Shale: claystone; red; crumbly; indurated; with common root traces, microslickensides.	5	8	1.73
		11. Eskridge Shale: claystone; olive green; crumbly; semi-indurated.	1	4	0.41
		10. Eskridge Shale: medium calcilutite; wackestone; medium gray, weathers tan; with common molluscan shell fragments.	1	1	0.33
	NT_7				
		9. Eskridge Shale: claystone; pale red to olive green; crumbly; indurated; locally calcareous.	1	2	1.57
		8. Neva limestone: medium calcilutite; wackestone; medium gray, weathers light gray; algal laminated; with scattered shark teeth.	2	11	0.89
		7. Neva limestone: medium calcilutite; wackestone; medium gray, weathers light gray; blocky to slabby; with common crinoids, shell fragments.	3	0	0.91
		6. Neva limestone: clay shale; light green; fissile; with common crinoids, echinoids; scattered <u>Composita</u>, <u>Wellerella</u>; few <u>Pseudoschwagerina</u>.	0	5	0.13
	NT_6				
		5. Neva limestone: medium calcilutite; mudstone to wackestone; medium gray, weathers light gray; slabby; algal laminated; with scattered shell fragments.	0	4	0.10
		4. Neva limestone: medium calcilutite; wackestone; medium gray, weathers light gray; massive; with common crinoids, <u>Juresania</u>; scattered <u>Hustedia</u>; scattered dissolution features.	2	7	0.79
	NT_5				
		3. Neva limestone: clay shale; brown; platy; with scattered <u>Orbiculoidea</u>.	0	3	0.08
		2. Neva limestone: fine calcarenite; wackestone; medium gray, weathers light gray; with common crinoids, <u>Juresania</u>; scattered bryozoa, echinoids.	0	5	0.13
	NT_4				
		1. Neva limestone: clay shale; olive green; platy to fissile; slightly calcareous; with common <u>Orbiculoidea</u>; few <u>Wellerella</u>.	1	1	0.33

Locality #4

NW NW Sec. 4, T. 14 S., R. 11 E., spillway cut along Lake Wabaunsee, Wabaunsee County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		19. Cottonwood limestone: fine calcrudite; packstone; medium gray, weathers light gray; massive; with abundant Psuedoschwagerina; common bedded chert.	2	10	0.86
		18. Cottonwood limestone: medium calcilutite, wackestone; medium gray, weathers light gray; massive; with common skeletal fragments, chert nodules.	3	1	0.94
CT_1					
		17. Eskridge Shale: clayshale; light green; crumbly; semi-indurated; non-fossiliferous.	4	0	1.22
		16. Eskridge Shale: fine calcilutite; mudstone to wackestone; slabby; with scattered molluscan shell fragments, ostracods.	0	4	0.10
	NT_{11}				
		15. Eskridge Shale: claystone; red; crumbly; indurated; with common root traces.	4	8	1.42
		14. Eskridge Shale: clay shale; light green; crumbly; indurated.	0	3	0.08
		13. Eskridge Shale: medium calcilutite; wackestone; light gray; with scattered microgastropods, ostracods, productids, Aviculopecten.	2	0	0.61
	NT_{10}				
		12. Eskridge Shale: claystone; light green; crumbly; indurated; with common plant fossils and root traces.	5	4	1.63
		11. Eskridge Shale: fine calcilutite; wackestone; medium gray, weathers green-gray; with common ostracods, skeletal fragments.	0	6	0.15
	NT_9				
		10. Eskridge Shale: claystone; light green; crumbly; indurated.	3	3	0.99
		9. Eskridge Shale: claystone; red; crumbly; indurated; with common root traces, microslickensides.	5	5	1.65
		8. Eskridge Shale: fine calcilutite; mudstone; gray-green; flaggy; with scattered Aviculopecten; common plant roots at top.	0	4	0.10
	NT_8				
		7. Eskridge Shale: claystone; pale red; indurated; common calcified ped structures, with root traces.	0	3	0.08
		6. Eskridge Shale: claystone; dark green, weathers light green; crumbly; indurated; with common root traces.	5	2	1.57
		5. Eskridge Shale: clay shale; light green; flaggy; with common root traces.	1	6	0.46
		4. Neva limestone: medium calcilutite; wackestone; medium gray, weathers light gray; slabby; algal laminated; with common skeletal fragments, scattered stromatolites at top surface.	0	6	0.15
		3. Neva limestone: coarse calcilutite; wackestone; medium gray, weathers light gray; with common crinoids, Juresania, Hustedia, Derbyia.	1	4	0.41
		2. Neva limestone: clay shale; black, weathers dark gray; platy; with common Neospirifer, Composita, Neochontes, echinoids; scattered crinoids, Derbyia, productids, Crurithyris, bryozoans; few Ditomopyge, Aviculopecten.	3	0	0.91
	NT_6				

	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	1. Neva limestone: medium calcilutite; medium gray, weathers light gray; slabby; with common crinoids, bryozoans; scattered productids.	3	4+	1.02+

Locality #5

NE NE Sec. 27, T. 11 S., R. 10 E., along mile Interstate Highway 70 at mile marker #328, Wabaunsee County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		41. Cottonwood limestone: fine calcirudite, packstone; gray, weathers yellow-gray; massive; with abundant fusulinids, scattered Composita, echinoids; common bedded chert nodules.	2	7	0.79
CT_1		40. Cottonwood limestone: medium calcarenite, wackestone; gray, weathers yellow-gray; with common skeletal fragments; two layers of nodular chert at upper 15 inches (0.38 m).	3	4	1.02
		39. Eskridge Shale: clay shale; green to red; crumbly; semi-indurated.	1	6	0.46
		38. Eskridge Shale: claystone; green to red; crumbly; indurated.	4	1	1.24
	NT_{11}	37. Eskridge Shale: medium calcilutite, wackestone; light gray; slabby; with scattered Aviculopecten, Pleurophorus, ostracods, plant roots at top.	0	9	0.23
		36. Eskridge Shale: clay shale; pale red; flaggy; calcareous; with common plant roots; scattered Pleurophorus in basal 12 inches (0.30 m).	1	10	0.56
		35. Eskridge Shale: medium calcilutite, wackestone; green-gray; flaggy to slabby; argillaceous; with common Aviculopecten, Bellerophon, ostracods, scattered productids.	0	8	0.20
	NT_{10}	34. Eskridge Shale: clay shale; green; platy to flaggy; calcareous; with scattered skeletal fragments.	0	3	0.08
		33. Eskridge Shale: clay shale; red, weathers pale red; crumbly; indurated.	7	8	2.34
		32. Eskridge Shale: clay shale; olive green; fissile to platy; calcareous; with abundant ostracods.	1	8	0.51
		31. Eskridge Shale: clay shale; black; papery; with common ostracods, few nuculoids; common plant fossils at basal 2 inches (0.05 m).	0	5	0.13
	NT_9	30. Eskridge Shale: medium calcilutite, wackestone; gray; flaggy to slabby; with scattered Aviculopecten, ostracods, Lingula, few Nuculopsis.	0	11	0.28
		29. Eskridge Shale: clay shale; olive green; flaggy; with common plant fossils, few Aviculopecten at top.	1	5	0.43
		28. Eskridge Shale: fine calcilutite, mudstone to wackestone; green-gray; slabby; with scattered Myalina, microgastropods, few spiroibid worm tubes.	0	8	0.20
	NT_8	27. Eskridge Shale: medium calcirudite, collapse breccia; brown; cherty.	0	2	0.05
		26. Eskridge Shale: clay shale; dark green,; calcareous.	1	6	0.46
		25. Eskridge Shale: claystone; brown-green; crumbly; indurated; with common root traces, caliche nodules.	2	2	0.66
		24. Eskridge Shale: claystone; maroon to purple; crumbly; indurated; with common root traces, caliche nodules.	5	5	1.65

	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	23. Eskridge Shale: claystone; green to red; crumbly; indurated; calcareous.	0	7	0.18
	22. Eskridge Shale: fine calcilutite, mudstone; green-gray; flaggy; argillaceous; with skeletal fragments; rooted at base.	0	9	0.23
NT_7				
	21. Eskridge Shale: claystone; red; crumbly; indurated.	0	4	0.10
	20. Eskridge Shale: fine calcilutite, mudstone; green-gray; argillaceous; with few shell fragments.	1	4	0.41
	19. Neva limestone: medium calcilutite, wackestone; gray; massive; algal laminated at top 4 inches (0.10 m); with common skeletal fragments, scattered productids, few Composita; 3 inch (0.08 m) vertical burrowed zone 6 inches (0.15 m) from top.	2	6	0.76
	18. Neva limestone: clay shale; green to dark gray; fissile to platy; calcareous; with common Derbyia, productids, echinoids, bryozoans (ramose, encrusting, fenestrate), scattered Composita, Neospirifer, Neochonetes.	3	2	0.97
NT_6				
	17. Neva limestone: fine calcarenite, packstone; gray; slabby; with common intraclasts; scattered crinoids, echinoids, Chonetes.	1	2	0.36
	16. Neva limestone: fine calcarenite, wackestone; gray, weathers tan; massive; common phylloid algal fronds, echinoids, crinoids, scattered Composita.	0	6	0.15
	15. Neva limestone: medium calcirudite, grainstone; gray; collapse brecciated; with common whole fossils, including productids, Husteadia, echinoids, scattered Crurithyris, few scaphapods.	2	6	0.76
NT_5				
	14. Neva limestone: fine calcarenite, packstone; gray, weathers tan; slabby to blocky; with common phylloid algal fronds, echinoids, crinoids, bryozoans, Composita, productids, scattered Hustedia, few rugosid corals.	1	0	0.30
	13. Neva limestone: fine calcarenite, packstone; gray, weathers tan; blocky; with common fusulinids, echinoids, crinoids, productids, scattered bryozoans.	0	11	0.28
NT_4				
	12. Neva limestone: clay shale; green-brown; fissile to flaggy; with scattered plant fossils; few large vertical burrows at top.	0	10	0.25
	11. Neva limestone: medium calcilutite, wackestone; gray; flaggy to slabby; with common skeletal fragments, productids, echinoids, scattered Aviculopecten.	1	1	0.33
NT_3				
	10. Neva limestone: clay shale; green-brown; non-fossiliferous.	0	3	0.08
	9. Neva limestone: clay shale; olive green; platy; with scattered fusulinids, crinoids, productids, few horn corals; non-fossiliferous at top 3 inches (0.08 m).	0	10	0.25
NT_2				
	8. Neva limestone: clay shale; brown mottled gray; platy; with abundant plant fossils, few Chonetinella.	0	8	0.20
	7. Neva limestone: clay shale; green-brown; fissile; with common Crurithyris, Orbiculoidea, few Wellerella.	0	2	0.05
	6. Neva limestone: medium calcilutite, wackestone; gray; slabby; with abundant phylloid algae, scattered fusulinids at top, few Composita, Crurithyris.	0	6	0.15
	5. Neva limestone: medium calcarenite, packstone; gray, weathers tan; slabby to blocky; crossbedded; with common skeletal fragments, ostracods, crinoids, Crurithyris; scattered Nuculopsis in situ at base.	1	1	0.33
NT_1				

	UNIT DESCRIPTIONS	Unit Thicknesses ft	in	m
	Transgressive Surface ——			
	4. Salem Point shale: claystone; dark green to yellow-brown; varigated; crumbly; indurated.	0	2	0.05
	3. Salem Point shale: clay shale; medium brown to gray; fissile to platy; with common mudcracks.	1	0	0.30
	2. Salem Point shale: clay shale; dark gray; fissile to platy; slightly silty; with common ostracods.	0	10	0.25
BT_6				
	1. Salem Point shale: clay shale; brown; platy to flaggy; slightly silty; with common plant fossils.	0	4	0.10

Locality #6

Center Sec. 19, T.9 S., R.8 E., outcrop along Tuttle Creek Lake Spillway, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		34. Florena shale: clay shale; black, weathers tan; fissile; with abundant Neochonetes, Derbyia, bryozoans (ramose and fenestrate), scattered Composita, Ditomopyge.	7	0+	2.13
		33. Cottonwood limestone: fine calcirudite, packstone; gray, weathers yellow-gray; massive; with abundant fusulinids, scattered crinoids; bedded chert nodules 8 inches (0.20 m) above base.	3	2	0.96
		32. Cottonwood limestone: medium calcarenite, wackestone; gray, weathers yellow-gray; blocky; with common productids, crinoids, scattered Composita.	3	4	1.02
CT_1					
		31. Eskridge Shale: clay shale; green; platy; non-fossiliferous.	1	0	0.30
		30. Eskridge Shale: clay shale; green-gray; platy to slabby; calcareous; with few bivalve fragments.	1	6	0.46
	NT_{11}				
		29. Eskridge Shale: clay shale; green-gray; crumbly; indurated.	1	5	0.43
		28. Eskridge Shale: medium calcilutite, wackestone; green-gray; platy; with common Aviculopecten, Nuculopsis, productids, scattered Aviculopinna, Allorisma, Bellerophon, Derbyia, Wilkingia in life position; Pleurophorus, few Hustedia; scattered plant fossils in top 12 inches (0.30 m).	4	2	1.27
	NT_{10}				
		27. Eskridge Shale: claystone; green; crumbly; indurated.	4	8	1.42
		26. Eskridge Shale: fine calcilutite, mudstone; green-gray, with common plant roots.	0	6	0.15
	NT_9				
		25. Eskridge Shale: clay shale; red; fissile to platy; semi-indurated; abundant plant roots in top 8 inches (0.20 m).	2	7	0.79
		24. Eskridge Shale: clay shale; olive green; flaggy; finely laminated, non-fossiliferous.	2	8	0.81
		23. Eskridge Shale: coarse calclutite, wackestone; gray; flaggy to slabby; with common productids, gastropods, skeletal fragments.	1	5	0.43
		22. Eskridge Shale: fine calcilutite, mudstone; gray, weathers gray-brown; slabby; with fenestral fabric.	0	7	0.18
	NT_8				
		21. Eskridge Shale: claystone; green; crumbly; indurated; with scattered caliche nodules at base.	2	4	0.71
		20. Eskridge Shale: claystone; red; crumbly; indurated; with abundant root traces, caliche nodules throughout.	3	4	1.02
		19. Eskridge Shale: claystone; green; crumbly; indurated; with common plant roots; calcified blocky ped strucures.	1	1	0.33
		18. Neva limestone: medium calclutite, wackestone; medium gray, weathers tan; slabby; algal laminated; with common skeletal fragments.	0	11	0.28

