

ENVIRONMENTAL MAPPING OF THE TOPEKA AND DEER
CREEK MEGACYCLES OF THE SHAWNEE GROUP
(UPPER PENNSYLVANIAN) OF THE
MIDCONTINENT

BY

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THESIS

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TABLE OF CONTENTS

INTRODUCTION-----	1
PREPARATION AND INTERPRETATION OF ENVIRONMENTAL MAPS-----	6
Severy Shale-----	10
Topeka Limestone-----	16
Coal Creek Limestone Member-----	16
Holt, DuBois, and Turner Creek Members-----	17
Sheldon Limestone Member-----	22
Jones Point Shale Member-----	23
Curzon Limestone Member-----	26
Iowa Point Shale Member-----	26
Hartford Limestone Member-----	27
Calhoun Shale-----	33
Deer Creek Limestone-----	35
Ervine Creek Limestone Member-----	35
Larsh-Burroak Shale Member-----	38
Rock Bluff Limestone Member-----	39
Oskaloosa Shale Member-----	41
Ozawkie Limestone Member-----	44
SUMMARY AND CONCLUSIONS-----	47
BIBLIOGRAPHY-----	48

ILLUSTRATIONS

PLATES		Page
I.	Control point distribution and cross-section location map -----	7
II.	Cross section A-A'-----	11
III.	Cross section B'-B-----	12
IV.	Cross section B''-B'-----	13
V.	Environmental map of the Severy Shale-----	15
VI.	Environmental map of the Coal Creek Limestone Member, Topeka Formation-----	18
VII.	Environmental map of the Holt-Turner Creek interval, Topeka Formation-----	20
VIII.	Environmental map of the Sheldon Limestone Member, Topeka Formation-----	24
IX.	Environmental map of the Jones Point Shale Member, Topeka Formation-----	25
X.	Environmental map of the Curzon Limestone Member, Topeka Formation-----	28
XI.	Environmental map of the Iowa Point Shale Member, Topeka Formation-----	30
XII.	Environmental map of the Hartford Limestone Member, Topeka Formation-----	32
XIII.	Environmental map of the Calhoun Shale-----	34
XIV.	Environmental map of the Ervine Creek Limestone Member, Deer Creek Formation-----	37
XV.	Environmental map of the Larsh-Burroak Shale Member, Deer Creek Formation-----	40
XVI.	Environmental map of the Rock Bluff Limestone Member, Deer Creek Formation-----	42

ILLUSTRATIONS (Continued)

PLATES		Page
XVII.	Environmental map of the Oskaloosa Shale Member, Deer Creek Formation -----	43
XVIII.	Environmental map of the Ozawkie Limestone Member, Deer Creek Formation -----	45

FIGURES

1.	Correlation chart for Topeka and Deer Creek megacycles -	2
2.	Correlation chart for Oklahoma and Kansas-----	3
3.	Diagrammatic east-west cross section showing alternating wedge-like relationship of Hartford Lime- stone, Calhoun Shale, and Ervine Creek Limestone-----	31

INTRODUCTION

In a large part of the Pennsylvanian column in the Mid-Continent region relatively thin strata can be traced over great distances with little change in the characteristics of each unit. This is true to a remarkable degree in the Shawnee group in which beds of only a few inches in thickness may be traced along the outcrop over a distance of ^{more than} ~~over~~ four hundred miles. Such widespread distribution of rock units, each with distinctive lithologic and faunal characteristics, suggests that the conditions under which each of these units were deposited were uniform over a large area.

The purpose of this study is to gain a better understanding of these conditions and their extent and relations to each other, through the construction of environmental maps.

The Shawnee Group is also remarkable in that it contains the most fully developed examples of megacycles. The interval studied in this paper comprises two complete megacycles. Moore (1949) divides the interval at the top of the Hartford Limestone (see correlation charts, Figs. 1 and 2). Thus the upper megacycle extends from the top of the Severy Shale to the base of the Iowa Point Shale Member of the Topeka Formation. The lower megacycle includes the remainder of the interval from the top of the Hartford Limestone Member of the Topeka Formation to the base of the Deer Creek Formation.

An ideal megacycle has four limestone units, designated "lower," "middle," "upper," and "super" (Moore, 1936). Each limestone (and each intervening shale) has distinctive characteristics. The limestones,

Fig. 1.

Oklahoma Tps. 22 23N.	Tps. 26-29N.	Iowa and Missouri	Nebraska	Kansas
Unnamed Sandstone and Shale		Severy Shale		
Turkey Run Limestone		Coal Creek Limestone		
Unnamed Sandstone and Shale	Unnamed Sandstone and Shale	Holt Shale DuBois Limestone Turner Creek Shale		
	Pearsonia Ls.	Sheldon Limestone		
	Unnamed Shale	Jones Point Shale		
	Unnamed Limestone	Curzon Ls.	Curzon (Meadow) Ls.	Curzon Ls.
	Unnamed Ss. and Sh.	Iowa Point Shale		
	Little Hominy Ls.	Hartford Ls.	Wolf River Ls.	Hartford Ls.
	Unnamed Ss. and Sh.	Calhoun Shale		
Deer Creek Limestone		Ervine Creek Limestone		
Unnamed Sandstone and Shale		Larsh- Mission Creek Sh.	Burroak Sh. Haynies Ls. Larsh Sh.	Larsh- Burroak Sh.
Plummer Limestone		Rock Bluff Limestone		
Unnamed Sandstone and Shale		Oskaloosa Shale		
		Ozawkie Limestone		

Fig. 1. Correlation chart for Topeka and Deer Creek Megacycles.

T 9 N Seminole Co.		Mabausee Group	T 21 N West of Cleveland	Tps. 26-29 N N. Osage Co., Okla.	Kansas Section	Ma- baun- see		
Vanoss	Shales Sandstones and Conglomerates		Mabausee Group	Bird Creek Ls.	Bird Creek Ls.		Howard Ls.	Shawnee Group
		Sandstones and Shales		Coaly smut sh. and ss.	Nodaway coal Severy Sh.			
		Pawhuska Group	Turkey Run Ls.	Turkey Run Ls.	Coal Creek Ls.	Topeka		
			coal	Shales and Sandstones	Holt Sh. Dubois Ls. Turner Creek Sh. Sheldon Ls. Jones Pt. Sh. Curzon Ls. Iowa Pt. Sh.			
			Sandstones		Hartford Ls.			
			and	Red Lime Shale Little Hominy Ls. Shale Deer Creek Ls.	Ervine Creek Ls.		Calhoun	
			Shales	Shale Limestone	Larsh-Burroak Sh. Rock Bluff Ls. Oskaloosa Sh. Ozawkie Ls.	Deer Creek		
				Shales and Sandstones	Rakes Creek Sh. Ost Ls. Kenosha Sh. Avoca Ls.	Recumseh		
			Pawhuska (?) Ls.	"Hominy-Pawhuska lime"	Lecompton	King Hill Sh. Beil Ls. Queen Hill Sh. Big Springs Ls. Doniphan Sh. Spring Branch Ls.	Lecompton	
			Upper Vanossa	Shales and Sandstones	Shales and Sandstones	Elgin Ss.	Kan- waka	
	Elgin Ss.	Elgin Ss.	Elgin Ss.	Fig. 2.				

Fig. 2. Correlation chart for Oklahoma and Kansas.

except for the fourth or "super," commonly contain fusulinids. The intervening shales differ from one another in different characteristics but occur in the same order in each megacycle. For example, the shale between the "middle" and "upper" limestones is in every case a black fissile shale (Moore, 1936).

Between each sequence of limestone and shale there occurs a thick shale sequence, which also has cyclic elements. Typically it consists of nonmarine shale, a thin limestone, nonmarine shale and locally thin coal at the top (Moore, 1936).

The area studied includes parts of Iowa, Missouri, Nebraska, Kansas, and Oklahoma. It extends westward from the outcrop belt in western Iowa, southeastern Nebraska, northwestern Missouri, eastern Kansas, and east central Oklahoma to central Oklahoma, west central Kansas and central Nebraska.

All available published outcrop data and cross sections were used, as well as unpublished sample studies of well cuttings and cross section and outcrop data from unpublished theses. In all there were over 1200 separate control points used (see Plate I).

The Severy, Topeka, Calhoun and Deer Creek formations were deposited during a relatively quiescent period in the tectonic history of the area of this study. Earlier structural features, however, were still affecting the relief of the area. The Nemaha anticline, which extends from eastern Nebraska through east central Kansas to northern Oklahoma, is reflected in the upper Shawnee Group by a slight arching of the sediments

over the buried structure. There is also some evidence of the Central Kansas Uplift, for the sediments thin slightly and arch over it.

Although there were no areas of high relief in the area studied during upper Shawnee time there are clastic sediments (mostly sandstones) in several units of the upper Shawnee Group which indicate the presence of elevated regions beyond the area in question.

PREPARATION AND INTERPRETATION OF ENVIRONMENTAL MAPS

In the preparation of the environmental maps a work map was made for each interval, indicating the lithology, thickness, fossil content, and sedimentary structures at each control point.

The lithology was most useful in determining general environmental conditions. For instance, a widespread limestone is obviously marine, and a coal with an underclay is, with little doubt, terrestrial. A change in lithologic composition often indicates a transition in environment. Thus, a normal limestone unit changing to gray shale is evidence of either an influx of sediment, or a change in depth, or both. By noting the lithology at each control point it was also possible to determine the extent and general configuration of sand bodies in the clastic units. The shape of the sand deposit is sometimes definitive in determining whether it is a narrow, elongate stream channel deposit or a more widespread, amorphous marine or deltaic sand.