	UNIT DESCRIPTIONS (Transgressive Surface ——)	ft	in	m
	17. Neva limestone: clay shale; dark gray, weathers olive; flaggy; calcareous; with common echinoids, bryozoans (ramose), Composita, crinoids, scattered Wellerella, Neospirifer.	1	8	0.51
NT_6				
	16. Neva limestone: medium calclutite, wackestone; gray; blocky; with common skeletal fragments, crinoids, productids.	2	10	0.86
	15. Neva limestone: clay shale; olive green; platy, calcareous; with scattered crinoids, productids, bryozoans (ramose and fenestrate).	0	3	0.08
	14. Neva limestone: fine calcilutite, mudstone to wackestone; gray, weathers tan; slabby; with common crinoids, productids at basal 12 inches (0.30 m).	2	4	0.71
NT_5				
	13. Neva limestone: clay shale; olive green mottled black; flaggy; calcareous; with scattered Crurithyris, crinoids, Aviculopecten in basal 6 inches (0.15 m).	1	0	0.30
	12. Neva limestone: medium calclutite, wackestone; green-gray, weathers tan; with common shell fragments, few Composita.	0	3	0.08
NT_4				
	11. Neva limestone: clay shale; brown, weathers tan; sandy; indurated.	1	8	0.51
	10. Neva limestone: clay shale; green-gray; indurated.	0	7	0.18
	9. Neva limestone: sandstone; brown; indurated; argillaceous; fine grained, dolomitic.	0	2	0.05
	8. Neva limestone: medium dololutite, wackestone; orange-gray; blocky to massive; vuggy; with common Bellerophon, Composita; scattered microgeodes at top.	2	6	0.76
NT_3				
	7. Neva limestone: clay shale; green; fissile; sparsely fossiliferous; with few skeletal fragments.	0	4	0.10
	6. Neva limestone: clay shale; green-gray; platy; calcareous; with common crinoids, scattered fusulinids, Crurithyris, few Hustedia.	1	0	0.30
NT_2				
	5. Neva limestone: clay shale; black; fissile; with common plant fossils.	0	1	0.03
	4. Neva limestone: coarse calcilutite, wackestone; gray, weathers yellow-gray; with common skeletal fragments.	1	3	0.38
NT_1				
	3. Salem Point shale: clay shale; dark green; crumbly; indurated.	0	5	0.13
	2. Salem Point shale: fine calcilutite, mudstone; medium gray; sparsely fossiliferous; with scattered ostracods.	0	4	0.10
	1. Salem Point shale: clay shale; olive green mottled black; slightly calcareous, with few ostracods.	1	10	0.56

Locality #7

SE SW Sec. 10, T. 10 S., R. 7 E., roadcut along Federal Aid Secondary Hi-way 1925, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		32. Florena shale: clay shale; black; fissile; calcareous; with abundant Neochonetes, common Derbyia, bryozoans (ramose and fenestrate), Reticulatia, scattered Composita, Ditomopyge.	6	0	1.83
		31. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, scattered echinoids, few productids.	3	4	1.02
		30. Cottonwood limestone: coarse calcarenite, wackestone: medium gray, weathers yellow-gray; massive; with common skeletal fragments, scattered crinoids.	2	10	0.86
CT_1					
		29. Eskridge Shale: clay shale; green; crumbly; indurated; with common plant fossils.	1	0	0.30
		28. Eskridge Shale: medium calcarenite, wackestone; light gray; flaggy to slabby; argillaceous; with common Aviculopecten, scattered Nuculopsis, productids; common plant fossils in upper 6 inches (0.15 m).	2	2	0.66
	NT_{11}				
		27. Eskridge Shale: clay shale; olive green; crumbly; indurated.	0	5	0.13
		26. Eskridge Shale: clay shale; red; crumbly; indurated; with common plant roots.	0	9	0.23
		25. Eskridge Shale: clay shale; olive green; crumbly; indurated; with common plant roots.	1	0	0.30
		24. Eskridge Shale: clay shale; brown-red to red; crumbly; indurated; with common plant roots.	1	4	0.41
		23. Eskridge Shale: clay shale; olive green; crumbly; indurated; with common plant roots.	0	10	0.25
		22. Eskridge Shale: fine calcarenite, wackestone; light gray; slabby; varved; with abundant intraclasts, ostracods, shell fragments, scattered crinoids, few shark teeth.	0	10	0.25
	NT_{10}				
		21. Eskridge Shale: clay shale; dark green; crumbly; indurated.	1	1	0.33
		20. Eskridge Shale: clay shale; olive green; fissile; with scattered Lingula, plant fragments.	0	7	0.18
		19. Eskridge Shale: medium calcilutite, mudstone; green-gray; slabby; with scattered Nuculopsis, few Aviculopecten; common plant roots at top.	1	2	0.36
		18. Eskridge Shale: fine calcilutite, mudstone; gray; flaggy to slabby; argillaceous; with few Nuculopsis.	3	3	0.99
		17. Eskridge Shale: clay shale; gray; flaggy; with scattered Aviculopecten, Nuculopsis, few Lingula.	1	1	0.33
	NT_9				
		16. Eskridge Shale: clay shale; light green; blocky; scattered Aviculopecten at basal 4 inches (0.10 m); upper 8 inches (0.20 m) non-fossiliferous.	[illegible]	0	0.30

	UNIT DESCRIPTIONS	Unit Thicknesses ft	in	m
	Transgressive Surface ——			
	15. Eskridge Shale: medium calcilutite, wackestone; medium gray; slabby; with abundant <u>Aviculopecten</u>, <u>Septimyalina</u>, scattered <u>Bellerophon</u>, <u>Myalina</u>.	0	6	0.15
NT_8				
	14. Eskridge Shale: clay shale; green; crumbly; indurated; with scattered plant roots.	1	3	0.38
	13. Eskridge Shale: clay shale; red; crumbly; indurated; with common plant roots.	3	3	0.99
	12. Eskridge Shale: clay shale; black; crumbly; indurated.	0	5	0.13
	11. Eskridge Shale: claystone; maroon; blocky; with common plant roots; calcified subangular blocky ped structures.	4	8	1.42
	10. Eskridge Shale: clay shale; green; crumbly; indurated.	0	6	0.15
	9. Eskridge Shale: clay shale; green to red; blocky; indurated; with common plant roots.	0	8	0.20
	8. Eskridge Shale: claystone; dark green; blocky; indurated; with common root traces.	0	7	0.18
	7. Eskridge Shale: fine calcilutite, mudstone; green-gray; platy; with abundant root traces.	0	2	0.05
NT_7				
	6. Eskridge Shale: clay shale; green; crumbly; indurated; with common plant roots.	0	6	0.15
	5. Neva limestone: coarse calcilutite, wackestone; medium gray; slabby; top 2 inches (0.05 m) algal laminated; with common skeletal fragments, scattered crinoids, productids.	1	1	0.33
	4. Neva limestone: clay shale; green-gray; platy to flaggy; calcareous; with common crinoids, productids, few <u>Composita</u>.	0	10	0.25
NT_6				
	3. Neva limestone: coarse calcilutite, wackestone; light gray; flaggy; with common shell fragments, scattered crinoids, bryozoans (ramose).	1	11	0.58
	2. Neva limestone: clay shale; green-gray; platy; calcareous; with scattered crinoids, fusulinids, shell fragments.	0	3	0.08
	1. Neva limestone: medium calcilutite, wackestone; gray; slabby; with scattered skeletal fragments.	0	6	0.15

Locality #8

SE SW Sec. 24, T.10S., R.7E., along Hi-way 18 near the Warner Park entrance, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		33. Cottonwood limestone: medium calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, scattered echinoids, productids, <u>Composita</u>, crinoids; bedded chert nodules 8 inches (0.20 m) above base.	3	2	0.97
		32. Cottonwood limestone: coarse calcarenite, wackestone; light gray, weathers yellow-gray; with scattered echinoids, productids, crinoids.	2	10	0.86
CT_1		31. Cottonwood limestone: medium calcilutite, mudstone to wackestone; light gray, weathers tan; flaggy; with common skeletal fragments, crinoids.	0	7	0.18
		30. Eskridge Shale: claystone; dark green mottled brown; crumbly; with common microslickensides, caliche nodules.	2	9	0.84
		29. Eskridge Shale: fine calcilutite, mudstone; green-gray; platy to flaggy; with common nuculoid bivalves, scattered <u>Aviculopecten</u>; abundant plant roots in upper 8 inches (0.20 m).	1	8	0.51
		28. Eskridge Shale: clay shale; light gray, weathers yellow-gray; fissile; with scattered ostracods.	1	1	0.33
	NT_{11}	27. Eskridge Shale: clay shale; pale green; fissile to platy; slightly calcareous; argillaceous; with abundant ostracods, common productids; abundant intraclasts.	0	3	0.08
		26. Eskridge Shale: claystone; red to brown; varigated; crumbly; indurated.	0	5	0.13
		25. Eskridge Shale: clay shale; dark green; platy; crumbly; semi-indurated.	4	3	1.30
	NT_{10}	24. Eskridge Shale: fine calcilutite, red; flaggy; argillaceous; with abundant plant roots.	1	2	0.36
		23. Eskridge Shale: clay shale; red; flaggy.	0	5	0.13
	NT_9	22. Eskridge Shale: fine calcilutite, mudstone; red to green; argillaceous; with scattered nuculoid bivalves.	2	1	0.64
		21. Eskridge Shale: clay shale; olive green; crumbly; indurated; with common plant roots at top.	0	10	0.25
		20. Eskridge Shale: fine calclutite, mudstone; pale red; flaggy; with common <u>Nuculopsis</u>, scattered <u>Lingula</u>; common dessication cracks, plant roots at top 3 inches (0.08 m).	0	10	0.25
	NT_8	19. Eskridge Shale: fine calcilutite, mudstone; light green to gray; with scattered bivalve fragments; common plant fossils at base.	1	6	0.46
		18. Eskridge Shale: claystone; dark green; blocky; with common plant fossils and roots.	2	1	0.64
		17. Eskridge Shale: claystone; deep red; crumbly; indurated; with common microslickensides, plant roots; 36 inch (0.91 m) zone of columnar caliche 20 inches (0.51 m) above base.	8	0	2.44

UNIT DESCRIPTIONS

Transgressive Surface ——

Transgressive Surface	Unit Descriptions	Unit Thicknesses ft	in	m
	16. Eskridge Shale: clay shale; olive green; crumbly; indurated.	1	4	0.41
	15. Neva limestone: fine calcilutite, mudstone; light gray; slabby; with scattered skeletal fragments.	0	11	0.28
	14. Neva limestone: clay shale; olive green mottled black; flaggy; calcareous; with common crinoids, few Crurithyris, Neochonetes.	1	6	0.46
NT_6				
	13. Neva limestone: coarse calcilutite, mudstone to wackestone; light gray, weathers tan; massive; with scattered skeletal fragments.	5	11	1.80
	12. Neva limestone: clay shale; olive green; flaggy; calcareous; with scattered crinoids, echinoids, skeletal fragments.	0	3	0.08
	11. Neva limestone: coarse calcilutite, wackestone; light gray, weathers orange; blocky; with scattered Neospirifer, crinoids, Composita; abundant vugs at base, basal 22 inces (0.56 m) collapse brecciated.	4	3	1.30
NT_5				
	10. Neva limestone: fine to coarse calcilutite; mudstone to wackestone; gray; slabby; coarsens upwards; with few Nerites, Lingula at base; scattered Bellerophon, crinoids, skeletal fragments at top.	1	7	0.48
NT_4				
	9. Neva limestone: clay shale; brown; flaggy; with abundant plant fossils.	0	3	0.08
	8. Neva limestone: clay shale; black; fissile to papery; silty; non-fossiliferous.	0	11	0.28
	7. Neva limestone: clay shale; brown; flaggy; with scattered Orbiculoidea, Crurithyris, Lingula, Hustedia.	0	4	0.10
	6. Neva limestone: coarse calcilutite, packstone; green-gray; flaggy; argillaceous; with common Recticulatia in life position, scattered fusulinids, crinoids, few Neochonetes, Wellerella, horn corals.	0	2	0.05
NT_2				
	5. Neva limestone: clay shale; brown; fissile; with abundant Orbiculoidea fragments.	0	1	0.03
	4. Neva limestone: medium calcarenite, wackestone to packstone; gray; blocky; with common productids, Crurithyris, bryozoans (ramose and fenestrate), crinoids, echinoids, skeletal fragments.	1	5	0.43
NT_1				
	3. Salem Point shale: claystone; green-gray; blocky; with common calcified blocky ped structures.	1	1	0.33
	2. Salem Point shale: clay shale; black; fissile; with common plant fragments, scattered ostracods, few Lingula.	1	11	0.58
	1. Salem Point shale: fine calcilutite, mudstone; gray; blocky; algal laminated; with scattered skeletal fragments.	1	1	0.33

Locality #9

NW NW Sec. 15 T. 11 S., R. 7 E., along Federal Aid Secondary Highway 1092 near Ashland, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		13. Florena shale: clay shale, black, weathers tan; fissile to platy; with abundant Neochonetes, common productids, Derbyia, Composita, bryozoans (ramose and fenestrate), crinoids, echinoids, scattered fusulinids, Ditomopyge.	6	6	1.98
		12. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, common echinoids, few Composita, productids; bedded chert nodules 8 inches (0.20 m) above base.	2	11	0.89
		11. Cottonwood limestone: medium calcarenite, wackestone; light gray, weathers yellow-gray; massive; with common skeletal fragments, crinoids, scattered Composita, few productids.	3	1	0.94
		10. Cottonwood limestone: coarse calcilutite, mudstone to wackestone; light gray, weathers yellow-gray; slabby; with scattered skeletal fragments.	0	9	0.23
CT_1					
		9. Eskridge Shale: clay shale; dark green; crumbly; indurated.	1	3	0.38
		8. Eskridge Shale: clay shale; maroon; crumbly; with common plant roots.	3	10	1.17
		7. Eskridge Shale: medium calcilutite, wackestone; light gray; slabby; with common Aviculopecten, Septimyalina, Pleurophorus, Reticulatia, few scaphapods.	0	8	0.20
	NT_{11}				
		6. Eskridge Shale: clay shale; green; crumbly; non-fossiliferous.	0	2	0.05
		5. Eskridge Shale: clay shale; red; crumbly; indurated; with common plant roots.	0	7	0.18
		4. Eskridge Shale: claystone; green-gray to tan; crumbly; indurated; with common plant roots.	1	9	0.53
		3. Eskridge Shale: coarse calcilutite, wackestone; gray; flaggy; with abundant ostracods, common skeletal fragments.	0	3	0.08
	NT_{10}				
		2. Eskridge Shale: clay shale; dark green; crumbly; indurated; with common plant fossils.	0	10	0.25
		1. Eskridge Shale: clay shale; red; crumbly; indurated; with common plant roots; 2 inch (0.05 m) zone of calcified blocky peds at top.	2	2	0.66

Locality #10

SE SE Sec. 12, T. 9 S., R 7 E., along Tuttle Creek Lake near "the rocks" Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		39. Cottonwood limestone: fine calcirudite, packstone; gray; blocky to massive; with abundant fusulinids, scattered crinoids, echinoids, few <u>Composita</u>, productids; two layers of chert nodules near middle.	2	10	0.86
		38. Cottonwood limestone: medium calcarenite, wackestone; gray, weathers yellow-gray; massive; with common crinoids, productids, echinoids, scattered <u>Composita</u>; bedded chert nodules 8 inches (0.20 m) from top.	2	7	0.79
		37. Cottonwood limestone: fine calcarenite, wackestone; gray, weathers tan; flaggy to slabby; with common skeletal fragments.	0	10	0.25
CT_1					
		36. Eskridge Shale: clay shale; green; crumbly; rooted.	1	8	0.51
		35. Eskridge Shale: medium calclutite, wackestone; medium gray; flaggy to slabby; with scattered <u>Aviculopecten</u>, <u>Septimyalina</u>, <u>Nuculopsis</u>, few <u>Wilkingia</u>, <u>Bellerophon</u>.	1	8	0.51
	NT_{11}				
		34. Eskridge Shale: clay shale; light green-gray; flaggy; flaser bedded; rooted.	1	10	0.56
		33. Eskridge Shale: fine calcilutite, mudstone; green-gray; flaggy; rooted.	0	5	0.13
		32. Eskridge Shale: medium calcilutite, wackestone; gray; flaggy to slabby; with abundant ostracods, common skeletal fragments, granular intraclasts.	0	8	0.20
		31. Eskridge Shale: fine calcilutite, mudstone; green; platy to flaggy; with common plant roots.	0	8	0.20
	NT_{10}				
		30. Eskridge Shale: clay shale; light green; blocky; non-fossiliferous.	1	6	0.46
		29. Eskridge Shale: claystone; green-gray; with abundant caliche; common plant roots.	1	5	0.43
		28. Eskridge Shale: clay shale; green; crumbly; indurated; rooted.	1	3	0.38
		27. Eskridge Shale: medium calcilutite, mudstone; gray; slabby; with common ostracods; rooted at top.	0	9	0.23
	NT_9				
		26. Eskridge Shale: clay shale; red to green; platy to flaggy; with scattered bivalves, <u>Lingula</u>; common plant roots at top 6 inches (0.15 m).	2	3	0.69
		25. Eskridge Shale: fine calcilutite, mudstone; gray; slabby; with scattered <u>Aviculopecten</u> at base.	0	4	0.10
		24. Eskridge Shale: clay shale; green; blocky; sparsely fossiliferous.	0	11	0.28
		23. Eskridge Shale: fine calcilutite, wackestone; light gray; flaggy to slabby; with abundant <u>Septimyalina</u>, common <u>Aviculopecten</u>, scattered <u>Nuculopsis</u>, <u>Pleurophorus</u>, few high spired gastropods; vertical burrows at top 21 inches (0.53 m); basal 6 inches (0.15 m) argillaceous.	1	9	0.53
	NT_8				

	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	22. Eskridge Shale: clay shale; green; blocky; semi-indurated; with common plant roots at top.	2	3	0.69
	21. Eskridge Shale: claystone; red to maroon; crumbly; indurated; with common calcified vertical peds, caliche nodules.	4	10	1.47
	20. Eskridge Shale: clay shale; light green; flaggy; calcareous.	0	5	0.13
	19. Eskridge Shale: clay shale; red; crumbly; indurated.	0	8	0.20
	18. Eskridge Shale: fine calcilutite, mudstone; gray,wethers tan; flaggy; with scattered bivalves.	0	2	0.05
NT_7				
	17. Eskridge Shale: clay shale; green; fissile; non-fossiliferous.	0	10	0.25
	16. Neva limestone: coarse calcilutite, wackestone; light gray; slabby; with common skeletal fragments, coated grains, gastropods, productids; top 2 inches (0.05 m) algal laminated.	1	1	0.33
	15. Neva limestone: clay shale; olive green; flaggy; calcareous; with common productids, crinoids, scattered Neospirifer, Neochonetes.	1	2	0.36
NT_6				
	14. Neva limestone: medium calcilutite, mudstone to wackestone; slabby to blocky; with common crinoids, shell fragments, scattered productids.	4	5	1.35
	13. Neva limestone: clay shale; green-gray; flaggy; with common fusulinids, few Wellerella, Ditomopyge.	0	7	0.18
	12. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; with common productids, crinoids, scattered Composita, Crurithyris; prominent vuggy zone 8 inches (0.20 m) above base.	3	1	0.94
NT_5				
	11. Neva limestone: clay shale; olive green; flaggy; with common plant fragments, scattered Crurithyris.	0	5	0.13
	10. Neva limestone: medium calcilutite, wackestone; gray; flaggy to slabby; with common fusulinids, scattered crinoids at top 3 inches (0.08 m); basal 12 inches (0.30 m) sparsely fossiliferous.	1	3	0.38
NT_4				
	9. Neva limestone: clay shale; brown; blocky; indurated.	0	5	0.13
	8. Neva limestone: clay shale; olive green, weathers tan; fissile; with scattered Hustedia, Neochonetes.	1	0	0.30
	7. Neva limestone: clay shale; green-gray; fissile; with scattered Lingula.	0	3	0.08
	6. Neva limestone: clay shale; dark brown; fissile to platy; with abundant Orbiculoidea fragments.	0	2	0.05
	5. Neva limestone: clay shale; olive green; fissile to flaggy; with common Crurithyris.	0	2	0.05
	4. Neva limestone: fine calcarenite, wackestone; gray; flaggy to slabby; argillaceous; with common fusulinids, scattered crinoids.	0	5	0.13
NT_2				
	3. Neva limestone: clay shale; brown; papery; with scattered Orbiculoidea.	0	2	0.05
	2. Neva limestone: medium calcarenite, wackestone to packstone; slabby to blocky; with common skeletal fragments, crinoids, productids, scattered Neospirifer, Composita.	1	3	0.38
NT_1				
	1. Salem Point shale: claystone; brown to tan; silty; indurated.	0	6	0.15

Locality #11

NE NE Sec. 26, T. 10 S., R 7 E., roadcut along service road near Sunset Zoo, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		22. Cottonwood limestone: coarse calcilutite, wackestone; light gray, weathers tan; flaggy to slabby; with common skeletal fragments, scattered productids, few <u>Composita</u>.	0	10	0.25
CT_1					
		21. Eskridge Shale: clay shale; light green; flaggy; silty; non-fossiliferous.	2	11	0.89
		20. Eskridge Shale: medium calcilutite, wackestone; light gray; papery to fissile; with common <u>Nuculopsis</u>, few <u>Pleurophorus</u>.	1	2	0.36
	NT_{11}				
		19. Eskridge Shale: clay shale; light gray, weathers tan; flaggy; with scattered plant fossils.	1	3	0.38
		18. Eskridge Shale: clay shale; light gray; fissile; with common plant fossils.	0	11	0.28
		17. Eskridge Shale: fine calcilutite, mudstone to wackestone; light gray; flaggy; with scattered <u>Aviculopecten</u>.	0	5	0.13
		16. Eskridge Shale: medium calcarenite, wackestone; gray; blocky; with abundant ostracods, scattered microgastropods.	0	6	0.15
		15. Eskridge Shale: medium calcilutite, mustone to wackestone; green-gray; papery to flaggy; with few <u>Nuculopsis</u>.	0	4	0.10
	NT_{10}				
		14. Eskridge Shale: claystone; green; crumbly; semi-indurated.	0	8	0.20
		13. Eskridge Shale: claystone; red to green; varigated; crumbly; indurated; with common plant roots.	4	11	1.50
		12. Eskridge Shale: claystone; light green; crumbly; indurated.	0	9	0.23
		11. Eskridge Shale: clay shale; pale red; flaggy; calcareous; with common plant fragments, root traces at top 4 inches (0.10 m).	1	0	0.30
		10. Eskridge Shale: fine calcilutite, mudstone; green-gray; slabby; with common dessication cracks at base, scattered nuculoid bivalves at middle, common plant fossils at top 3 inches (0.08 m).	0	8	0.20
	NT_9				
		9. Eskridge Shale: clayshale; dark green mottled brown-green; blocky; non-fossiliferous.	5	10	1.78
		8. Eskridge Shale: fine calcilutite, mudstone; light green; flaggy; argillaceous; with scattered skeletal fragments, few <u>Nuculopsis</u>.	0	8	0.20
		7. Eskridge Shale: fine calcilutite, mudstone; gray; slabby; non-fossiliferous.	0	2	0.05
		6. Eskridge Shale: fine calcarenite, wackestone; gray; slabby; with common shell fragments, ostracods, scattered bivalves, productids.	0	2	0.05
	NT_8				
		5. Eskridge Shale: claystone; dark green; blocky; semi-indurated.	1	1	0.33

	UNIT DESCRIPTIONS	Unit Thicknesses		
	Transgressive Surface ——	ft	in	m
	4. Eskridge Shale: fine calcilutite, mudstone; green-gray; flaggy; argillaceous; with scattered skeletal fragments.	0	5	0.13
	3. Eskridge Shale: fine calcilutite, mudstone; light green-gray; slabby; thin bedded; with scattered plant roots.	0	7	0.18
NT7	2. Eskridge Shale: fine calcilutite, mudstone; light green; flaggy; silty; with scattered intraclasts, plant roots, few productid spines.	0	11	0.28
	1. Eskridge Shale: claystone; brown; indurated; with common caliche nodules.	0	5+	0.13

Locality #12

Center Sec. 18, T. 9 S., R. 8 E., one-half mile east of Tuttle Creek Spillway along Kansas Hi-way 13, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		14. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, common echinoids, productids, crinoids; three layers of nodular chert at 15 (0.38), 18 (0.46), and 32 inches (0.81 m) above base.	2	10	0.86
		13. Cottonwood limestone: medium calcarenite, wackestone; medium gray, weathers tan; massive; with common crinoids, echinoids, productids, scattered <u>Composita</u>; two prominent nodular chert beds at 20 (0.51) and 28 inches (0.71 m) above base.	3	0	0.91
		12. Cottonwood limestone: coarse calcilutite, wackestone; light gray, weathers yellow-gray; flaggy to slabby; with common skeletal fragments, productids, scattered <u>Neochonetes</u>, <u>Composita</u>.	0	9	0.23
CT_1					
		11. Eskridge Shale: clay shale; green; flaggy; non-fossiliferous.	2	7	0.79
		10. Eskridge Shale: medium calcilutite, wackestone; light gray; flaggy; with abundant <u>Aviculopecten</u>, common nuculoid bivalves, few <u>Pleurophorus</u>.	1	9	0.53
	NT_{11}				
		9. Eskridge Shale: clay shale; light green; flaggy; slightly calcareous; with scattered <u>Aviculopecten</u>, nuculoid bivalves, few pinned bivalves; common plant roots in upper one-half.	3	7	1.09
		8. Eskridge Shale: fine calcilutite, mudstone; green-gray; flaggy; argillaceous; with common <u>Aviculopecten</u>, few productids in upper 5 inches (0.13 m); common plant roots in basal 9 inches (0.23 m).	1	2	0.36
	NT_{10}				
		7. Eskridge Shale: clay shale; brown to light green; blocky; semi-indurated; with common plant roots.	2	11	0.89
		6. Eskridge Shale: fine calcilutite, wackestone; green-gray; slabby; with common plant roots, scattered intraclasts, skeletal fragments, shark teeth; common dessication cracks.	0	4	0.10
	NT_9				
		5. Eskridge Shale: claystone; red; flaggy; crumbly; with abundant root traces, microslickensides.	3	0	0.91
		4. Eskridge Shale: clay shale; green-gray; flaggy; calcareous; with few <u>Aviculopecten</u>, <u>Nuculopsis</u>.	0	8	0.20
		3. Eskridge Shale: medium calcilutite, wackestone; green-gray; slabby; with common <u>Aviculopecten</u>, <u>Septimyalina</u>, scattered <u>Bellerophon</u>.	0	7	0.18
		2. Eskridge Shale: fine calcilutite, mudstone; medium gray; flaggy; argillaceous; with common shell fragments.	0	10	0.25
	NT_8				
		1. Eskridge Shale: clay shale; dark green; blocky; finely laminated.	0	8+	0.20

Locality #13

NW SW Sec. 26, T.11 S., R. 8 E., near Interstate 70, at exit 316 along Deep Creek Road, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		21. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, scattered crinoids, echinoids, shell fragments; two prominent nodular chert beds at 14 (0.36) and 18 inches (0.46 m) above base.	2	9	0.84
		20. Cottonwood limestone: fine calcarenite, wackestone; medium gray, weathers yellow-gray; massive; with abundant skeletal fragments, scattered productids; two prominent nodular chert beds at 26 (0.66 m) and 29 inches (0.74 m) above base.	2	11	0.89
		19. Cottonwood limestone: coarse calcilutite, wackestone; light gray, weathers tan; slabby; with common skeletal fragments, intraclasts.	0	8	0.20
CT_1					
		18. Eskridge Shale: clay shale; light green mottled light brown; crumbly; semi-indurated.	3	2	0.97
		17. Eskridge Shale: claystone; deep red; crumbly; indurated; with common caliche nodules.	1	3	0.38
		16. Eskridge Shale: fine calcilutite, wackestone; light green-gray; flaggy; with abundant nuculoid bivalves, scattered _Aviculopecten_.	2	0	0.61
	NT_{11}				
		15. Eskridge Shale: clay shale; light green; fissile to platy; non-fossiliferous.	0	6	0.15
		14. Eskridge Shale: fine calcilutite, mudstone to wackestone; light gray; slabby; with scattered productids.	0	9	0.23
	NT_{10}				
		13. Eskridge Shale: clay shale; light green mottled light brown; fissile to platy; semi-indurated.	3	2	0.97
		12. Eskridge Shale: fine calcilutite, mudstone; green-gray; platy to flaggy; with abundant root traces, few dessication cracks.	0	9	0.23
		11. Eskridge Shale: clay shale; pale red to light gray; platy; with common dessication cracks.	1	6	0.46
		10. Eskridge Shale: clay shale; dark green; blocky; non-fossiliferous.	0	10	0.25
		9. Eskridge Shale: clay shale; dark gray; flaggy; calcareous; with scattered _Aviculopecten_, few _Nuculopsis_; few _Lingula_ at top.	1	11	0.58
	NT_9				
		8. Eskridge Shale: clay shale; light green; platy to flaggy; with common plant fossils, few _Lingula_.	0	4	0.10
		7. Eskridge Shale: medium calcarenite, wackestone; light gray; flaggy to slabby; with abundant _Aviculopecten_, _Septimyalina_, scattered _Nuculopsis_, calcareous intraclasts.	0	5	0.13
	NT_8				
		6. Eskridge Shale: clay shale; green; crumbly; semi-indurated; with scattered orange brown root traces.	1	7	0.48
		5. Eskridge Shale: claystone; deep red; crumbly; indurated; with abundant caliche nodules.	5	6	1.68

UNIT DESCRIPTIONS	Unit Thicknesses		
Transgressive Surface ——	ft	in	m
4. Eskridge Shale: claystone; light green; crumbly; semi-indurated; with scattered caliche nodules.	0	9	0.23
3. Eskridge Shale: claystone; red to gray; crumbly; indurated; with abundant root traces.	1	3	0.38
2. Eskridge Shale: clay shale; light green; fissile to platy; non-fossiliferous.	0	9	0.23
1. Neva limestone: coarse calclutite, wackestone; light gray; massive; with common skeletal fragments.	1	0+	0.30+

Locality #14

Center north line Sec. 18, T. 11 S., R 8 E., along Kings Creek on the Konza Prairie, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		12. Eskridge Shale: clay shale; light green to gray; fissile; semi-indurated; non-fossiliferous.	4	6	1.37
		11. Eskridge Shale: clay shale; pale red; fissile; semi-indurated.	2	6	0.76
		10. Eskridge Shale: clay shale; light green to gray; fissile; semi-indurated.	1	0	0.30
		9. Eskridge Shale: medium calcilutite, wackestone; light gray; slabby; with abundant *Aviculopecten*, *Septimyalina*, scattered *Bellerophon*, few *Hustedia*.	0	7	0.18
	NT_8				
		8. Eskridge Shale: clay shale; light green; fissile; semi-indurated.	1	3	0.38
		7. Eskridge Shale: claystone; deep red; blocky; with common caliche nodules in top 21 inches (0.37 m), calcified subangular blocky peds.	3	3	0.99
		6. Eskridge Shale: clay shale; light green; fissile; non-fossiliferous.	0	7	0.18
		5. Eskridge Shale: fine calcilutite, mudstone; dark gray; flaggy; silty; with common plant roots.	0	7	0.18
	NT_7				
		4. Eskridge Shale: clay shale; light green; fissile; with scattered plant fossils.	1	1	0.33
		3. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; crystalline; with common shell fragments, scattered *Bellerophon*.	1	2	0.36
		2. Neva limestone: clay shale; light green; flaggy; calcareous; with common shell fragments, scattered echinoids.	1	6	0.46
	NT_6				
		1. Neva limestone: fine calcilutite, wackestone; dark gray; blocky; with scattered skeletal fragments.	0	6+	0.15+