Thickness is again a factor for interpreting general environmental conditions. A clastic unit generally thickens toward the source of the clastics and a marine limestone may have a greater thickness toward the open sea or toward the passage along which the sea invaded the ancient land surface.

A more specific determinant of environment is the fossil content. Brachiopods, pelecypods, and most other invertebrates indicate marine conditions, as against plant fragments and coal which are evidence of

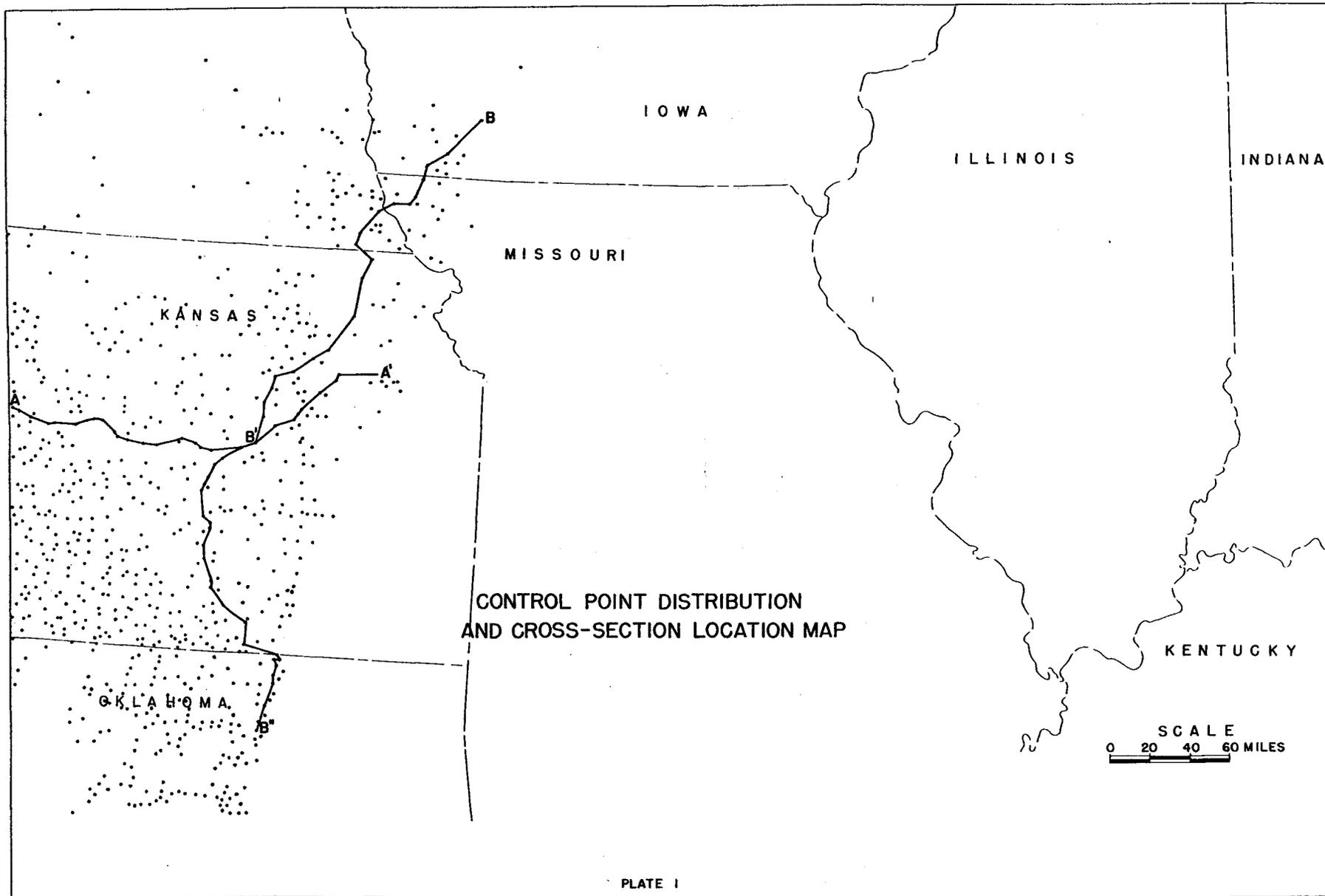


PLATE I

terrestrial conditions. More specifically, however, certain genera of pelecypods (such as Myalina) indicate shallow marine conditions, and coal is evidence of a swamp or marsh environment. Marine algae (such as Osagia) are also indicative of relatively shallow water. Although fossils are good indicators of environment, they could not always be used. In areas where only electric logs and studies of well cuttings were available fossil content was seldom recorded.

This is true for records of sedimentary structures as well. For, here again, they cannot be recognized in electric logs and often are not apparent in studies of well cuttings. The most common sedimentary features are oolitic beds, ripple marks, and stream channels. The first two of these are produced commonly in shallow water and always where tides or currents affect the sea bottom. Stream channels are normally indicative of a land surface, as, for example, a delta.

Other factors were also important in specific cases--most of which are explained under the descriptions of the intervals in which they occurred.

Color is a useful criteria for the shales particularly. Black shale appears to be the result of a rather unique set of conditions. Where it occurs in the upper part of the Shawnee Group it is usually fissile and contains only conodonts or no fossils at all. The black color is believed to be due to undecayed bits of organic debris in the shale. Apparently, the shale formed from muds which were deposited in water containing little oxygen, due to a lack of circulation. The paucity of fossils is a sign

that bottom conditions were toxic to almost all life. The thin fissile character may be a result of the slow, even settling of clay particles in stagnant water. Therefore, the environment must have been marine with restricted circulation.

As in the case of the interpretation of the black shale above, environmental conditions were determined using all available evidence. In most cases, therefore, more than one piece of evidence was considered in deciding upon the conditions prevalent in an area during a particular interval.

A basic factor in the preparation of environmental maps is the correct correlation of each unit. This is probably the part of the work in which the greatest amount of error and subjective judgment is involved. As the writer worked with records further and further from the outcrop belt, it became increasingly difficult to correlate with certainty. The writer, however, found several factors helpful in correlating. Among these were: the black shales, which, where present, are distinctive and reliable markers; the thick clastic units (Severy and Calhoun shales) which isolated and delineated the limestone formations except where these shales were thin or absent; and the rather uniform distinguishing characteristics of several of the limestone members (for example, the Ervine Creek Limestone Member is thicker and commonly contains more fusulinids than the other limestones).

To the west, in central Kansas, all the shale units thin to two feet or less and the limestones thicken and become more uniform (see

cross section, Plate II). The great distance from the outcrop and the change in character of the beds makes correlation quite difficult.

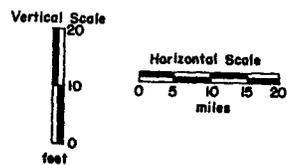
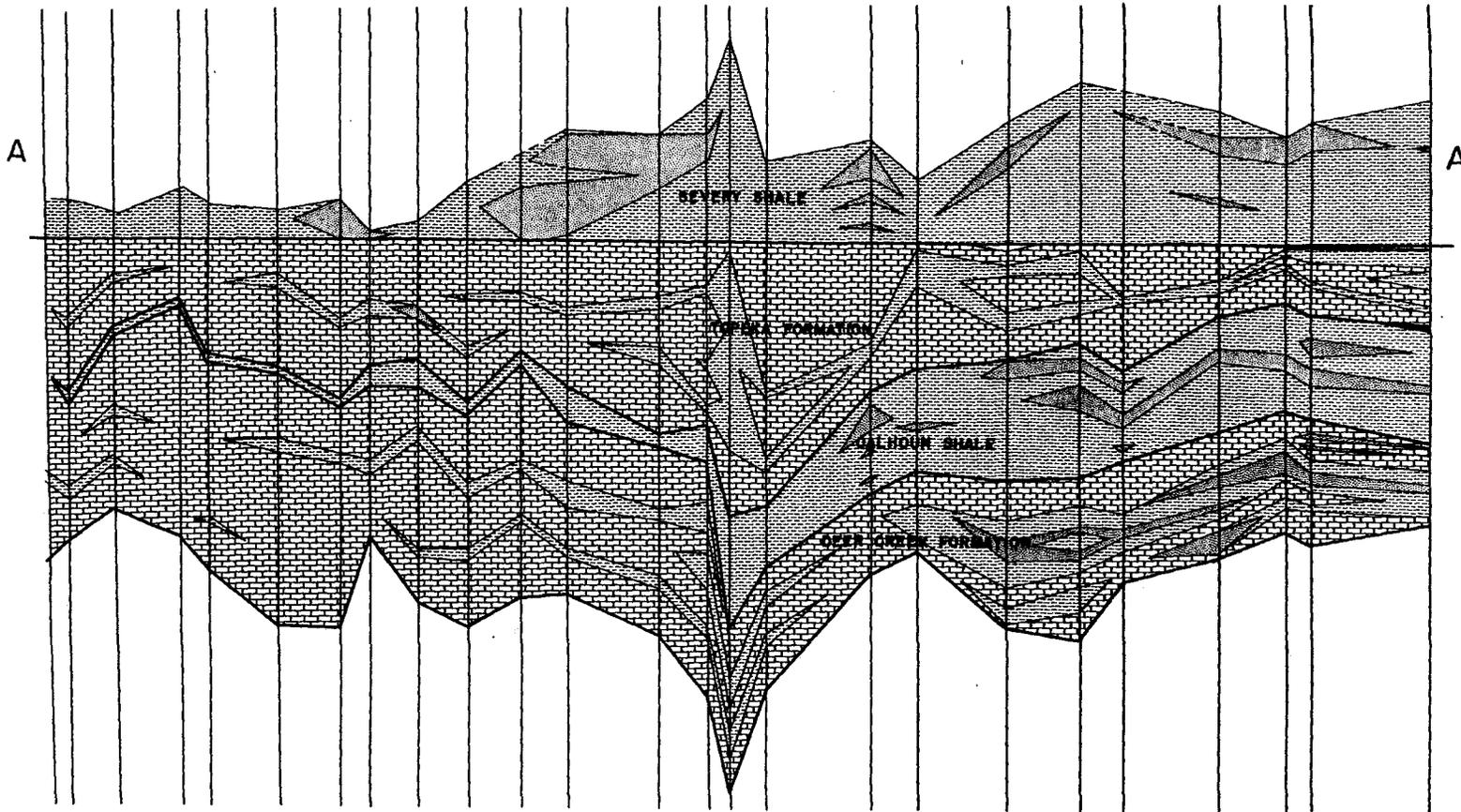
In Oklahoma electric logs, which had been reduced for inclusion in theses, provided most of the information. From these only lithology and general thickness could be determined. Therefore, some of the distinguishing characteristics used elsewhere in correlating were not available here.