5th order T-R units/boundaries	6th order T-R units/boundaries	Locality #15 Center south line Sec. 7, T. 10 S., R. 8 E., along North Manhattan Avenue, Manhattan, Riley County, Kansas.			
		UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		13. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yelow-gray; massive; with abundant fusulinids, scattered echinoids; two prominent nodular chert beds at 8 (0.20) and 11 inches (0.28 m) above base.	2	8	0.81
		12. Cottonwood limestone: medium calcarenite, wackestone; medium gray, weathers yellow-gray; with common shell fragments, scattered crinoids, echinoids; three prominent nodular chert beds at 18 (0.46), 25 (0.63), and 34 inches (0.86 m) above base.	3	1	0.94
		11. Cottonwood limestone: coarse calcilutite, wackestone; light gray, weathers tan; blocky; with common shell fragments.	0	9	0.23
CT_1					
		10. Eskridge Shale: clay shale; light green mottled brown; flaggy; semi-indurated.	1	10	0.56
		9. Eskridge Shale: fine calcilutite, mudstone; light gray; platy; argillaceous; common root traces at top.	0	10	0.25
	NT_{11}				
		8. Eskridge Shale: claystone; brown to light green; blocky; indurated; with common root traces.	1	1	0.33
		7. Eskridge Shale: medium calcilutite, wackestone; green-gray; platy to flaggy; with common Aviculopecten, nuculoid bivalves, plant roots; common dessication cracks.	3	7	1.09
	NT_{10}				
		6. Eskridge Shale: claystone; deep red; crumbly; indurated; with common root traces.	0	7	0.18
		5. Eskridge Shale: claystone; dark up to light green; crumbly; common calcified subangular blocky peds.	2	8	0.81
		4. Eskridge Shale: claystone; red; blocky; indurated; with abundant root traces; subangular blocky peds.	2	1	0.64
		3. Eskridge Shale: medium calcilutite, wackestone; green-gray; flaggy to blocky; with common plant fossils, root traces, scattered Aviculopecten, nuculoid bivalves.	0	10	0.25
		2. Eskridge Shale: fine calcilutite, mudstone; pale red to green-gray; flaggy; with common plant roots.	2	0	0.61
	NT_9				
		1. Eskridge Shale: clay shale; green; flaggy; with few plant fossils near top; few Aviculopecten, and plant fossils at base.	2	1	0.64

Locality #16

SE SW Sec. 18, T. 9 S., R. 9 E., at the Bayer Quarry, two miles southwest of Flush, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		27. Cottonwood limestone: fine calcirudite, packstone; light gray, weathers yellow-gray; massive; with abundant fusulinids, scattered echinoids, crinoids, productids; two prominent nodular chert beds at 19 (0.33) and 22 inches (0.56 m) above base.	2	0	0.61
		26. Cottonwood limestone: fine calcarenite, wackestone to packstone; medium gray, weathers yellow-gray; massive; with common shell fragments, crinoids, scattered echinoids, productids; prominent nodular chert bed at 24 inches (0.61 m) above base.	2	4	0.71
CT_1		25. Cottonwood limestone: coarse calcilutite, wackestone; light gray, weathers tan; slabby; with scattered shell fragments.	0	10	0.25
		24. Eskridge Shale: clay shale, mudstone; light green; platy to fissile; sparsely fossiliferous.	2	2	0.66
		23. Eskridge Shale: clay shale, mudstone; light green mottled red-brown; locally calcareous; with scattered shell fragments.	1	4	0.41
	NT_{11}	22. Eskridge Shale: medium calcilutite, wackestone; green-gray; flaggy; argillaceous; with abundant shell fragments, scattered nuculoid bivalves, red-brown plant roots.	1	6	0.46
		21. Eskridge Shale: clay shale, mudstone; light green-gray; fissile; sparsely fossiliferous.	0	7	0.18
	NT_{10}	20. Eskridge Shale: fine calcilutite, mudstone; green-gray; slabby; with scattered ostracods.	0	5	0.13
		19. Eskridge Shale: clay shale, mudstone; tan to brown; indurated.	0	9	0.23
		18. Eskridge Shale: covered interval.	2	6	0.76
		17. Eskridge Shale: clay shale, mudstone; light green; fissile to platy; semi-indurated; non-fossiliferous.	1	3	0.38
		16. Eskridge Shale: clay shale, mudstone; red; blocky; thinly bedded; fissile; indurated; non-fossiliferous.	1	8	0.51
		15. Eskridge Shale: clay shale, mudstone; light green; blocky; calcareous; thinly bedded; with few Aviculopecten.	0	5	0.13
	NT_9	14. Eskridge Shale: fine calcilutite, mudstone; light gray; platy; with common crinkly algal laminae.	0	2	0.05
		13. Eskridge Shale: clay shale, mudstone; light green; blocky; thinly bedded; sparsely fossiliferous.	0	6	0.15
	NT_8	12. Eskridge Shale: fine calcilutite, mudstone to wackestone; light green-gray; platy to flaggy; argillaceous; with scattered Aviculopecten.	1	2	0.36
		11. Eskridge Shale: clay shale, mudstone; light green; blocky; semi-indurated; with scattered orsnge-brown plant roots.	1	4	0.41

	UNIT DESCRIPTIONS	Unit Thicknesses		
	Transgressive Surface ——	ft	in	m
	10. Eskridge Shale: claystone, mudstone; red; blocky; indurated; with abundant clay films, root traces; slickensides, calcified subangular blocky peds.	6	8	2.03
	9. Eskridge Shale: clay shale, mudstone; light green; flaggy; semi-indurated; sparsely fossiliferous.	0	8	0.20
	8. Esridge Shale: fine calcilutite, mudstone; green-gray; slabby; argillaceous; with abundant plant roots, few nuculoid bivalves.	1	0	0.30
NT_7				
	7. Eskridge Shale: clay shale, mudstone; red; flaggy; semi-indurated.	0	5	0.13
	6. Eskridge Shale: clay shale, mudstone; light green; flaggy; sparsely fossiliferous.	0	9	0.23
	5. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; blocky to massive; with common shell fragments.	2	1	0.64
	4. Neva limestone: clay shale, mudstone; medium gray; flaggy; calcareous; with common shell fragments, scattered crinoids.	0	11	0.28
NT_6				
	3. Neva limestone: medium calcilutite, wackestone; light gray; blocky; with scattered microcrinoids, skeletal fragments.	0	9	0.23
	2. Neva limestone: clay shale, mudstone; olive green; flaggy; calcareous; with scattered skeletal fragments.	0	5	0.13
	1. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; slabby; with common shell fragments, few crinoids.	2	11	0.89

Locality #17

SE NE Sec. 10, T. 7 S., R. 10 E., at Hamm Construction quarry, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
CT_1		35. Cottonwood limestone: coarse calcilutite, wackestone; light gray, weathers tan; platy to slabby; with common shell fragments, intraclasts.	0	10	0.25
		34. Eskridge Shale: clay shale; light green; fissile to platy; non-fossiliferous.	1	7	0.48
		33. Eskridge Shale: claystone; brown to red; crumbly; indurated; with common subangular blocky peds, caliche nodules at top 5 inches (0.13 m).	1	8	0.51
	NT_{11}	32. Eskridge Shale: fine calcilutite, mudstone; light green-gray; platy to flaggy; argillaceous; root mottled; with few <u>Aviculopecten</u>.	0	8	0.20
		31. Eskridge Shale: claystone; light green; blocky; with nodular casts after gypsum.	0	3	0.08
		30. Eskridge Shale: fine calcilutite, mudstone; light gray; slabby; argillaceous; with scattered skeletal fragments.	0	5	0.13
		29 Eskridge Shale: fine calcilutite, mudstone; light gray; blocky; argillaceous; with scattered large vugs possibly after gypsum; scattered <u>Crurithyris</u> at base; scattered productids, <u>Derbyia</u>, 12 inches (0.30 m) from top.	2	2	0.66
	NT_{10}	28. Eskridge Shale: medium calclutite, wackestone; gray; platy to flaggy; argillaceous; root mottled; with scattered <u>Aviculopecten</u>, productids at top.	0	7	0.18
		27. Eskridge Shale: clay shale; light green; platy to flaggy; with scattered plant fossils.	2	3	0.69
		26. Eskridge Shale: clay shale; light gray; blocky; with scattered plant fossils.	2	10	0.86
		25. Eskridge Shale: clay shale; light green; blocky; with common ostracods, scattered <u>Lingula</u> fragments.	2	1	0.64
		24. Eskridge Shale: fine calcilutite, mudstone; gray, weathers tan; massive; crystalline; algal laminated; with scattered skeletal fragments.	0	5	0.13
		23. Eskridge Shale: clay shale; light green; platy; calcareous; with scattered skeletal fragments.	0	4	0.10
	NT_9	22. Eskridge Shale: medium calcilutite, wackestone; green-gray; slabby; with abundant <u>Aviculopecten</u>, common <u>Bellerophon</u>, <u>Septimyalina</u>, few shark teeth.	0	5	0.13
		21. Eskridge Shale: clay shale; light gray; fissile to papery; with scattered plant fossils.	0	5	0.13
		20. Eskridge Shale: fine calcilutite, mudstone; green-gray; flaggy to slabby; with scattered plant fossils.	0	6	0.15
		19. Eskridge Shale: clay shale; dark gray; flaggy; calcareous; with common plant roots.	0	5	0.13

	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	18. Eskridge Shale: medium calcilutite, mudstone to wackestone; light green-gray; flaggy; with scattered bivalve fragments.	0	6	0.15
NT_8				
	17. Eskridge Shale: claystone; red; crumbly; indurated; with common elongate, vertical, prismatic, calcified peds.	2	10	0.86
	16. Eskridge Shale: clay shale; light green; platy; sparsely fossiliferous.	0	3	0.08
	15. Eskridge Shale: fine calcilutite, mudstone; dark gray; flaggy; with abundant root traces.	1	1	0.33
NT_7				
	14. Eskridge Shale: clay shale; light green; platy; semi-indurated.	0	8	0.20
	13. Neva limestone: medium calcilutite, wackestone; medium gray, weathers tan; blocky; crystalline; top 2 inches (0.05 m) algal laminated; with common shell fragments, productids, ostracods; common birdseye structures throughout.	0	11	0.28
	12. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; with scattered shell fragments; common vertical to subvertical burrows up to 8 inches (0.20 m) in length.	1	4	0.41
	11. Neva limestone: coarse calcilutite, wackestone; dark gray; slabby; argillaceous; with common crinoids, <u>Composita</u>, echinoids, productids, few <u>Wellerella</u>.	1	0	0.30
NT_6				
	10. Neva limestone: medium calcilutite, wackestone; light gray; slabby to blocky; with scattered crinoids, shell fragments; few <u>Wilkingia</u> in life position at top.	2	6	0.76
	9. Neva limestone: medium calcilutite, mudstone; medium gray, weathers tan; blocky; with scattered skeletal fragments; few crinoids.	0	9	0.23
	8. Neva limestone: clay shale; green-gray; platy; calcareous; with abundant crinoids, productids, scattered <u>Composita</u>, echinoids, bryozoans (ramose), few horn coral.	0	8	0.20
NT_5				
	7. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; blocky; with common productids, crinoids.	1	2	0.36
	6. Neva limestone: clay shale; light green; platy; calcareous; with common fusulinids, shell fragments.	0	1	0.03
NT_4				
	5. Neva limestone: fine calcilutite, mudstone to wackestone; light gray; slabby to blocky; crystalline; well sorted; with common skeletal fragments.	1	7	0.48
	4. Neva limestone: medium calcilutite, wackestone; green-gray; slabby; with scattered fusulinids, crinoids.	0	5	0.13
NT_3				
	3. Neva limestone: clay shale; black; platy to flaggy; with abundant <u>Crurithyris</u>, <u>Orbiculoidea</u>, scattered <u>Hustedia</u>, few <u>Lingula</u>; top 3 inches (0.08 m) sparsely fossiliferous.	0	9	0.23
	2. Neva limestone: clay shale; brown; platy; with abundant <u>Crurithyris</u>.	0	2	0.05
	1. Neva limestone: fine calcarenite, wackestone to packstone; medium gray, weathers tan; blocky; with abundant skeletal fragments; base of unit lies below quarry floor.	0	6+	0.15+

Locality #18

NE 1/4 NW 1/4 Sec. 3, T.8 S., R. 9 E., along stream cut one mile southeast of Westmoreland, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		18. Neva limestone: fine calcilutite, wackestone; light gray; flaggy to blocky; with scattered crinoids, echinoids, shell fragments.	1	7	0.48
		17. Neva limestone: clay shale; light green; with scattered productids, fenestral bryozoans, echinoid spines.	0	4	0.10
		16. Neva limestone: fine calcilutite, wackestone; light gray; with few crinoids, shell fragments, poorly sorted.	3	3	0.99
		15. Neva limestone: clay shale; light green; platy; with common crinoids, fenestral and ramose bryozoans, Hustedia.	0	4	0.10
	NT_6				
		14. Neva limestone: fine calcilutite, wackestone; flaggy to slabby; with scattered productids, Composita near top.	0	10	0.25
		13. Neva limestone: calcilutite, wackestone; light green; blocky to massive; argillaceous; with many crinoids, fusulinids, scattered trilobites, Straporollus, echinoid spines and plates, productids, Crurithyris, Hustedia, Derbyia.	0	7	0.18
		12. Neva limestone: clay shale, mudstone; light green; with common fusulinids, ramose bryozoans, productids, shell fragments, scattered Hustedia, Crurithyris, Derbyia, echinoids.	0	4	0.10
		11. Neva limestone: medium calcilutite,wackestone; medium gray; heavily weathered; argillaceous; with many productids, scattered echinoid spines, few gastropods 12 inches (0.30 m) above base, few Derbyia.	5	10	1.78
	NT_5				
		10. Neva limestone: clay shale; light green; fissile.	0	1	0.03
		9. Neva limestone: coarse calcrudite, packstone to grainstone; light gray; limestone intraclasts, up to 20 mm; common sparry calcite, with scattered crinoids, skeletal fragments.	0	8	0.20
		8. Neva limestone: clay shale; light green; platy; with common crinoids throughout, many fusulinids near top 5 inches (0.13 m), scattered brachiopods, including Quadrochonetes, scattered echinoid spines.	0	10	0.25
	NT_4				
		7. Neva limestone: clay shale; black; flaggy to platy; scattered Orbiculoidea in basal 3 inches (0.08 m), common Lingula in upper 5 inches (0.13 m).	1	1	0.33
		6. Neva limestone: clay shale; light brown; fissile to platy; with abundant Crurithyris, few Orbiculoidea.	0	1	0.03
		5. Neva limestone: fine calcilutite, wackestone; greenish-gray; platy to flaggy; with common fusulinids, scattered small crinoids.	0	5	0.13
	NT_2				
		4. Neva limestone: clay shale; black; papery; mottled brown to light gray; scattered Lingula.	0	4	0.10
		3. Neva limestone: medium calcilutite, wackestone; sorted biomicrite, many shell fragments, microcrinoids.	1	5	0.43

		UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
NT1		2. Neva limestone: fine calcilutite, mudstone; greenish-gray; flaggy to platy; mudcracked.	0	7	0.18
		1. Salem Point shale: clay shale; light green; fissile to platy; with root mottling.	0	6+	0.15+

Locality #19

SW SE Sec. 13, T. 7 S., R 11 E., roadcut along county road three and half miles southeast of Onaga, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		36. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive, with abundant fusulinids, scattered echinoids; eroded and covered with soil.	1	0+	0.30
		35. Cottonwood limestone: fine calcarenite, wackestone; medium gray, weathers yellow-gray; massive; with many productids, crinoids, scattered horn corals, echinoids, bedded cherts.	2	3	0.69
CT_1		34. Cottonwood limestone: coarse calcilutite, wackestone; medium gray, weathers yellow-gray; flaggy; with many skeletal fragments, scattered <u>Composita</u>, large rounded intraclasts at base.	0	11	0.28
		33. Eskridge Shale: clay shale; light green, weathers gray-green; crumbly, semi-indurated.	1	0	0.30
		32. Eskridge Shale: clay shale; pale red crumbly; with root traces.	1	1	0.41
	NT_{11}	31. Eskridge Shale: fine calcilutite, mudstone; light gray, weathers green-gray; flaggy; argillaceous; with root traces.	1	4	0.41
		30. Eskridge Shale: claystone; pale red and light green; crumbly; indurated; with root traces, clay films.	6	0	1.83
	NT_{10}	29. Eskridge Shale: fine calcilutite, mudstone; medium gray, weathers light gray; platy; mudcracked.	0	2	0.05
		28. Eskridge Shale: clay shale; light green mottled black; platy; non-fossliferous.	1	5	0.43
	NT_9	27. Eskridge Shale: medium calcilutite, mudstone; medium gray, weathers light gray; slabby; with few nuculoids and skeletal fragments.	0	5	0.13
		26. Eskridge Shale: claystone; pale red and dark green; varigated; blocky; non-fossiliferous.	3	4	1.02
		25. Eskridge Shale: clay shale; light green; fissile to platy; with light brown-orange root traces.	1	2	0.36
		24. Eskridge Shale: clay shale; dark green; blocky; sandy; with common limestone and cherty intraclasts, angular, up to 10 mm in diameter.	3	11	1.19
		23. Eskridge Shale: fine calcarenite, wackestone to packstone; light gray, weathers yellow-orange; with common ostracods, microgastropods, and skeletal fragments.	0	1	0.03
	NT_8	22. Eskridge Shale: fine calcilutite, wackestone; medium gray, weathers light gray; slabby; with common <u>Aviculopecten</u>, <u>Septimyalina</u>, scattered <u>Bellerophon</u>, ostracods, microgastropods.	0	4	0.10
		21. Eskridge Shale: clay shale; green-gray; calcareous; platy; non-fossiliferous.	0	6	0.15
		20. Eskridge Shale: claystone; light green; crumbly; with root traces, clay films, microslickensides.	2	8	0.81

	UNIT DESCRIPTIONS	Unit Thicknesses ft	in	m
	Transgressive Surface ——			
	19. Eskridge Shale: claystone; pale red; crumbly; with clay films, root traces.	1	9	0.53
	18. Eskridge Shale: claystone; light green; blocky; with root traces.	0	5	0.13
	17. Eskridge Shale: claystone; pale red; crumbly; indurated; with clay films, root traces, slickensides, subangular blocky ped structure, peds are slightly calcified but no caliche nodules are present.	5	4	1.63
	16. Eskridge Shale: clay shale: light green; crumbly; top 18 inches (0.46 m) is very indurated, basal 12 inches (0.30 m) is semi-indurated.	2	6	0.76
	15. Neva limestone: medium calcilutite, wackestone; medium gray, weathers light gray; massive; with common skeletal fragments, productids; algal laminated at top.	1	1	0.33
	14. Neva limestone: medium calcilutite, wackestone; medium gray, weathers light gray; flaggy to slabby; with common skeletal fragments, crinoids, productids.	2	5	0.74
NT_6				
	13. Neva limestone: medium calcilutite; mudstone to wackestone; light gray; slabby; algal laminated.	0	5	0.13
	12. Neva limestone: medium calcilutite, wackestone; medium gray, weathers light gray; massive; with common echinoids, Hustedia, crinoids, productid spines and shell fragments; 8 inch (0.20 m) vuggy zone near middle.	2	6	0.76
NT_5				
	11. Neva limestone: fine calcilutite; mudstone; light grey; slabby; algal laminated.	0	3	0.08
	10. Neva limestone: fine calcilutite, mudstone to wackestone; medium gray, weathers light gray; slabby; with scattered productids, crinoids, echinoids.	2	8	0.81
NT_4				
	9. Neva limestone: clay shale; light green mottled black: fissile; with scattered plant fossils.	0	9	0.15
	8. Neva limestone: clay shale; black; platy; with scattered Lingula, Crurithyris, Orbiculoidea.	0	8	0.20
	7. Neva limestone: clay shale; brown; platy; with abundant Orbiculoidea, scattered Crurithyris, increasing near top, few Lingula at base.	1	4	0.41
	6. Neva limestone: fine calcarenite, wackestone; medium gray, weathers gray-green; flaggy; argillaceous; with abundant fusulinids, scattered crinoids, skeletal fragments.	0	4	0.10
NT_2				
	5. Neva limestone: clay shale; brown,; platy; with scattered Crurithyris.	0	5	0.05
	4. Neva limestone: coarse calcilutite, wackestone to packstone; light gray, weathers yellow-gray; slabby to blocky; with abundant shell fragments, scattered fusulinids, bryozoans (ramose and fenestrate).	0	10	0.28
NT_1				
	3. Salem Point shale: clay shale; brown; platy; non-fossiliferous.	0	11	0.28
	2. Salem Point shale: fine calcilutite; green-gray; slabby; silty; sparsely fossiliferous with few ostracods.	0	6	0.15
BT_6				
	1. Salem Point shale: claystone; red to green; crumbly; with scattered caliche nodules.	2	0	0.61

Locality #20

NW NE Sec. 1, T. 6 S., R. 12 E., roadcut along county road in extreme northwestern Jackson County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	ft	in	m
		27. Cottonwood limestone: fine calcarenite wackestone; medium gray, weathers yellow-gray; flaggy; with scattered Composita, horn coral, and skeletal fragments.	0	10	0.25
CT_1					
		26. Eskridge Shale: clay shale; light green; fissile; non-fossiliferous.	2	4	0.71
		25. Eskridge Shale: fine calcilutite; mudstone; green-gray; argillaceous; with root traces.	1	0	0.30
	NT_{11}				
		24. Eskridge Shale: clay shale; pale red to green; semi-indurated; fissile to platy.	3	9	0.84
		23. Eskridge Shale: fine calcilutite, mudstone; dark gray; platy to flaggy; mudcracked; with few root traces.	1	2	0.36
	NT_{10}				
		22. Eskridge Shale: clay shale; red and green; fissile to platy; semi-indurated.	8	4	2.54
		21. Eskridge Shale: fine calcarenite, packstone; moderately well sorted; with many fossil fragments; algal laminated, scattered microgastropods and Bellerophon.	0	5	0.13
	NT_9				
		20. Eskridge Shale: clay shale; brown-green; flaggy; with scattered plant fossils.	0	2	0.05
		19. Eskridge Shale: fine calcilutite, wackestone; greenish-gray; flaggy; with abundant Aviculopecten, Septimyalina, ostracods.	0	4	0.10
	NT_8				
		18. Eskridge Shale: clay shale; light green; flaggy to blocky; semi-indurated.	4	8	1.42
		17. Eskridge Shale: clay shale; light green; fissile to platy; semi-indurated.	4	5	1.35
		16. Eskridge Shale: claystone; deep red; crumbly; indurated; with common clay films, root traces, caliche nodules.	1	6	0.46
		15. Eskridge Shale: fine calcilutite, mudstone; pale red;platy; rooted.	0	2	0.05
	NT_7				
		14. Eskridge Shale: clay shale;red to green; platy; semi-indurated; mudcracked.	3	2	0.96
		13. Neva limestone: fine calcilutite, wackestone; gray; with many productid fragments; algal laminated at top.	1	11	0.58
		12. Neva limestone: medium calcilutite, wackestone; green-gray; flaggy; with scattered productid fragments, crinoids.	1	6	0.46
	NT_6				
		11. Neva limestone: fine calcilutite, wackestone; light gray; with scattered productids and crinoids, many fossil fragments; top 2 inches (0.05 m) algal laminated.	2	11	0.89
		10. Neva limestone: medium calcilutite, wackestone; gray; flaggy; with scattered fusulinids, skeletal fragments.	0	10	0.25
	NT_5				

		UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		9. Neva limestone: clay shale; brown-green; papery; with scattered plant fossils.	0	2	0.05
		8. Neva limestone: clay shale; brown; platy; with common Composita, Wellerella, scattered Lingula, Crurithyris, Aviculopecten, large crinoid columnals, small Chonetes.	1	0	0.30
	NT_4				
		7. Neva limestone: clay shale; black; platy; with common Orbiculoidea, scattered Crurithyris and Lingula.	1	0	0.30
		6. Neva limestone: medium calcilutite, wackestone; greenish-gray; flaggy; with common shell fragments, productid spines, crinoids; scattered Crurithyris.	0	3	0.08
	NT_3				
		5. Neva limestone: clay shale; black mottled brown; fissile; with abundant Crurithyris, Orbiculoidea.	1	11	0.58
		4. Neva limestone: coarse calcilutite, wackestone to packstone; green-gray; flaggy; with common fusulinids, scattered whole productids, Crurithyris and Lingula near top.	0	5	0.13
	NT_2				
		3. Neva limestone: clay shale; black; papery; with common Orbiculoidea.	0	1	0.03
		2. Neva limestone: medium calcilutite, wackestone to packstone; light gray; flaggy; with abundant skeletal fragments, common coated grains, ostracods, productids, microcrinoids, fusulinids near middle, scattered Crurithyris at top.	1	6	0.46
NT_1					
		1. Salem Point shale: claystone; dark green to brown; crumbly; indurated.	0	11	0.28

Locality #21

Center Sec. 22, T.8 S., R. 11E., Along county road, eight and a half miles north of Belvue, Pottawatamie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		20. Eskridge Shale: claystone; red; crumbly; with abundant root traces, clay films, slickensides, caliche nodules are common in top 24 inches (0.61 m).	4	2+	1.27+
		19. Eskridge Shale: clay shale; light green: blocky.	0	6	0.15
	NT_7	18. Eskridge Shale: fine calcilutite, mudstone; light green; rooted.	0	2	0.05
		17. Eskridge Shale: clay shale; light green; blocky; with common plant roots.	1	10	0.56
		16. Neva limestone: fine calcilutite, wackestone; light gray; massive; upper 4 inches (0.10 m) algal laminated, stromatolites at top, many fossil fragments, upper 6 inches (0.15 m) moderately vuggy.	0	10	0.25
	NT_6	15. Neva limestone: fine calcilutite, wackestone; light gray; flaggy; moderately well sorted, scattered whole Wellerella, Composita, echinoid spines, crinoids, top 8 inches (0.20 m) more argillaceous.	1	9	0.53
		14. Neva limestone: fine calcilutite, wackestone; light gray; slabby to blocky; with scattered crinoids, echinoids, productids, Composita, ramose bryozoa, upper 10 inches (0.25 m) algal laminated, many fossil fragments, moderately well sorted.	2	10	0.86
		13. Neva limestone: clay shale; lt. green; fissile; with scattered fusilinids (Pseudoschwagerina), Crurithyrus, large crinoid columnals, Hustedia.	0	8	0.20
	NT_5	12. Neva limestone: fine calclutite, wackestone; green-gray; flaggy; with many fusulinids, scattered Fenestrellina.	0	3	0.08
		11. Neva limestone: clay shale; olive green; flaggy; with scattered crinoids, echinoids, Crurithyrus, Permophorus.	0	10	0.25
	NT_4	10. Neva limestone: medium calcilutite, wackestone; green-gray; flaggy; with scattered skeletal fragments.	0	3	0.08
		9. Neva limestone: calcareous shale; gray; fissile to platy; with horizontal burrows.	0	4	0.10
	NT_3	8. Neva limestone: fine calcilutite, wackestone; green-gray mottled black; with scattered fragments, Orbiculoidea.	0	4	0.10
		7. Neva limestone: clay shale; brown; platy; with abundant plant fossils, Crurithyris, Lingula, Orbiculoidea.	0	8	0.20
		6. Neva limestone: clay shale; brown, mottled black; flaggy; with abundant Orbiculoidea and Crurithyris, scattered Lingula, few Wellerella, Crurithyris more abundant in top half, Orbiculoidea in bottom half, Lingula throughout.	2	10	0.86
	NT_2	5. Neva limestone: fine calcarenite, packstone; green-gray; flaggy; with common fusulinids, microcrinoids, shell fragments, shark teeth, and Crurithyris.	0	4	0.10

	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	4. Neva limestone: clay shale; brown; papery; with abundant <u>Orbiculoidea</u> fragments.	0	2	0.05
	3. Neva limestone: coarse calcilutite, packstone; medium gray, weathers yellow-gray; moderately well sorted; with common small crinoids, <u>Composita</u>, productids, and echinoids, coated grains.	1	4	0.41
NT_1				
	2. Salem Point shale: clay shale; green; blocky; indurated; with root mottles.	0	5	0.13
	1. Salem Point shale: clay shale; light brown; platy to flaggy; non-fossiliferous.	1	0	0.30

Locality #22

NE NE Sec. 17, T. 13 S., R. 11 E., one half mile north of Hessdale, Wabaunsee County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		8. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, few echinoids.	0	10+	0.25+
		7. Cottonwood limestone: fine calcarenite, wackestone to packstone; medium gray, weathers yellow-gray; blocky; with abundant skeletal fragments, scattered crinoids, echinoids, bryozoans (ramose), <u>Juresenia</u>, few <u>Composita</u>; two prominent nodular chert beds at 18 (0.46) and 24 inches (0.61 m) above base.	2	8	0.81
		6. Cottonwood limestone: medium calcilutite, wackestone; light gray, weathers tan; slabby; with scattered skeletal fragments,	0	9	0.23
CT_1					
		5. Eskridge Shale: clay shale, mudstone; light green; blocky; semi-indurated; non-fossiliferous.	2	10	0.86
		4. Eskridge Shale: medium calcilutite, mudstone; light green-gray, weathers tan; platy to flaggy; argillaceous; with abundant plant roots in upper 7 inches (0.18 m).	0	11	0.28
	NT_{11}				
		3. Eskridge Shale: claystone, mudstone; pale red to green; blocky; crumbly; with microslickensides.	2	2	0.66
		2. Eskridge Shale: covered interval.	5	0	1.52
		1. Eskridge Shale: fine calcilutite, wackestone; green-gray; flaggy to slabby; with scattered skeletal fragments, <u>Aviculopecten</u>, productids, <u>Derbyia</u>.	1	5	0.43
	NT_{10}				