Another major complication in correlating southward in Oklahoma is the facies changes, especially the disappearance of the limestones. Where the limestones are not present, correlation, even along the outcrop, is not very dependable. The occurrence of numerous, very local sandstones also complicates correlation southward in Oklahoma.

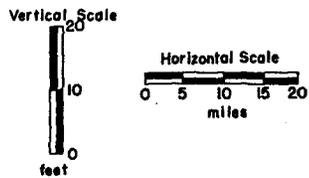
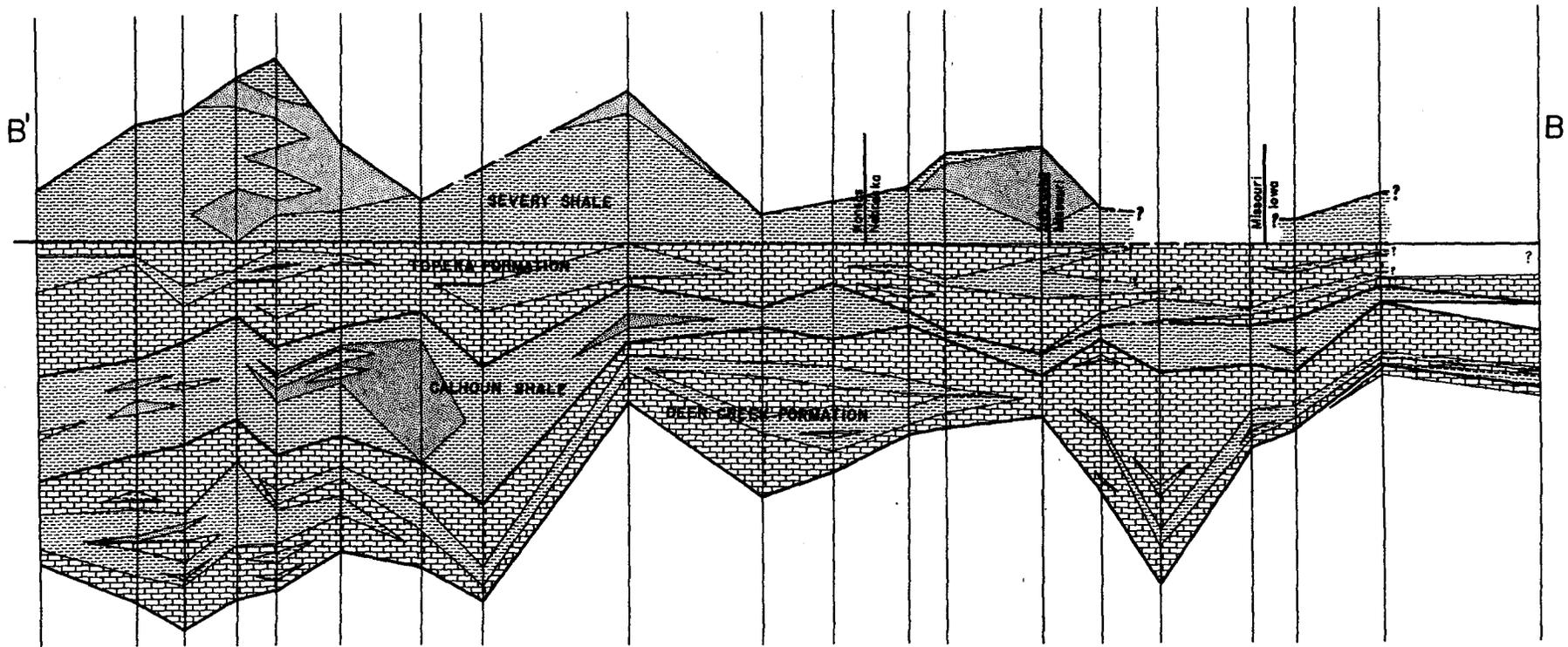
The writer is quite confident in the correlations made in the eastern part of the map area and becomes gradually less certain of the validity of the correlations as one progresses westward away from the outcrop.

Severy Shale

The Severy Shale is the interval between the base of the Howard Limestone and the top of the Topeka Formation. It was named for Severy, Kansas, by Haworth (1898). Where members of the Howard limestone are missing the base of the Nodaway coal (a bed in the Aarde Shale Member of the Howard Limestone) is considered the top of the Severy Shale. There is a disconformity at the base of the Severy Shale, and

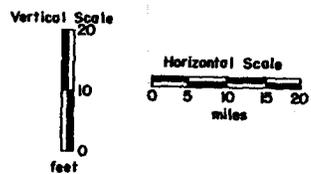
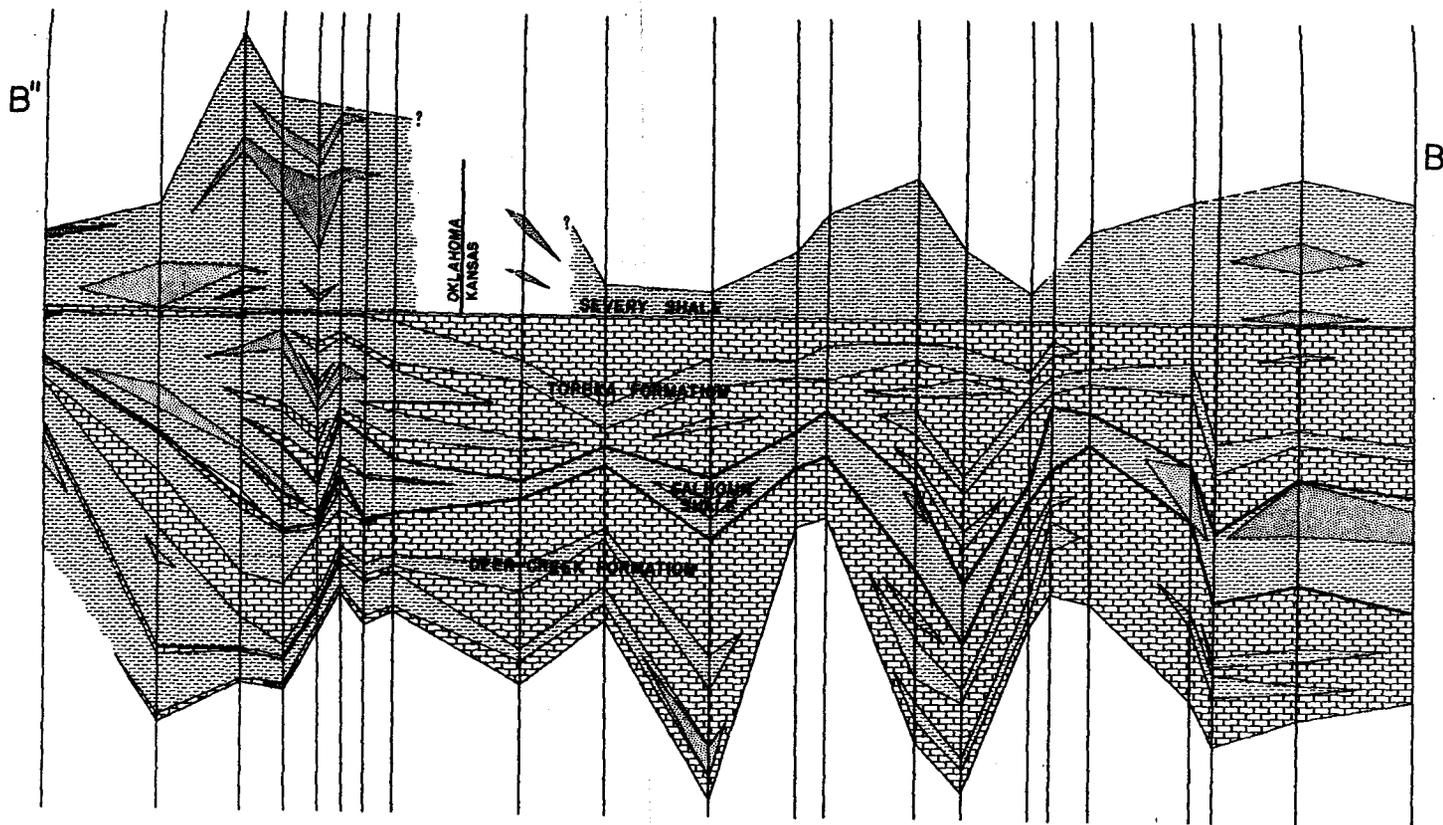


CROSS SECTION A-A'