Locality #23

NE SW Sec. 12, T. 12 S., R. 10 E., along roadcut 2 miles east of Alma, Wabaunsee County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	ft	in	m
		41. Cottonwood limestone: fine calcirudite, packstone; light gray, weathers yellow-gray; massive; with abundant fusulinids, scattered echinoid spines, bedded chert nodules.	2	8	0.81
		40. Cottonwood limestone: medium calcarenite, wackestone to packstone; light gray, weathers yellow-gray; with common crinoids, echinoids, productids, scattered <u>Hustedia</u>, <u>Composita</u>, few horn corals, bedded chert nodules.	3	0	0.91
		39. Cottonwood limestone: medium calcilutite, wackestone; light gray, weathers tan; with scattered <u>Composita</u>, horn coral, and skeletal fragments.	1	0	0.30
CT_1					
		38. Eskridge Shale: clay shale; light green; fissile to platy; slightly calcareous; non-fossiliferous.	2	9	0.84
		37. Eskridge Shale: claystone: brown-red; crumbly; indurated.	1	3	0.38
		36. Eskridge Shale: fine calcilutite, mudstone; light gray, weathers tan; slabby; with abundant plant roots, few productid spines.	0	7	0.18
	NT_{11}				
		35. Eskridge Shale: clay shale; light green; platy, non-fossiliferous.	1	2	0.36
		34. Eskridge Shale: medium calcilutite, wackestone; light gray, weathers gray; blocky; with scattered <u>Aviculopecten</u>, productids, skeletal fragments.	1	1	0.33
		33. Eskridge Shale: fine calcilutite, mudstone; light gray, weathers gray; flaggy; with few skeletal fragments.	0	8	0.20
	NT_{10}				
		32. Eskridge Shale: clay shale; light green; flaggy; non-fossiliferous.	1	4	0.41
		31. Eskridge Shale: claystone; light green; blocky; indurated.	0	11	0.28
		30. Eskridge Shale: claystone; red; crumbly; indurated; with microslickensides, clay films.	3	0	0.91
		29. Eskridge Shale: clay shale; dark green mottled black; platy.	2	8	0.81
		28. Eskridge Shale: clay shale; black; papery; with scattered plant fossils.	0	1	0.03
		27. Eskridge Shale: medium calcilutite, mudstone to wackestone; light gray; massive; algal laminated; with scattered ostracods, microgastropods.	0	9	0.23
	NT_9				
		26. Eskridge Shale: clay shale; olive green; flaggy; with scattered ostracods, plant fossils at top.	0	11	0.28
		25. Eskridge Shale: medium calcilutite, wackestone; gray; slabby; with abundant ostracods.	0	1	0.03
	NT_8				
		24. Eskridge Shale: clay shale; dark green; blocky; semi-indurated.	0	8	0.20
		23. Eskridge Shale: claystone; brown; blocky; indurated.	0	10	0.25

	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	22. Eskridge Shale: claystone; green to red to brown; varigated; crumbly; indurated; with microslickensides, clay films.	5	6	1.68
	21. Eskridge Shale: claystone; red; crumbly; indurated; with common microslickensides, clay films; 10 inch (0.25 m) zone calcified blocky peds near top; scattered nodular caliche zone at basal 14 inches (0.36 m).	3	4	1.02
	20. Eskridge Shale: clay shale; light green; calcareous; non-fossiliferous.	0	8	0.20
	19. Eskridge Shale: fine calcilutite, mudstone; green-gray; flaggy; argillaceous; with common root mottling.	0	4	0.10
NT_7				
	18. Eskridge Shale: clay shale; light green; flaggy; semi-indurated.	1	5	0.43
	17. Neva limestone: coarse calcilutite, wackestone; light gray, weathers gray; massive; with common skeletal fragments; top 10 inches (0.25 m) algal laminated.	2	5	0.74
	16. Neva limestone: clay shale; gray-green, weathers light green; platy to flaggy; with abundant large echinoid spines, scattered Composita, Juresenia.	1	3	0.38
NT_6				
	15. Neva limestone: fine calcilutite, mudstone to wackestone; light gray, weathers yellow-gray; flaggy to slabby; algal laminated; with skeletal fragments.	1	11	0.58
	14. Neva limestone: medium calcilutite, wackestone; medium gray, weathers tan; slabby to blocky; with abundant shell fragments; 8 inch (0.20 m) vuggy zone near middle.	3	6	1.07
NT_5				
	13. Neva limestone: clay shale; brown; fissile; with scattered Orbiculoidea, Crurithyris.	1	2	0.36
	12. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; flaggy; with common skeletal fragments, microcrinoids, echinoids, coated grains, scattered Fenestrellina, Hustedia, fusulinids.	0	5	0.13
	11. Neva limestone: medium calcilutite, mudstone to wackestone; light gray, weathers orange; soft; punky; highly weathered; with scattered crinoids, echinoids; fusulinids at base.	0	8	0.20
	10. Neva limestone: clay shale; light green; papery; with common fusulinids, echinoids, Composita, productids, crinoids, scattered bryozoans (ramose and encrusting), Hustedia, horn corals.	0	3	0.08
NT_4				
	9. Neva limestone: fine calcilutite, mudstone; light gray; slabby; with common algal fronds, scattered bivalve fragments, few crinoids.	0	5	0.13
	8. Neva limestone: medium calcilutite, mudstone to wackestone; light gray; platy to flaggy; with scattered bryozoans, productids, crinoids, few Composita, fusulinids, Hustedia, Ditomopyge.	0	8	0.20
	7. Neva limestone: clay shale; olive green; fissile; with scattered fusulinids, crinoids, productids, echinoids, few bryozoans.	0	2	0.05
NT_3				
	6. Neva limestone: clay shale; olive green mottled dark green; flaggy; non-fossiliferous.	0	5	0.13
	5. Neva limestone: medium calcilutite, mudstone to wackestone; green-gray; with common fusulinids, crinoids, echinoids, scattered Composita, Ditomopyge.	0	4	0.10

		UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		4. Neva limestone: clay shale; green-gray; fissile; with scattered crinoid columnals, productids, echnoids, bryozoans, few horn coral, Ditomopyge, Lissochonetes, Composita, Crurithyris.	0	5	0.13
	NT_2				
		3. Neva limestone: clay shale; brown; papery; with common Orbiculoidea fragments, plant fossils, few Crurithyris, shark teeth.	0	3	0.08
		2. Neva limestone: coarse calcilutite, wackestone to packstone; light gray, weathers yellow-gray; massive; with scattered microgastropods, echinoids, productid spines, coated grains; common Orbiculoidea, Crurithyris, few Wellerella found in top 3 inches (0.08 m).	1	4	0.41
NT_1					
		1. Salem Point shale: claystone; dark green to brown; crumbly; indurated.	0	11	0.28

Locality #24

NW SE Sec. 30 T. 12 S., R. 12 E., roadcut along county road 4 miles west of Keene, Wabaunsee County, Kansas

Transgressive Surface ——

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS	Unit Thicknesses ft	in	m
		12. Neva limestone: medium calcilutite, wackestone; light gray, weathers yellow-gray; slabby to blocky; with common crinoids, productids, echinoids; algal laminated at basal 14 inches (0.36 m); 6 inch (0.15 m) vuggy zone immediately above algal laminated zone.	2	10	0.86
	NT_5				
		11. Neva limestone: clay shale; green-brown; fissile; with abundant plant fossils, common <u>Orbiculoidea</u> fragments at base.	0	10	0.25
		10. Neva limestone: medium calcilutite, wackestone; light gray, weathers yellow-gray; with common algal fronds; common <u>Crurithyris</u>, echinoids, and crinoids in top half; common fusulinids in basal half.	0	9	0.23
		9. Neva limestone: clay shale; green-gray, weathers light green; fissile; calcareous; with abundant fusulinids.	0	4	0.10
	NT_4				
		8. Neva limestone: clay shale; green-brown; flaggy; with few skeletal fragments.	0	11	0.28
		7. Neva limestone: clay shale; olive green; flaggy; calcareous; with common crinoids, scattered productids,bryozoans, <u>Derbyia</u>, <u>Hustedia</u>, <u>Composita</u>.	0	10	0.25
	NT_3				
		6. Neva limestone: clay shale; brown; flaggy; laminated; with few <u>Crurithyris</u>.	1	4	0.41
		5. Neva limestone: clay shale; brown; fissile; with common <u>Orbiculoidea</u> fragments.	0	3	0.08
		4. Neva limestone: fine calcarenite, wackestone; green-gray; flaggy; argillaceous; with common fusulinids, scattered crinoids.	0	3	0.08
	NT_2				
		3. Neva limestone: clay shale; yellow-brown; fissile; with scattered <u>Crurithyris</u>, <u>Orbiculoidea</u> fragments, few <u>Neochonetes</u>.	0	1	0.03
		2. Neva limestone: fine calcarenite, wackestone; medium gray, weathers light gray; slabby to blocky; moderaely well sorted; with common productids, crinoids, echinoids, gastropods, bryozoans, coated grains, ostracods.	1	9	0.53
NT_1					
		1. Salem Point shale: claystone; dark green; blocky; indurated.	0	5	0.13

Locality #25

SW SW Sec. 16, T 9 S., R. 12 E., at Hamm Construction Quarry five miles southwest of Emmett, Pottawatomie County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		17. Eskridge Shale: clay shale; light green; fissile; non-fossiliferous.	1	6+	0.46+
		16. Eskridge Shale: clay shale; pale red; fissile; with common plant roots.	0	8	0.20
		15. Eskridge Shale: clay shale; light green; crumbly; with common plant roots.	0	6	0.15
		14. Eskridge Shale: fine calcilutite, mudstone; dark gray to red; flaggy; argillaceous; with abundant root traces.	1	3	0.38
	NT_9				
		13. Eskridge Shale: claystone; deep red; crumbly; indurated; with common plant fossils, microslickensides.	2	3	0.69
		12. Eskridge Shale: clayshale; green-gray; crumbly; indurated; with common plant roots.	0	6	0.15
		11. Eskridge Shale: fine calcilutite, mudstone; pale red to gray; slabby; argillaceous; with abundant root traces.	0	11	0.28
	NT_8				
		10. Eskridge Shale: clay shale; deep red; crumbly; semi-indurated.	1	2	0.36
		9. Eskridge Shale: fine calcilutite, mudstone; light green-gray; flaggy; with common plant roots.	1	1	0.33
	NT_7				
		8. Eskridge Shale: clay shale; light green; flaggy; calcareous; sparsely fossiliferous.	1	0	0.30
		7. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; blocky; crystalline; with common skeletal fragments; common birdseye structures.	0	11	0.28
		6. Neva limestone: medium calcilutite, wackestone; gray; massive; thick bedded; argillaceous; with common skeletal fragments, echinoids.	1	4	0.41
		5. Neva limestone: clay shale; gray mottled light green; flaggy; calcareous; with scattered echinoids, skeletal fragments, few _Neochonetes_.	1	3	0.38
	NT_6				
		4. Neva limestone: medium calcilutite, wackestone; light gray; massive; algal laminated; with common skeletal fragments.	1	2	0.36
		3. Neva limestone: clay shale; olive green; platy; calcareous; with scattered echinoids, crinoids, shell fragments.	0	4	0.10
		2. Neva limestone: medium calcilutite, wackestone; light gray; slabby to blocky; thick bedded; with common shell fragments, scattered echinoids, crinoids.	4	5	1.35
	NT_5				
		1. Neva limestone: clay shale; dark gray to black; flaggy; calcareous; with scattered plant roots at top; few _Orbiculoidea_ near base.	1	0+	0.30+

Locality #26

SW SW Sec. 14, T. 13 S., R. 10 E., along Hi-way 99 four miles west of Hessdale, Wabaunsee County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	ft	in	m
		12. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, scattered echinoids, bryozoans (fenestrate); eroded and covered with soil.	0	10+	0.25+
		11. Cottonwood limestone: fine calcarenite, wackestone to packstone; medium gray, weathers tan; slabby to blocky; with common crinoids, echinoids, shell fragments, scattered *Composita*; two layers of chert nodules in upper 14 inches (0.36 m).	2	5	0.74
		10. Cottonwood limestone: medium calcilutite, wackestone; light gray, weathers tan; flaggy to slabby; with common skeletal fragments.	0	5	0.13
CT_1					
		9. Eskridge Shale: clay shale; light brown-green; platy to flaggy; finely laminated.	1	0	0.30
		8. Eskridge Shale: fine calcilutite, mudstone to wackestone; gray; slabby; with common skeletal fragments.	0	3	0.08
		7. Eskridge Shale: medium calcilutite, wackestone; green-gray; flaggy; argillaceous; with common skeletal fragments, intraclasts.	1	6	0.46
	NT_{11}				
		6. Eskridge Shale: clay shale; green, weathers tan; flaggy; calcareous; non-fossiliferous.	0	10	0.25
		5. Eskridge Shale: fine calcilutite, mudstone; gray, weathers tan; flaggy; with scattered skeletal fragments.	0	6	0.15
		4. Eskridge Shale: medium calcilutite, wackestone; gray, weathers tan; blocky; with common skeletal fragments, scattered microcrinoids, ostracods.	0	9	0.23
	NT_{10}				
		3. Eskridge Shale: clay shale; green-gray; flaggy; non-fossiliferous.	0	7	0.18
		2. Eskridge Shale: clay shale; green; blocky; with common small, rounded intraclasts.	2	0	0.61
		1. Eskridge Shale: fine calcilutite, mudstone; gray; nodular; with few plant roots.	0	2	0.05

Locality #27

SE NE Sec.35 T.14 S., R.11E., 5 miles southwest of Eskridge, Wabaunsee County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	Unit Thicknesses ft	in	m
		10. Neva limestone: coarse calcilutite, wackestone to packstone; medium gray, weathers tan; blocky; with scattered productids, Composita, echinoids, crinoids, bryozoans.	3	1	0.94
	NT_4	9. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; flaggy; top 4 inches (0.10 m) argillaceous; with scattered fusulinids, echinoids, crinoids in basal 4 inches (0.10 m).	0	8	0.20
		8. Neva limestone: clay shale; black; platy; with abundant Lingula, scattered Crurithyris, Wellerella.	1	0	0.30
		7. Neva limestone: medium calcilutite, wackestone; light gray, weathers tan; blocky; vuggy; with common skeletal fragments, Composita, scattered Ditomopyge; common fusulinids at base.	0	10	0.25
	NT_3	6. Neva limestone: clay shale; dark gray; platy to flaggy; with scattered fusulinids.	0	7	0.18
		5. Neva limestone: clay shale; gray; flaggy; with scattered crinoids.	0	6	0.15
	NT_2	4. Neva limestone: fine calcilutite, mudstone; medium gray; slabby; with few echinoids, Derbyia.	0	5	0.13
		3. Neva limestone: clay shale; black; platy; with scattered plant fossils, horizontal burrows.	0	10	0.25
		2. Neva limestone: clay shale; brown; papery; with common Lingula, Crurithyris, Orbiculoidea.	0	3	0.08
NT_1		1. Neva limestone: fine calcarenite, wackestone to packstone; medium gray, weathers tan; massive; with abundant shell fragments.	1	6	0.46

Locality #28 (Core)

NE NE NE Sec. 32, T. 7 S., R. 6 E., Amoco Oil Company #1 Hargrove core, Riley County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS (Transgressive Surface ——)	ft	in	m
		36. Cottonwood limestone: fine calcirudite; packstone; medium gray; massive; with abundant Psuedoschwagerina.	3	4	1.02
		35. Cottonwood limestone: medium calcarenite; wackestone to packstone; light gray; massive; with common crinoids, productids, echinoids, Composita; scattered Osagia coated grains, horn corals; few Psuedoschwagerina in top 8 inches (0.20 m).	2	8	0.81
		34. Cottonwood limestone: fine calcarenite; wackestone; medium gray; massive; with scattered productids, Composita.	1	2	0.36
CT_1					
		33. Eskridge Shale: clay shale; light green; fissile; non-fossiliferous.	0	10	0.25
		32. Eskridge Shale: clay shale; light green; platy; non-fossiliferous.	1	7	0.48
		31. Eskridge Shale: fine calcilutite; mudstone; light gray mottled light green; flaggy; with abundant root traces.	1	8	0.51
	NT_{11}				
		30. Eskridge Shale: clay shale; light gray-green; platy; fine clay laminations; non-fossiliferous.	5	11	1.80
		29. Eskridge Shale: fine calcilutite; mudstone; light gray; slabby; with common root traces; common small (to 1 mm) spar filled vugs.	0	8	0.20
		28. Eskridge Shale: clay shale; brown-red; fissile to platy; thin bedded; with few Lingula.	3	6	1.07
	NT_{10}				
		27. Eskridge Shale: clay shale; dark green-gray; flaggy; finely laminated; non-fossiliferous.	2	3	0.69
		26. Eskridge Shale: fine calcilutite; mudstone; green-gray; slabby; with scattered shell fragments.	1	1	0.33
	NT_9				
		25. Eskridge Shale: clay shale; green mottled brown; flaggy; non-fossiliferous.	1	6	0.46
		24. Eskridge Shale: fine calcilutite; mudstone; light gray; slabby; with abundant plant roots; brown clay shale from above fills rooted zone near top.	2	7	0.79
	NT_8				
		23. Eskridge Shale: claystone; black at base upward to brown-red; with abundant root traces; common caliche nodules; selenite and gypsum filled fractures in upper 16 inches (0.41 m).	6	1	1.85
		22. Eskridge Shale: clay shale; olive green; fissile to platy; non-fossiliferous.	1	5	0.43
		21. Eskridge Shale: clay shale; black; carbonaceous; silty.	0	2	0.05
		20. Eskridge Shale: fine calcilutite; mudstone; light gray to light green; mudcracked; with few root traces.	0	7	0.18
	NT_7				
		19. Eskridge Shale: clay shale; light green; platy; non-fossiliferous.	1	5	0.43

	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	18. Neva limestone: fine calcilutite; wackestone; light gray; algal laminated; with scattered shell fragments.	0	7	0.18
	17. Neva limestone: clay shale; dark gray; flaggy; with common crinoids, echinoids, Juresania.	1	9	0.53
NT_6				
	16. Neva limestone: fine calcarenite; wackestone to packstone; brown-gray; massive; with common skeletal fragments; scattered crinoids, echinoids; few Osagia coated grains in top 10 inches (0.25 m).	3	0	0.91
	15. Neva limestone: clay shale; medium gray; platy; with scattered crinoids, productids; few fusulinids.	0	5	0.13
	14. Neva limestone: fine calcilutite; mudstone; light gray; massive; algal laminated; few productids; 1 inch (0.03 m) gypsum beds found at 9 (0.23) and 26 inches (0.66 m) from base; basal 2 inches (0.05 m) contains sulfide deposits.	2	8	0.81
	13. Neva limestone: medium calcilutite; wackestone; medium gray; with common brachiopod shell fragments; scattered fusulinids.	0	8	0.20
NT_5				
	12. Neva limestone: clay shale; dark gray; platy; with scattered Crurithyris in basal 2 inches (0.05 m); upper 4 inches (0.10 m) non-fossiliferous.	0	6	0.15
	11. Neva limestone: medium calcilutite; wackestone; medium gray; blocky; with common fusulinids in top 5 inches (0.13 m); scattered crinoid and brachiopod fragments.	2	1	0.64
	10. Neva limestone: clay shale; black; platy; carbonaceous; with common Orbiculoidea; scattered Crurithyris.	0	3	0.08
NT_4				
	9. Neva limestone: gypsum; colorless to white; massive.	0	2	0.05
	8. Neva limestone: clay shale; dark gray to black; fissile; with abundant Orbiculoidea at basal 2 inches (0.05 m); scattered Orbiculoidea, Crurithyris, and Lingula throughout.	1	8	0.51
	7. Neva limestone: fine calcarenite; wackestone; medium gray; slabby; with abundant fusulinids; scattered Hustedia.	0	4	0.18
NT_2				
	6. Neva limestone: clay shale; black; fissile; carbonaceous; with scattered Crurithyris.	0	1	0.03
	5. Neva limestone: fine calcarenite; wackestone; medium dark gray; massive; with common fusulinids in top 2 inches (0.05 m); scattered bryozoans, brachiopods, Osagia coated coated grains.	1	8	0.51
NT_1				
	4. Salem Point shale: claystone; dark green; blocky; non-fossiliferous.	0	7	0.18
	3. Salem Point shale: medium calcirudite; wackestone; light gray; with common angular intraclasts.	0	3	0.08
	2. Salem Point shale: fine calcilutite; mudstone; light gray; flaggy; fine grained; laminated; non-fossiliferous.	0	5	0.13
	1. Salem Point shale: clay shale; dark green-gray; fissile; non-fossiliferous.	1	3	0.38

Locality #29

NW SE Sec. 33, T.17 S., R.9 E., outcrop at Lake Kahola Spillway, Morris County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		28. Cottonwood limestone: fine calcirudite, packstone; medium gray, weathers yellow-gray; massive; with abundant fusulinids, scattered echinoids.	1	10	0.56
CT1		27. Cottonwood limestone: medium calcarenite, wackestone; medium gray, weathers yellow-gray; massive; with common crinoids, echinoids, productids, scattered Composita.	2	2	0.66
		26. Eskridge Shale: clay shale; light green to gray; fissile to platy; non-fossiliferous.	3	10	1.17
		25. Eskridge Shale: clay shale; light gray, weathers tan; platy; calcareous; non-fossiliferous.	3	6	1.07
		24. Eskridge Shale: clay shale; light gray, weathers tan; platy to flaggy; non-fossiliferous.	3	0	0.91
		23. Eskridge Shale: fine calcilutite, mudstone; light gray; blocky to massive; abundant dessication features; with common plant roots at top.	1	9	0.53
	NT11	22. Eskridge Shale: fine calcilutite, mudstone; light gray; slabby; thinly bedded; algal laminated.	0	10	0.25
		21. Eskridge Shale: clay shale; green-gray; flaggy; calcareous; with scattered plant roots at top.	2	1	0.64
		20. Eskridge Shale: clay shale; red; flaggy; calcareous; non-fossiliferous.	1	2	0.36
		19. Eskridge Shale: clay shale; light green to gray; flaggy; calcareous; non-fossiliferous.	2	7	0.79
		18. Eskridge Shale: medium calcilutite, wackestone; light gray, weathers tan; slabby; with common productids, scattered Hustedia, Aviculopecten.	0	6	0.15
	NT10	17. Eskridge Shale: fine calcilutite, mudstone; light gray, weathers tan; blocky; with common algal fronds, few productid fragments.	0	9	0.23
		16. Eskridge Shale: claystone; medium gray; blocky; indurated; with common clay films on angular blocky peds; scattered small caliche nodules.	3	6	1.07
		15. Eskridge Shale: clay shale; dark gray to black; platy; with abundant plant fossils including Calamites; scattered pyrite nodules occur along bedding planes.	0	11	0.28
		14. Eskridge Shale: clay shale; light green; platy; with scattered plant fossils.	0	3	0.08
	NT9	13. Eskridge Shale: coarse calcarenite, wackestone; light gray; slabby; algal laminated; with abundant productids, scattered Bellerophon; with abundant limestone intraclasts in top 5 inches (0.13 m).	0	10	0.25
		12. Eskridge Shale: clay shale; light green; fissile to papery; non-fossiliferous.	0	2	0.05

	UNIT DESCRIPTIONS	Unit Thicknesses ft	in	m
	Transgressive Surface ——			
	11. Eskridge Shale: coarse calcilutite, mudstone to wackestone; green-gray; slabby; with common Septimyalina, scattered Aviculopecten, few Bellerophon.	0	5	0.13
NT_8				
	10. Eskridge Shale: clay shale; light green; flaggy; non-fossiliferous.	1	3	0.38
	9. Eskridge Shale: fine calcilutite, mudstone; light gray; flaggy; scattered skeletal fragments.	0	5	0.13
NT_7				
	8. Eskridge Shale: clay shale; green; blocky; sparsely fossiliferous.	0	10	0.25
	7. Neva limestone: fine calcilutite, mudstone; light gray, weathers tan; slabby to blocky; with abundant large vugs, due to dissolution of evaporites (boxwork limestone).	3	6	1.07
NT_6				
	6. Neva limestone: clay shale; light green to dark gray; flaggy; calcareous; non-fossiliferous.	1	7	0.48
	5. Neva limestone: fine calcilutite, mudstone; light gray; flaggy; argillaceous; with few skeletal fragments.	1	3	0.38
NT_5	4. Neva limestone: coarse calcilutite, packstone; light gray; with common high spired gastropods, productid fragments.	0	11	0.28
	3. Neva limestone: clay shale; green; flaggy; non-fossiliferous.	0	6	0.15
	2. Neva limestone: medium calcarenite, packstone; gray; massive; with abundant shell fragments, common echinoids, microcrinoids, high spired gastropods, scattered Derbyia.	1	5	0.43
NT_4				
	1. Neva limestone: clay shale; dark gray; flaggy; with common Orbiculoidea fragments.	2	0	0.61

5th order T-R units/boundaries	6th order T-R units/boundaries	Locality #30 SW NE Sec. 17, T. 19 S., R 8 E., along Hiway 50, just west of Junction 177, near Strong City, Chase County, Kansas			
		UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		11. Eskridge Shale: clay shale; platy; with scattered plant fossils.	1	6	0.46
		10. Eskridge Shale: fine calcilutite; wackestone; light gray, weathers green-gray; with common _Aviculopecten_; scattered productids.	1	3	0.38
	NT_9				
		9. Eskridge Shale: clay shale; brown to green; flaggy; slightly calcareous; with scattered plant fossils.	0	6	0.15
		8. Eskridge Shale: fine calcilutite; wackestone; slabby; with abundant _Aviculopecten_.	0	4	0.10
	NT_8				
		7. Eskridge Shale: clay shale; light green; fissile; semi-indurated.	2	10	0.86
		6. Eskridge Shale: fine calcilutite; wackestone; medium gray, weathers light gray; with abundant shell fragments.	0	2	0.05
	NT_7				
		5. Eskridge Shale: clay shale; light green; fissile; non-fossiliferous.	1	2	0.36
		4. Eskridge Shale: clay shale; medium gray; flaggy; non-fossiliferous.	1	8	0.51
		3. Eskridge Shale: clay shale; light green mottled brown; fissile; with common root mottling.	1	4	0.41
		2. Neva limestone: fine calcilutite; packstone; medium gray, weathers light gray; with abundant skeletal fragments; common gastropods, _Skolithus_; hardground surface at top.	0	7	0.18
		1. Neva limestone: coarse calcilutite; wackestone; medium gray, weathers light gray; blocky; with common crinoids, _Juresania_; scattered large (up to 1 inch (0.03 m) in diameter) vugs.	1	9	0.53

Locality #31

SW NE Sec. 26, T. 19 S., R 7 E., along county road one mile east of Elmdale, Chase County, Kansas

5th order T-R units/boundaries	6th order T-R units/boundaries	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
		30. Cottonwood limestone: fine calcirudite; packstone to wackestone; light gray; massive; with abundant fusulinids; scattered echinoids.	1	8	0.51
		29. Cottonwood limestone: medium calcarenite; wackestone to packstone; light gray; slabby; with scattered <u>Composita</u>, crinoids, echinoids, productids.	2	6	0.76
CT_1					
		28. Eskridge Shale: clay shale; light green; platy to flaggy; non-fossiliferous.	4	11	1.50
		27. Eskridge Shale: claystone; dark red; crumbly; indurated; with common microslickensides, root traces.	2	6	0.76
		26. Eskridge Shale: clay shale; red; flaggy; slightly calcareous; non-fossiliferous.	2	2	0.66
		25. Eskridge Shale: fine calcilutite; mudstone to wackestone; light gray; platy to flaggy; argillaceous; with scattered <u>Aviculopecten</u>, productids.	0	8	0.20
	NT_{10}				
		24. Eskridge Shale: clay shale; pale red; fissile; non-fossiliferous.	1	8	0.51
		23. Eskridge Shale: fine calcilutite; mudstone; pale red to light grey; flaggy; mudcracked; with few skeletal fragments.	2	0	0.61
	NT_9				
		22. Eskridge Shale: clay shale; pale red; platy; non-fossiliferous.	2	4	0.71
		21. Eskridge Shale: fine calcilutite; wackestone; green-gray; flaggy; argillaceous; with scattered <u>Aviculopecten</u>.	0	5	0.13
	NT_8				
		20. Eskridge Shale: claystone; light green; crumbly; indurated.	1	4	0.41
		19. Eskridge Shale: claystone; dark red; crumbly; indurated; with abundant clay films, caliche nodules, calcified ped structures.	2	11	0.89
		18. Eskridge Shale: clay shale; light green; flaggy;non-fossiliferous.	0	9	0.23
		17. Neva limestone: fine calcilutite; wackestone; light gray; blocky; argillaceous; with abundant echinoids; few pinned bivalves.	1	4	0.41
		16. Neva limestone: medium calcilutite; wackestone; medium gray; flaggy; with scattered <u>Composita</u>; few crinoids, productids.	1	2	0.36
	NT_6				
		15. Neva limestone: medium calcirudite; packstone; light gray; massive; collapse brecciated with large (up to 10mm) angular clasts; with common echinoids; few gastropods.	3	0	0.91
		14. Neva limestone: medium calcilutite; wackestone; light gray; blocky; with common echinoids, crinoids, shell fragments.	1	1	0.33
		13. Neva limestone: fine calcilutite; wackestone; light gray; flaggy to slabby; with common echinoids, crinoids; few <u>Juresania</u>.	0	6	0.15

Cycle	UNIT DESCRIPTIONS Transgressive Surface ——	Unit Thicknesses ft	in	m
	12. Neva limestone: clay shale; green-gray; fissile; with common fusulinids; scattered Crurithyris.	0	3	0.08
NT_4				
	11. Neva limestone: fine calcilutite; mudstone to wackestone; light gray; platy; argillaceous; with scattered Crurithyris.	0	3	0.08
	10. Neva limestone: fine calcarenite; wackestone to packstone; light gray; massive; with abundant Psuedoschwagerina.	0	6	0.15
NT_3				
	9. Neva limestone: clay shale; green-gray; platy to flaggy; with few microcrinoids, skeletal fragments.	0	3	0.08
	8. Neva limestone: fine calcilutite; wackestone; light gray; slabby; with common productids, microcrinoids.	0	4	0.10
	7. Neva limestone: clay shale; brown; flaggy; with common Orbiculoidea, Crurithyris, crinoids; scattered shark teeth, Composita, Derbyia.	0	6	0.15
NT_2				
	6. Neva limestone: clay shale; brown; papery; with abundant Orbiculoidea.	0	2	0.05
	5. Neva limestone: medium calcilutite; mudstone to wackestone; light gray; slabby; with scattered Orbiculoidea.	0	4	0.10
	4. Neva limestone: medium calcarenite; packstone; light gray; massive; with common productids; scattered echinoids, Bellerophon, Hustedia, bryozoans.	1	3	0.38
	3. Neva limestone: medium calcirudite; packstone; light gray; slabby; with common large (up to 8mm) shale intraclasts.	0	5	0.13
NT_1				
	2. Salem Point shale: clay shale; light brown; platy; mudcracked; with common ostracods; scattered plant fossils at top 3 inches (0.08 m).	1	8	0.51
	1. Salem Point shale: clay shale; green-gray mottled black; fissile; non-fossiliferous.	1	0+	0.30+

HIERARCHAL GENETIC STRATIGRAPHY OF THE NEVA
LIMESTONE MEMBER OF THE GRENOLA LIMESTONE AND ESKRIDGE
SHALE (LOWER PERMIAN) IN NORTHEASTERN KANSAS

by

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ABSTRACT

An interval of Lower Permian strata consisting of the Neva Limestone Member of the Grenola Limestone and the Eskridge Shale was studied in northeastern Kansas utilizing a hierarchal genetic stratigraphic framework. This approach allowed for detailed correlations and interpretations of sea level changes on a scale that has not previously been done.