CROSS SECTION B'-B

PLATE III



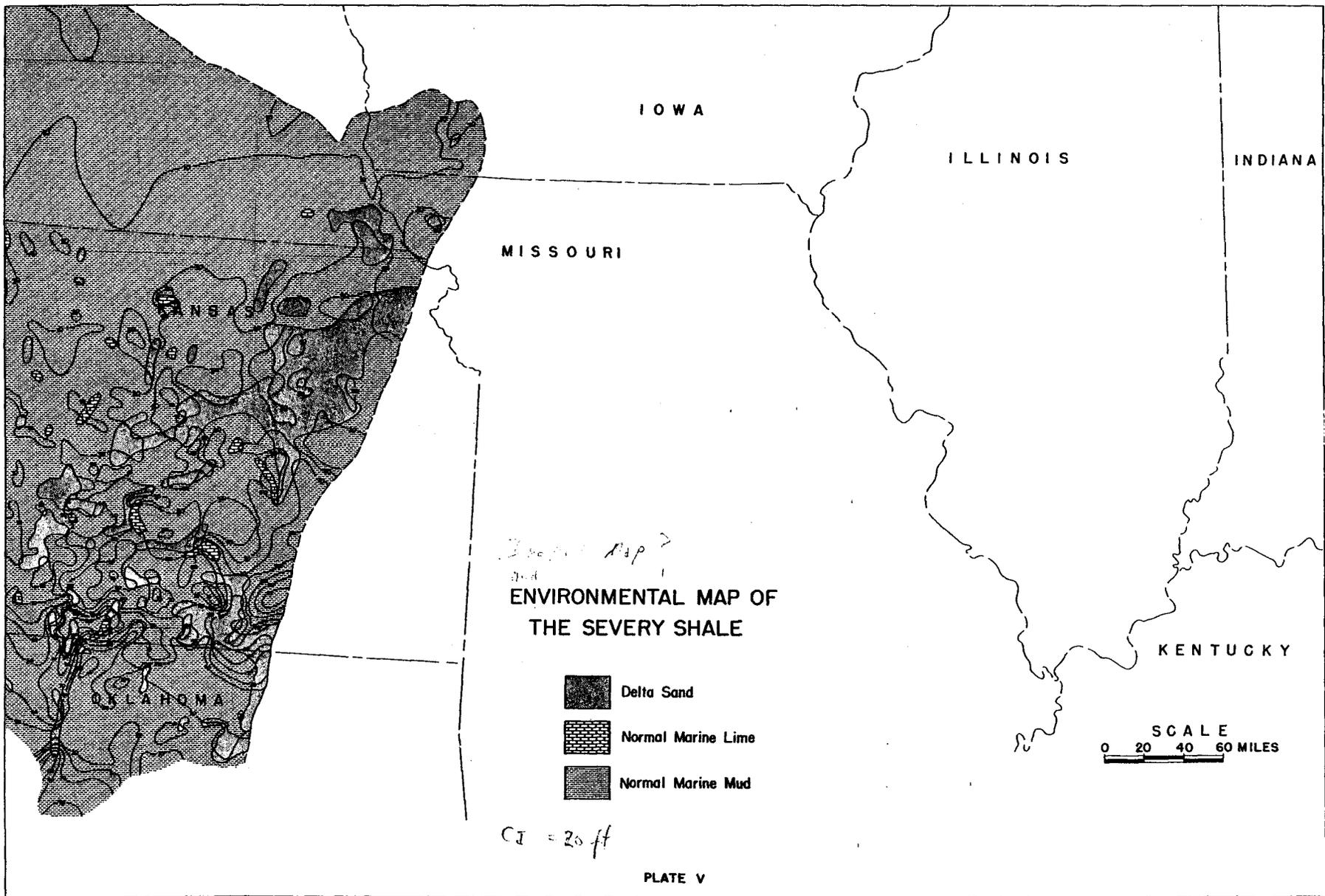
CROSS SECTION B''-B'

parts of the Topeka Limestone are locally absent. In Oklahoma the interval between the base of the Bird Creek Limestone and the top of the Turkey Run Limestone was regarded as Severy Shale.

The Severy Shale is a series of red and gray sandy shales which range in thickness from a few feet in Iowa and Nebraska to over one hundred feet in south central Kansas along the Oklahoma border. It commonly contains sandstones up to 20 feet thick and locally includes thin limestones which occur, in most cases, near the base. Fossils are lacking except for a few marine fossils in the uppermost beds and beneath the limestones (Moore, et al., 1951). The major part of the Severy Shale was probably nonmarine. The areal configuration of the sandstones (see Plate V) suggests that they are channel and deltaic sands deposited by streams.

The source area appears to be to the east - apparently from a distant source such as the Canadian Shield, or from the Ouachita Mountains. Evidence of this is the thickening of the beds toward the outcrop and a more widespread occurrence of sand in the eastern part of the area (see Plate V).

The absence of marker beds makes it impossible to subdivide this rather thick sequence. As a result the map (Plate V) represents conditions over a relatively long period of time. The Severy Shale was deposited during an interval of emergence and submergence. The normal marine lime environments represented on the map were present in the earlier stages of emergence or in the later stages of submergence. Shale



and sandstone were accumulated during most of the interval as streams meandered across the area toward the sea.

Topeka Limestone

Beneath the Severy Shale is a series of five limestones with interbedded shales called the Topeka Formation. It was named by Bennett (1896) for beds occurring in the southeastern part of Topeka, Kansas. The nine members are: Coal Creek Limestone, Holt Shale, DuBois Limestone, Turner Creek Shale, Sheldon Limestone, Jones Point Shale and Hartford Limestone.

Coal Creek Limestone Member

The Coal Creek Limestone Member was named by Condra (1927). Its type area is on Coal Creek north of Union, Nebraska. It is correlated with the Turkey Run Limestone of northern Oklahoma (Moore, 1948) (see Fig. 1).

Locally the limestone contains one or two beds of shale and in north central Oklahoma a band of sandstone replaces the limestone (Plate VI). The sandstone appears to have been deposited in a shallow marine environment as indicated by the presence of oolitic limestone beds in two nearby wells and the thinness of the limestone (5 to 15 feet) around the sandstone. Therefore, it may be a beach or bar deposit. Also, along the eastern outcrop in northern Oklahoma the limestone is conglomeratic, algal, and contains Myalina, indicating deposition in relatively shallow water.

The Coal Creek Limestone seldom exceeds 20 feet in thickness and is generally thicker than two feet. It is thicker in south central Kansas, and thins northward to 10 feet or less in Nebraska, Iowa and Missouri. In Oklahoma it thins southward until it disappears along the outcrop at about Tsp. 15 N.

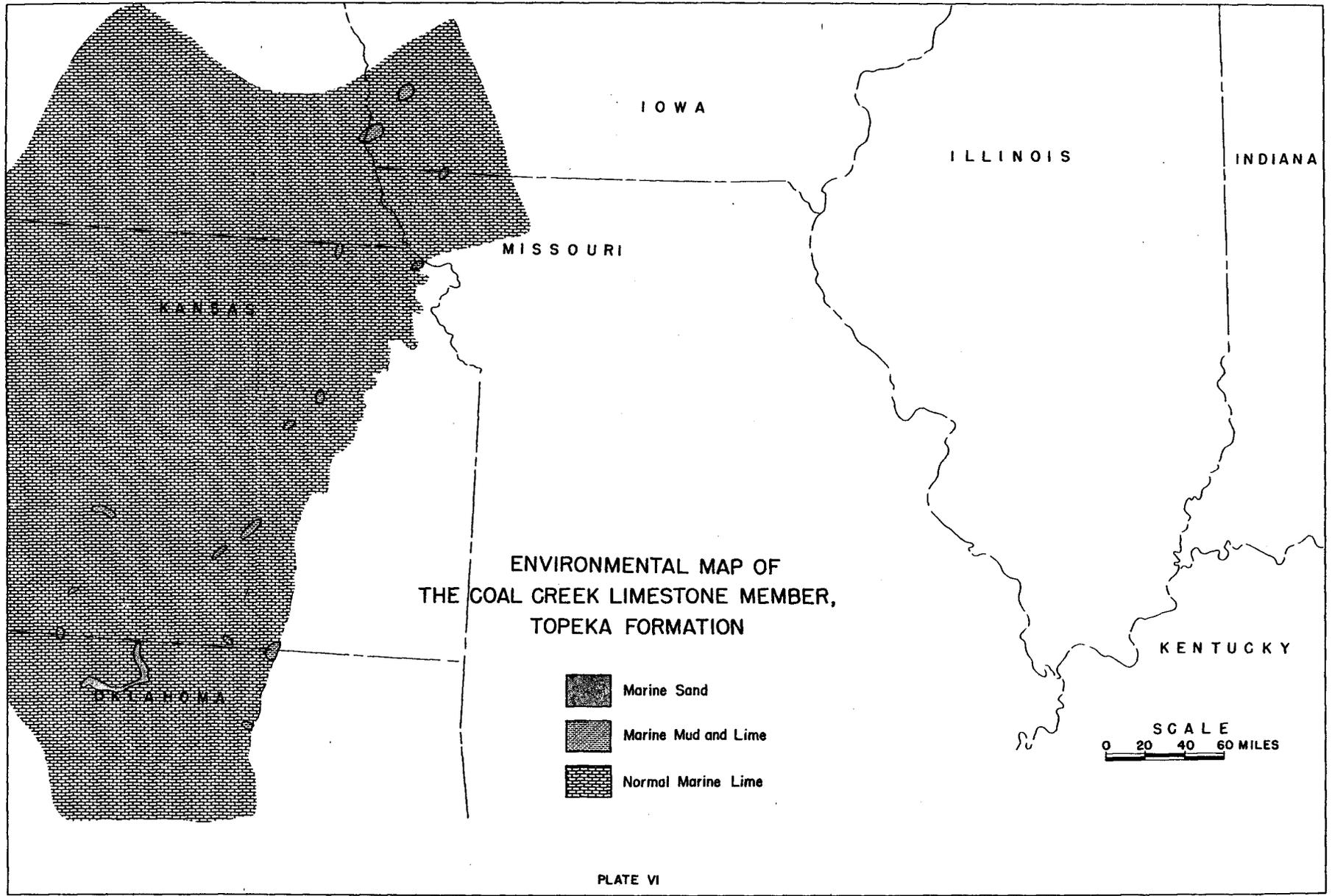
The limestone is commonly quite fossiliferous, containing, fusulinids, brachiopods, bryozoa, and crinoids.

The Coal Creek is locally eroded by the overlying Severy Shale. There is some indication that the erosion is more widespread than the writer believed when the maps were made. Further study may indicate the disconformity to be more significant than considered in this paper.

Holt, DuBois, and Turner Creek Members

Underlying the Coal Creek Limestone is a shale unit called the Holt Shale. The type area of the Holt Shale is in the bluffs of the Missouri River southeast of Forest City, Holt County, Missouri (Condra, 1927).

The Holt Shale is bluish-gray in the upper part and black and fissile in the lower part. The upper layers contain marine brachiopods and the black layers contain brachiopods and conodonts (Moore, et al, 1951). South and west of northeastern Kansas the black shale occurs only locally and the shale is generally gray. The fossil content indicates that the Holt Shale is marine but the specific marine environment under which the black shale formed is not known. The high organic content which causes the black color could only have been preserved by being deposited



in an environment free from oxidation, and, therefore, in water undisturbed by currents. Such restricted marine environments may occur in submarine depressions or in shallow near-shore lagoons.

The Holt Shale is underlain by the DuBois Limestone Member which is a very thin (maximum 3 feet) bed which occurs only in parts of Nebraska, Iowa, Missouri, and northeastern Kansas (see marine lime in Plate VII). The DuBois was named by Condra (1927) for beds four miles southeast of DuBois, Nebraska.

The DuBois Limestone consists of one or more beds of dark blue fine-grained limestone with vertical jointing. Pelecypods and brachiopods are common in it, and locally form coquina-like beds.

It is underlain by the Turner Creek Shale whose type section also occurs four miles southeast of DuBois, Nebraska, in Turner Creek (Condra, 1927).

The Turner Creek Shale is much less fossiliferous. It is a bluish or greenish-gray clayey and calcareous shale containing pelecypods, gastropods, ostracods, and some brachiopods.

Since the DuBois Limestone is present in a rather small part of the area mapped, and, since it is not possible to clearly distinguish the Holt and Turner Creek shales where the DuBois Limestone is absent, the entire Holt-DuBois-Turner Creek interval is treated as one interval.

The Holt-Turner Creek interval (Plate VII) is absent in parts of west central Kansas and Oklahoma. This is either due to a true break in deposition or to continuous marine lime deposition. Maximum thickness

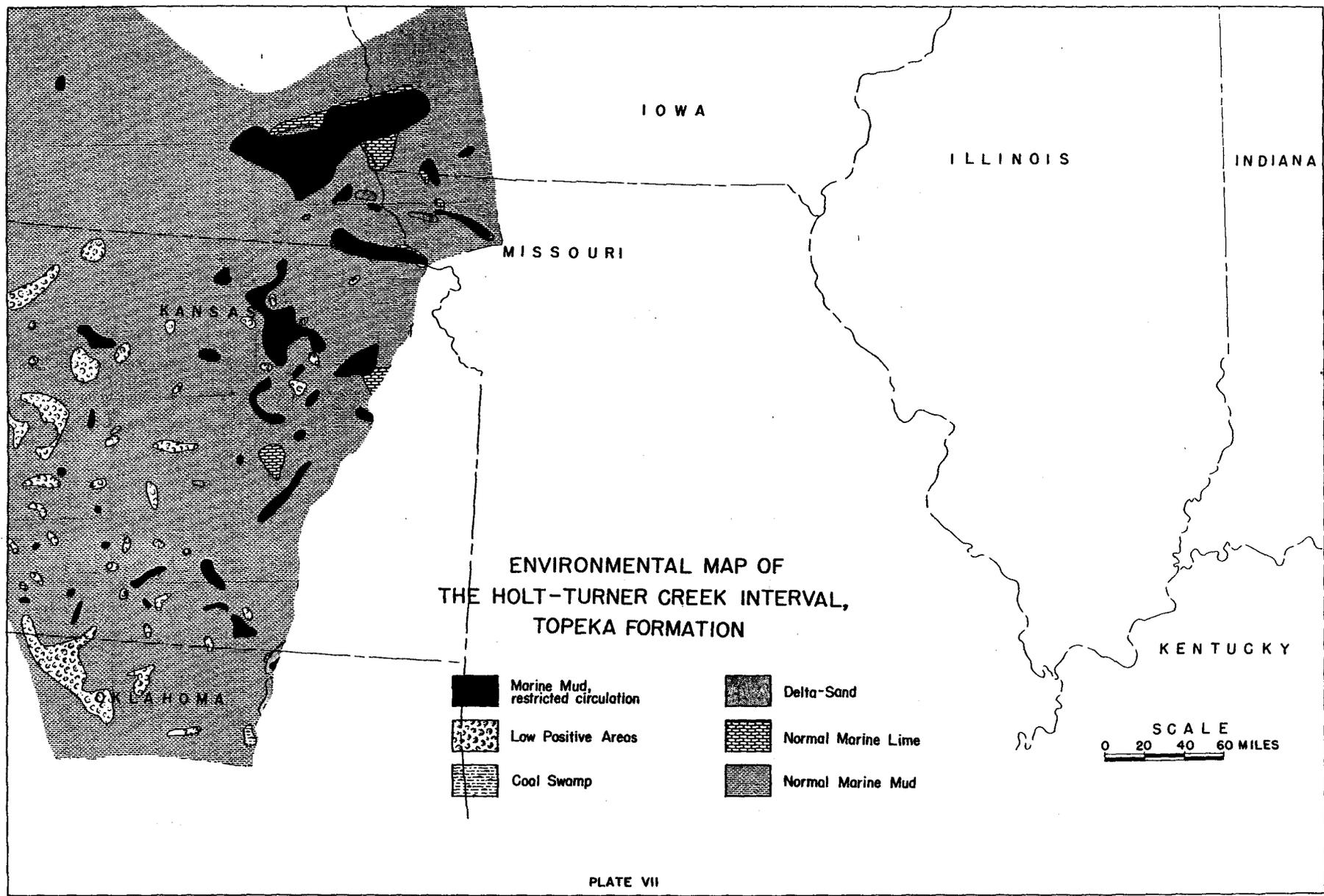


PLATE VII

is reached along the outcrop in Oklahoma where 30 feet or more of shale and sandstone occur. In Oklahoma the interval between the Turkey Run Limestone and the Pearsonia Limestone is mapped as Holt-Turner Creek. Moore (1949) correlates the "Red Lime" with the Curzon Limestone of Kansas. Carter (1954) gave the "Red Lime" the formal name Pearsonia Limestone. If these correlations are correct, the interval in Oklahoma mapped as Holt-Turner Creek includes the Sheldon Limestone and Jones Point Shale equivalents as well. Carter (1954) notes that the Pearsonia is underlain by another limestone which is unnamed and not included in Moore's (1949) correlation chart. The writer believes that this lower, unnamed limestone is the true Curzon equivalent and correlates the Pearsonia or "Red Lime" with the Sheldon Limestone of Kansas. This belief is based partly on the presence of abundant fusulinids in the unnamed limestone and their absence in the Pearsonia Limestone, and partly on the fact that no limestone occurs in the shale below the Curzon Limestone in Kansas. The Curzon Limestone in northern Kansas has abundant fusulinids in its lower beds whereas the Sheldon does not.

The average thickness of the Holt-Turner Creek interval is 4-5 feet.

Most of the western two thirds of the area is gray shale which indicates a normal marine environment in which mud was being deposited (see Plate VII). There are isolated patches of black shale where normal circulation was restricted. The black shale is more widespread in northeastern Kansas, eastern Nebraska, and southwestern Iowa. It

occurs near the top of the interval. In Nebraska and Iowa it is directly underlain by a thin normal marine limestone (DuBois Limestone). The abrupt change from a normal marine lime environment to a restricted marine black shale environment is a difficult problem which has not yet been solved. The black shale may be more widespread in Oklahoma than is shown on the map (Plate VII), since no records of sample studies in Oklahoma were available and the thin shale is not traceable on electric logs.

Along the outcrop in townships 21 and 22 north in Oklahoma there occurs a thin coal layer (0.05 to 1.0 feet) with a thin underclay. Northward along the outcrop the interval is represented by interbedded sandstones and shales. Near the Oklahoma-Kansas line a conglomeratic algal limestone occurs. The conglomeratic nature and algal remains in the limestone indicate a very shallow marine environment. From this evidence and the presence of a coal swamp to the south the sandstones are considered to be either sand deposited near the edge of a small river delta or near-shore marine sand. Other sands in eastern Nebraska and Missouri are normal marine sands.

Sheldon Limestone Member

Beneath the Turner Creek Shale is a light gray commonly massive limestone which contains algal growths (Osagia) in many places. This limestone is named the Sheldon Limestone from its type section at the Sheldon farm and quarry one mile east of Nehawka, Nebraska,

(Condra, 1930). As noted above the writer correlates the Pearsonia Limestone of Oklahoma with the Sheldon Limestone (see Fig. 1).