The Neva Limestone Member and Eskridge Shale comprise one full transgressive-regressive sequence of a fifth-order T-R unit scale. The lower boundary of this fifth-order T-R unit crosses the formal lithostratigraphic boundary that was based on megacyclothemic evidence and occurs at the base of the Neva Limestone Member. The underlying Salem Point Shale Member represents a regressive part of the underlying Burr fifth-order T-R unit. The upper Neva-Eskridge fifth-order boundary occurs at the base of the Cottonwood Limestone Member, which represents the base of the overlying Cottonwood fifth-order T-R unit.

Detailed study of 28 closely spaced localities within a three county area revealed eleven sixth-order T-R units within the Neva-Eskridge fifth-order T-R unit. Allowing for a few local exceptions, these 11 sixth-order T-R units were found to correlate consistently, and a generalized sea level curve for this interval of sedimentation could be deduced.

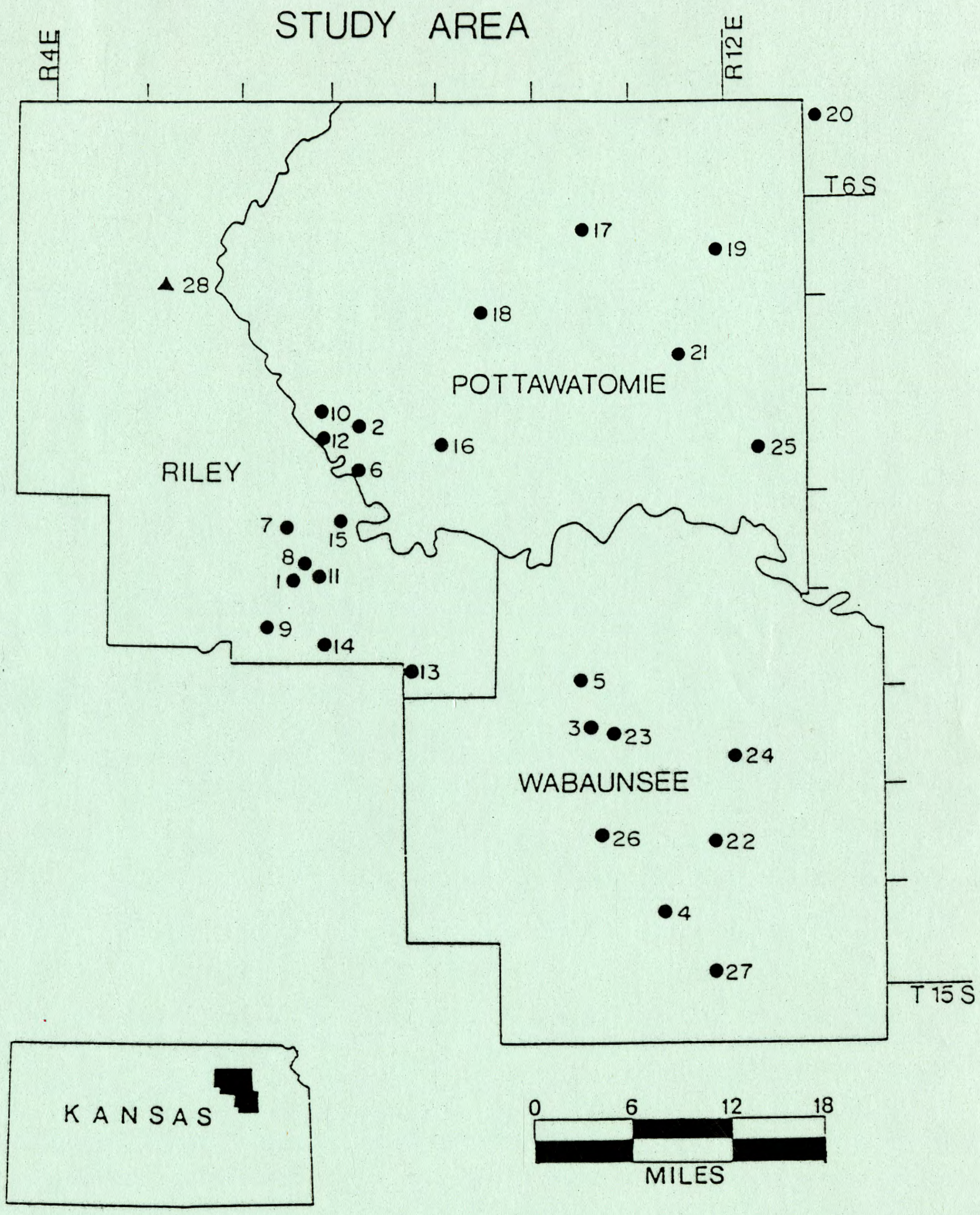
A scheme of 13 offshore to onshore biofacies

representing four distinct paleoenvironments was devised to aid in identification and interpretation of genetic surfaces. This biofacies scheme developed for the Neva-Eskridge fifth-order T-R unit should have useful applications for other intervals of Permo-Carboniferous rocks.

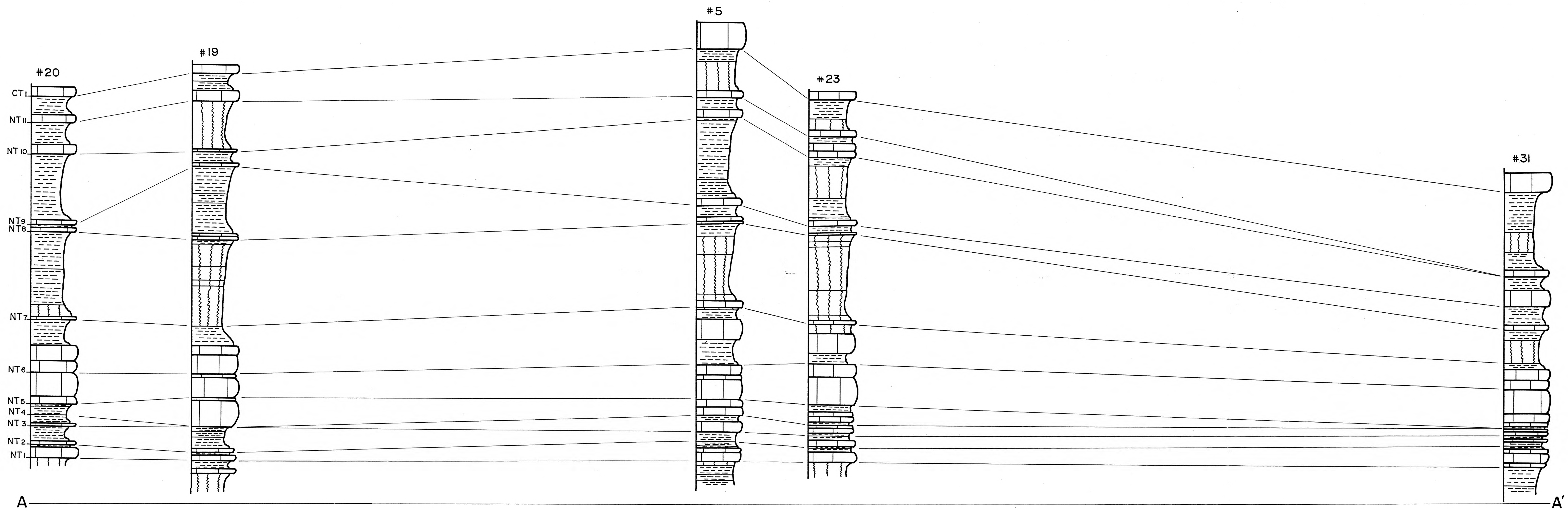
Detailed paleogeographic maps were constructed for times of maximum transgression for each sixth-order T-R unit. The litho- and biofacies data derived from these maps allowed for the definition of recurrent facies changes. A composite paleogeographic map for the Neva-Eskridge fifth-order T-R unit could then be defined with recurrent shallower marine facies interpreted to be deposited on topographic highs and recurrent relatively deeper marine facies deposited in topographic lows.

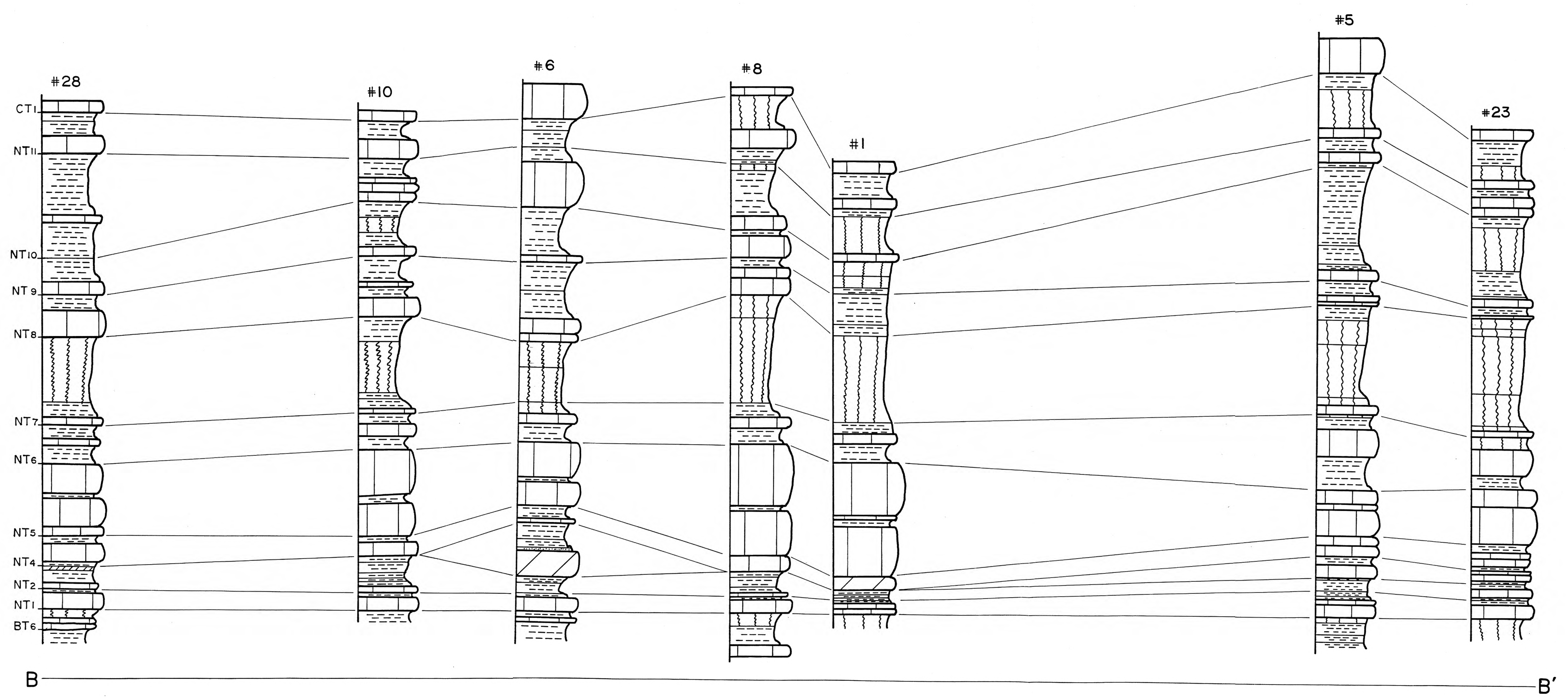
Isopach maps drawn for the Neva-Eskridge T-R unit exhibited characteristically similar patterns of sedimentation. Those areas suggested as topographic highs from paleogeographic data are represented by thinner intervals of sedimentation. While those areas suggested to be topographic lows were consistently represented by thicker intervals of sedimentation.

Structure contour maps drawn for underlying sediments suggest that several structural elements of the Nemaha Tectonic Zone occur within the area of study. These structural features, both positive and negative, display numerous affinities to the topographic irregularities defined by paleogeographic and isopach mapping. This relationship is concluded to be more than coincidental as depositional patterns within the Neva-Eskridge fifth-order T-R unit seem to have been definitely influenced by the existing structural elements.



Acetate overlay of the location map of measured sections (1-27) and core (28) for Riley, Pottawatomie, and Wabaunsee Counties, Kansas.





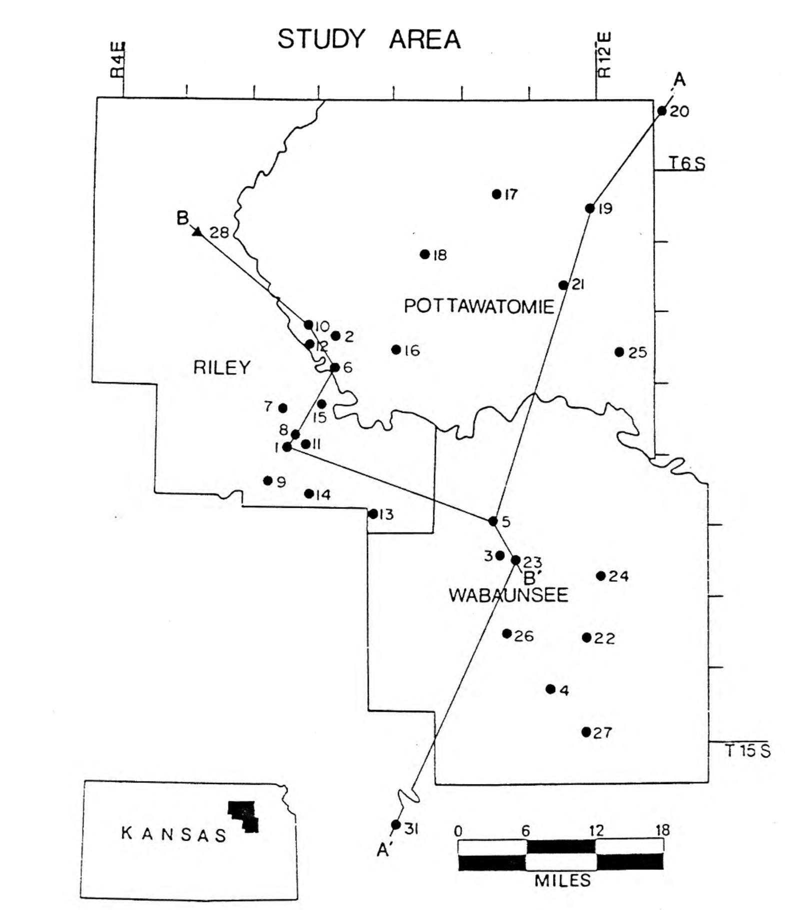


Figure 23. Cross-sections A-A', and B-B' drawn parallel to, and perpendicular to the Nemaha Anticline.