The environment of the Sheldon interval was one of widespread normal marine conditions (Plate VIII). Lime was deposited throughout the Mid-continent area except for one or two areas of local marine sand or mud deposition. In small areas in Nebraska, Missouri, and Oklahoma (Plate VIII) either a break in deposition or, more probably, deposition of thin marine muds occurred. In the southern part of the map area mud and sand were deposited on a delta which was building northward.

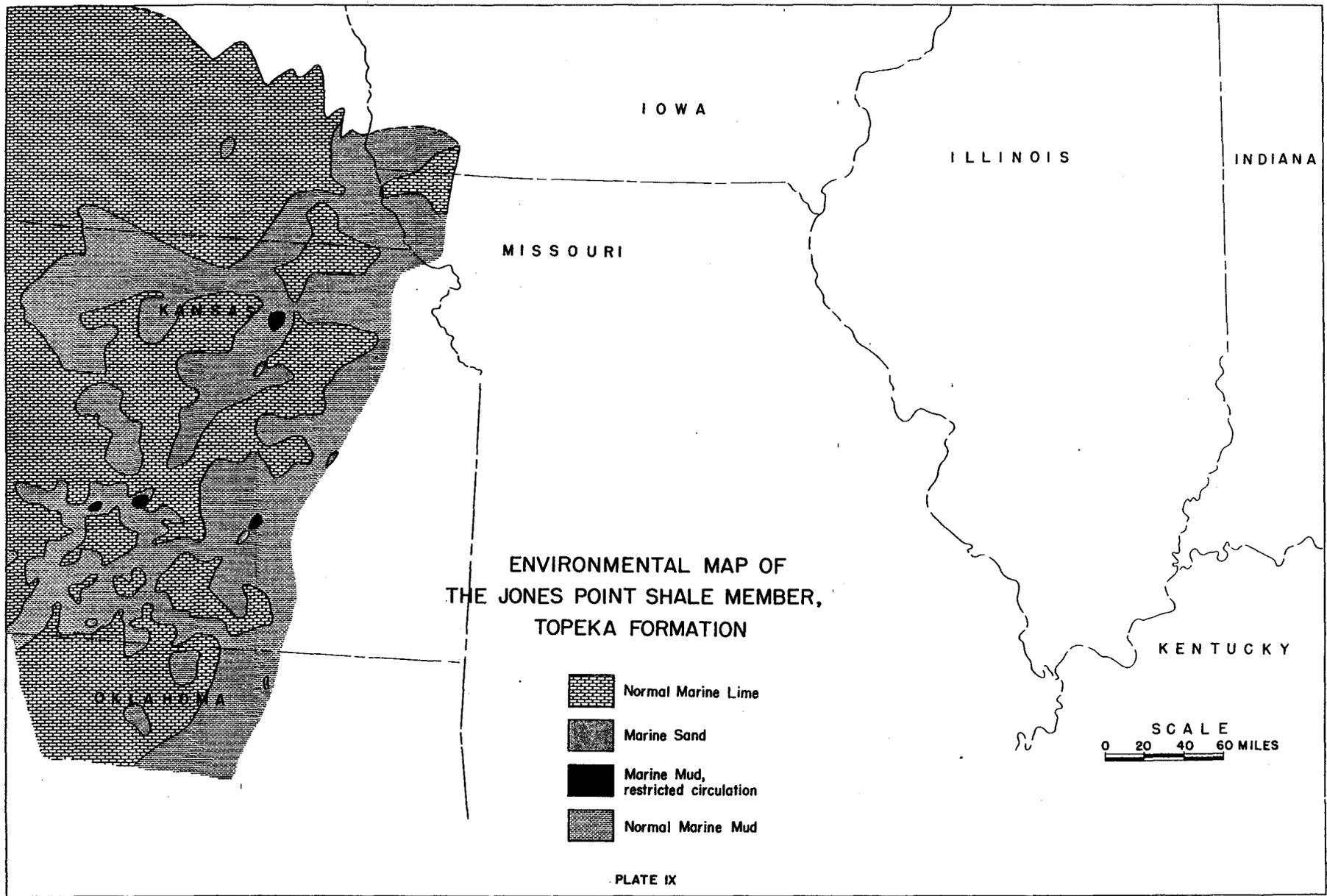
The Sheldon is locally oolitic and this, along with its algal characteristics, indicates that the seas were shallow.

Jones Point Shale Member

The Jones Point Shale directly underlies the Sheldon Limestone. Its type section is at Jones Point in the Missouri River bluffs four miles east of Union, Nebraska, (Condra, 1927).

It is a calcareous, silty gray shale containing brachiopods and pelecypods. The shale is rather restricted in its area because much of the Mid-continent experienced continuous lime deposition through this interval. The Jones Point reaches a maximum thickness of 15 feet in northern Oklahoma along the outcrop. Local sandstones and black shales occur in Kansas and Oklahoma.

The environment during Jones Point time was for the most part normal marine (Plate IX). The shoreline was probably to the east and



south of the area mapped. The influx of sediments from this land caused marine muds to be deposited, rather than lime. Black mud formed in small restricted pockets and sand was deposited in submarine banks.

Curzon Limestone Member

The Curzon Limestone Member was named by Condra (1927) for exposures in the bluffs east of Curzon Station, Missouri. In Nebraska it was earlier called Meadow Limestone. As mentioned above the writer considers it equivalent to an unnamed limestone in Oklahoma below the Pearsonia Limestone.

The Curzon is a bluish-gray massive limestone containing fusulids, brachiopods, and other invertebrates. It is thickest in south central Kansas where there is up to 30 feet of limestone. Plate X, the environmental map of the Curzon interval, shows the widespread normal marine conditions which prevailed. In a few isolated areas marine mud formed and was intercalated with lime, and locally marine sand beds developed. In Nebraska, Missouri, and Oklahoma small areas were sites of non-deposition or more probably of thin marine mud deposition.

To the southeast a delta reached the area and deposited muds and sands.

Iowa Point Shale Member

Underlying the Curzon Limestone is a gray shale named the Iowa Point Shale Member. Its type section is in the Missouri River bluffs

east of Iowa Point, Kansas, (Condra, 1927 and 1930). It reaches a maximum thickness of 15 feet in eastern Kansas near the Nebraska border.

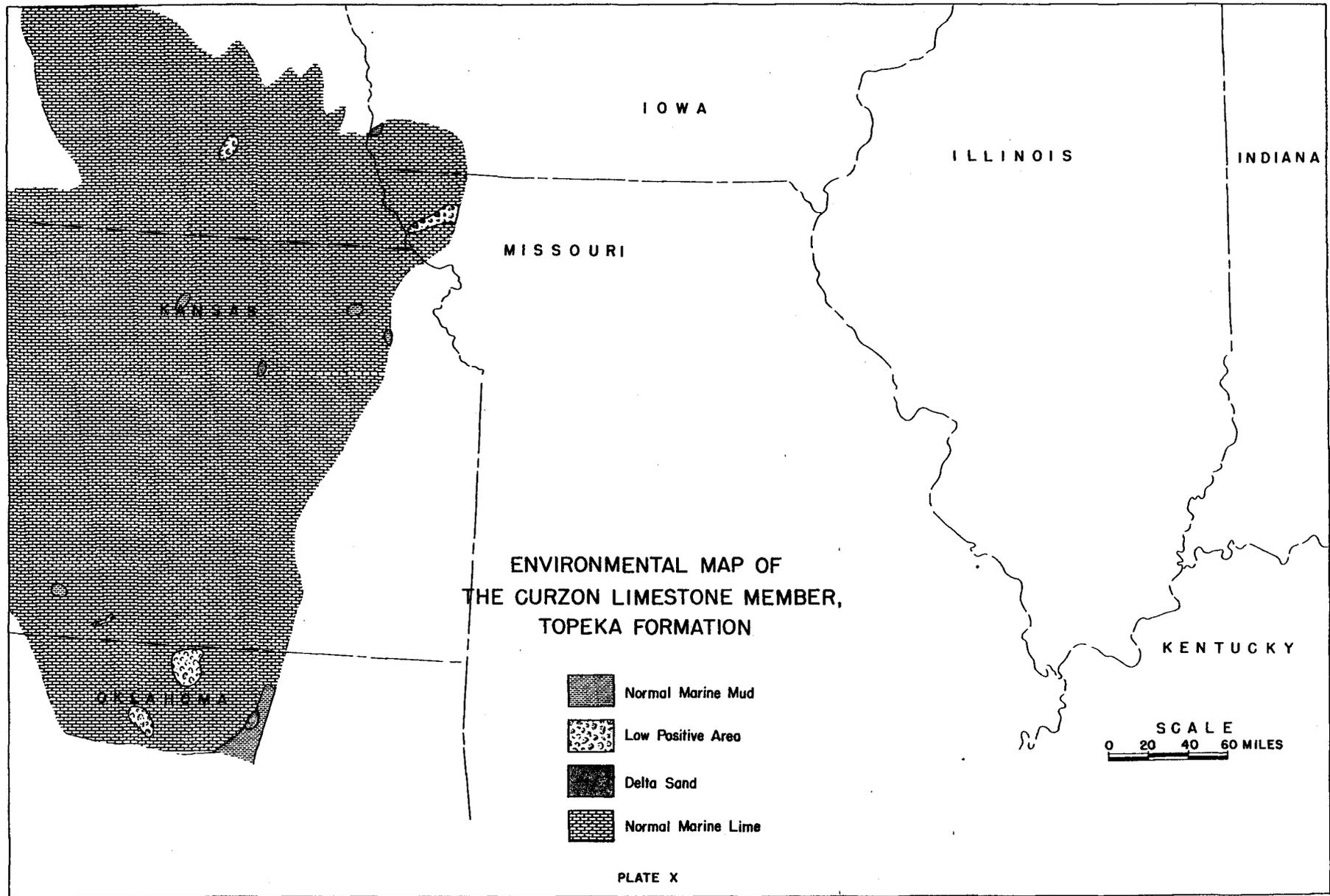
In parts of Nebraska, Iowa, and Missouri the Iowa Point Shale is absent due to nondeposition during this interval (see Plate XI). This area was covered by shallow seas and gray marine muds formed. Small basins or lagoons of restricted circulation allowed the deposition of black muds in northeastern Kansas. In Missouri and northeastern Kansas along the line of present-day outcrop deltaic conditions were present. Local short-lived coal swamps formed, and streams crossing the delta left thin sand beds.

To the west where the sea was deeper and sediments from the shore had less effect, the sea floor was the site of marine mud deposition and further west of lime deposition.

Along the present eastern outcrop in Oklahoma sand and silt were deposited, sometimes intercalated with thin lime beds as the shifting distributaries of the delta dropped their sediment load in the sea.

Hartford Limestone Member

The Hartford Limestone Member is a massive, bluish-gray limestone with numerous fusulinids, and in the uppermost beds algal growths (Osagia) occur. Hartford is the name given by Kirk (1896) for the lowermost limestone of the Topeka Formation. Its type exposure is near the Neosho River in Hartford, Kansas. In Nebraska the equivalent limestone is named Wolf River (Condra and Reed, 1937), and in



Oklahoma it is correlated with the Little Hominy Limestone (Moore, 1949) (see Fig. 1).

The thickness ranges from local areas of nondeposition in eastern Kansas to thicknesses greater than 60 feet to the south and west. This great variation in thickness is a result of deposition over the wedge-shaped Calhoun Shale which is thicker to the east and thinner to the west. It is most probable that deposition of lime occurred in the western part of the area while muds and sands were still being deposited to the east. Thus, the basal Hartford in central Kansas may be contemporaneous with uppermost Calhoun in eastern Kansas.

The environmental map (Plate XII) should, therefore, be imagined as representing a marine environment which began in the west and moved eastward until it engulfed nearly all the Mid-continent area (see Fig. 3 and discussions under Calhoun Shale and Ervine Creek Limestone Member below). In eastern Kansas small areas were never sites of marine lime deposition during the transgression and probably received no sediments or only thin muds during this interval. Locally in Kansas muds became interbedded with lime. In east central Oklahoma a delta building northward, with sediments from the Ouachitas to the south, deposited sands and interfingered its sediments with the marine lime.

Outcrop records indicate the presence of Osagia (algal colonies) and locally limestone conglomerates in Oklahoma in the uppermost beds of the Hartford Limestone. This is evidence of the shoaling of the sea as it withdrew at the end of this interval.

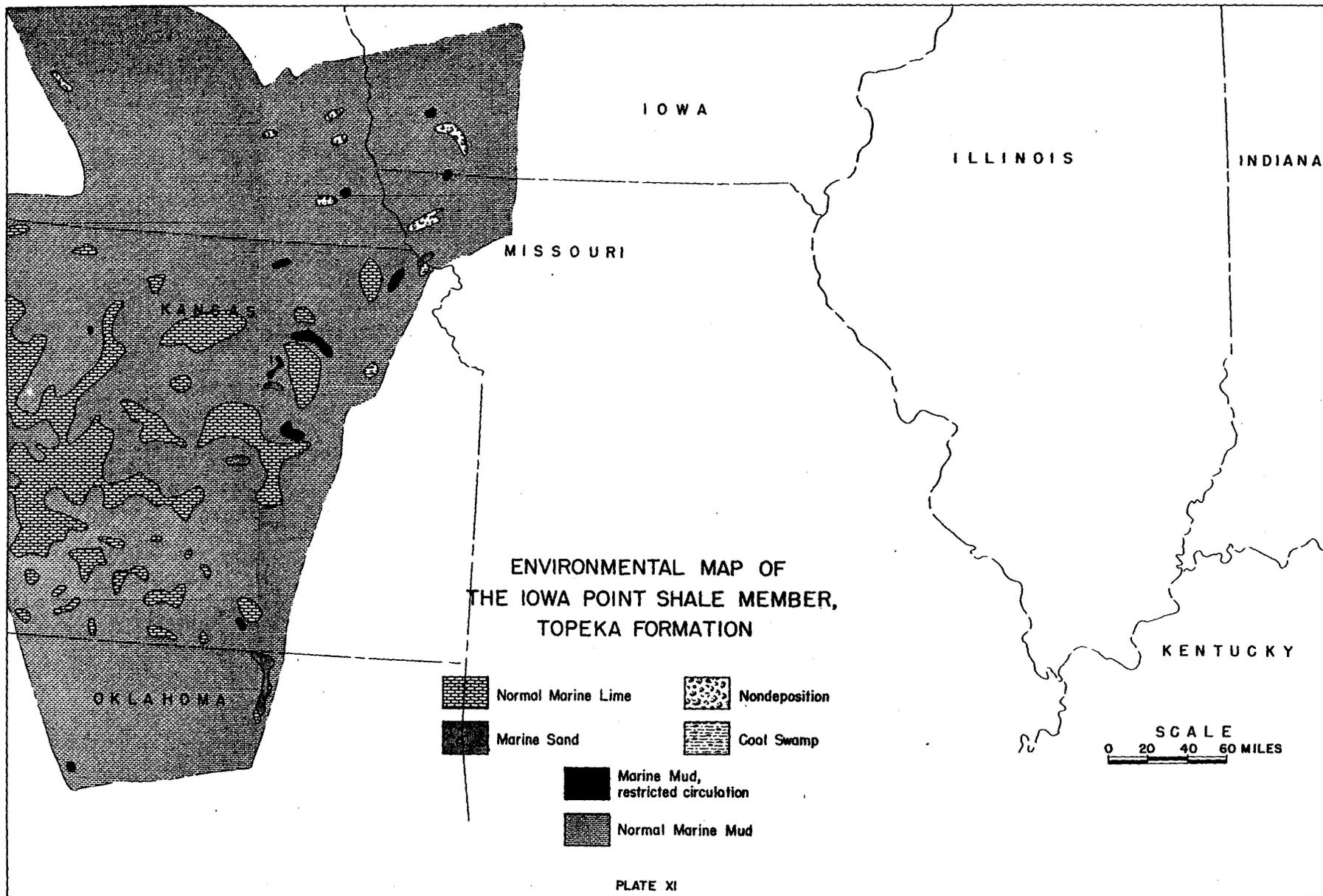


Fig. 3.

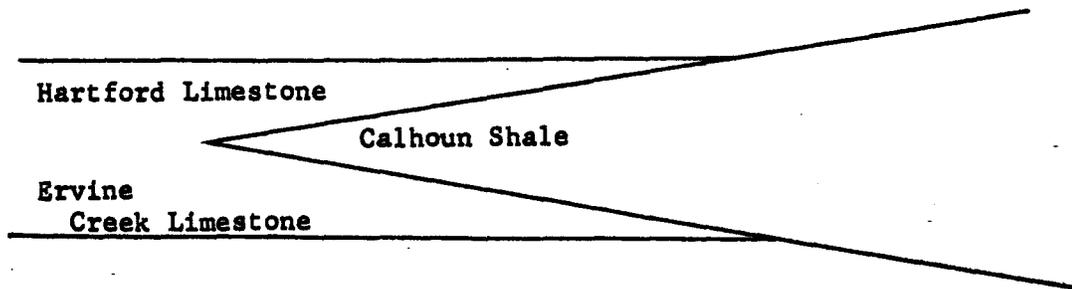
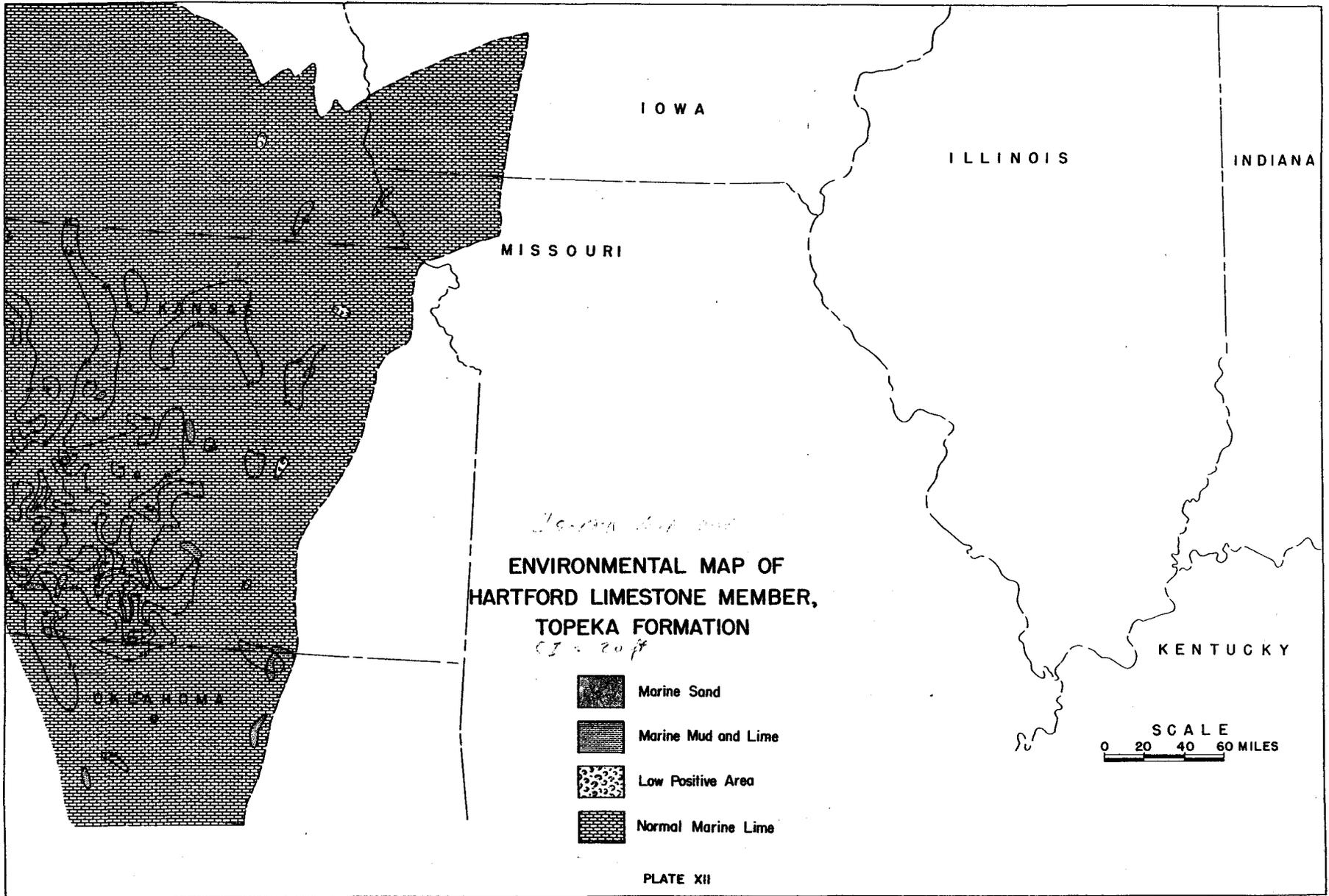


Fig. 3. Diagrammatic east-west cross section showing alternating wedge-like relationship of Hartford Limestone, Calhoun Shale, and Ervine Creek Limestone.



Topeka dip and

**ENVIRONMENTAL MAP OF
HARTFORD LIMESTONE MEMBER,
TOPEKA FORMATION**

CI = 20 ft

-  Marine Sand
-  Marine Mud and Lime
-  Low Positive Area
-  Normal Marine Lime

SCALE
0 20 40 60 MILES

PLATE XII

Calhoun Shale

Underlying the Hartford Limestone Member of the Topeka Formation is the Calhoun Shale. It was named by Beede (1898) for exposures in the Calhoun bluffs three miles northeast of Topeka, Kansas.

The Calhoun Shale is a series of clayey and sandy shales with sandstones lenses and local limestones and coals (see Plate XIII). It varies in thickness from a featheredge in central Kansas to 50 feet in eastern Kansas and to 150 feet in west central Oklahoma.

In Kansas both the overlying Hartford Limestone and the underlying Ervine Creek Limestone are thicker to the west and thinner to the east; whereas, the Calhoun Shale is thinner to the west and thicker to the east (see Fig. 2). This alternating wedge-like configuration indicates (1) that the marine transgressions came from the west and the sediments came from the east and (2) that the two limestones may be in part contemporaneous with the shale. Thus, in parts of central Kansas the Calhoun interval was a period of continuous marine conditions like the adjacent periods, except that marine mud formed rather than lime due to the greater influx of sediment.

To the east and south, great deltas gradually encroached upon the sea (see Plate XIII). Their early deposits were mostly clay and silt, but later streams flowing across the deltas left channel and other types of sand deposits. Marine lime (unnamed) developed when a slight rise in sea level in mid-Calhoun time flooded the lower parts of the deltas for a short interval. Swamps formed thin coal layers and black muds near

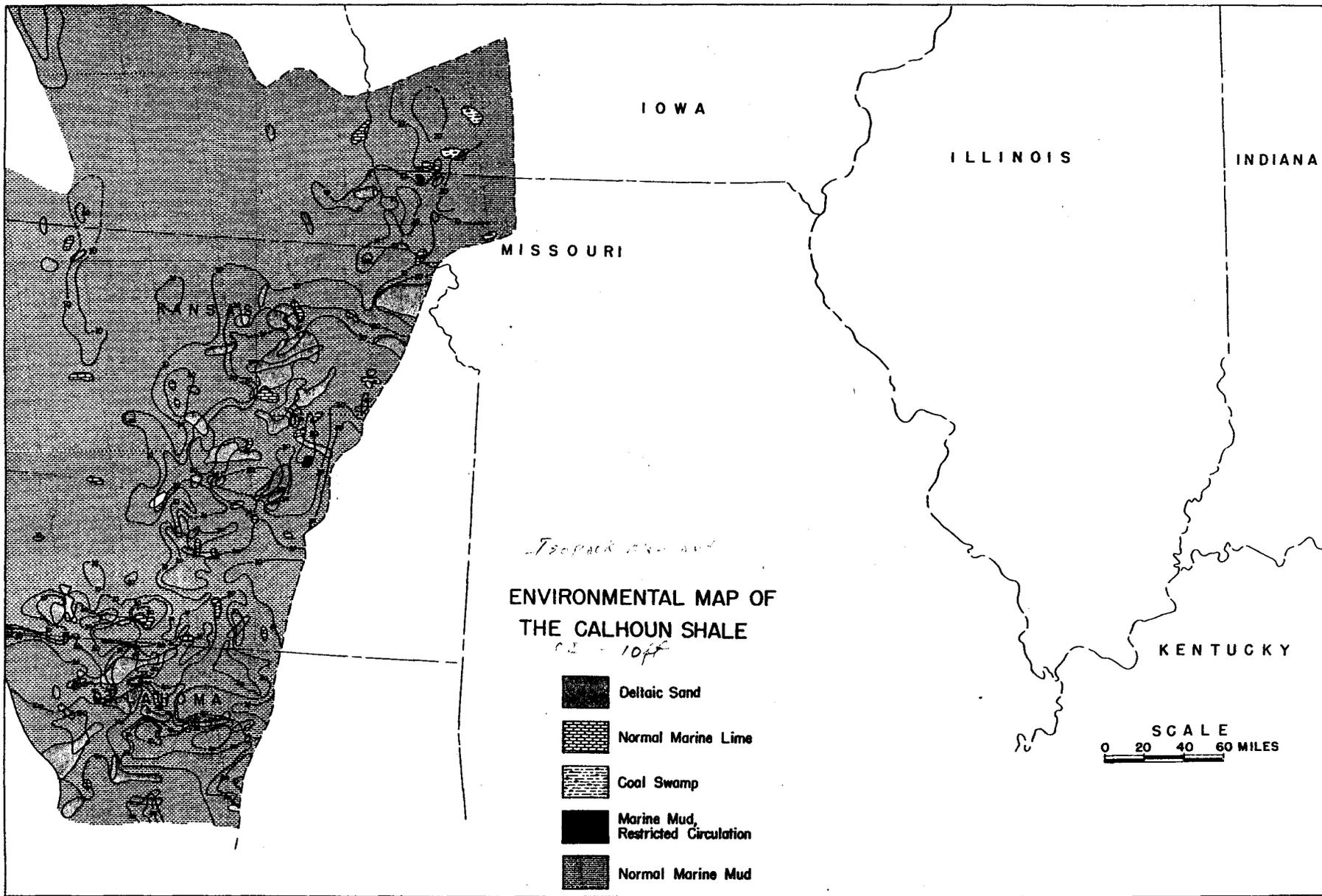


PLATE XIII

the border of the present outcrop.

Like the Severy Shale, the Calhoun Shale represents a rather long break in the alternating deposition of limestone and shale. Moore (1949) considers these two units as occupying corresponding positions (each at the top of a megacycle). Thus the limestones and shales of the Deer Creek Formation underlying the Calhoun correspond to limestones and shales of the Topeka Formation underlying the Severy Shale. Moore (1949) makes an exception of the Hartford Limestone Member which he considers as occurring at the top of its megacycle and, therefore, corresponding to the upper beds of the Severy Shale.

Deer Creek Limestone

The Deer Creek Limestone comprises three limestones and two shales. Bennett (1896) first proposed the name Deer Creek for exposures in Deer Creek Valley east of Topeka, Kansas.

The five members are: Ervine Creek Limestone, Larsh-Burroak Shale, Rock Bluffs Limestone, Oskaloosa Shale, and Ozawkie Limestone.

Ervine Creek Limestone Member

The Ervine Creek Limestone Member is a light gray, fine-grained limestone with wavy bedding and, locally, chert nodules. In Oklahoma it is known as the Deer Creek Limestone and is also equivalent to the Pawhuska Limestone as originally defined and as used by some authors.

The Ervine Creek Limestone is very fossiliferous, containing fusulinids, corals, echinoid and crinoid fragments, bryozoans, and mollusks (Moore, et al., 1951). In many places there is a massive algal layer at the top which is locally oolitic. Clay partings are common.

The environmental map of this interval (Plate XIV) discloses the widespread marine conditions which prevailed. Lime deposition occurred throughout most of the area with short episodes of mud deposition in isolated areas. To the southeast, in Oklahoma, marine sands were deposited in the shallower seas where offshore bars had formed.

As noted above the Ervine Creek is wedge-shaped with its thinner edge to the east (5-30 feet thick) and its greater thickness to the west (60-80 feet) (see Fig. 2). The thin limestone of the eastern part of the area was deposited contemporaneously with part of the limestone in central Kansas. The seas in the eastern area became shallower allowing growth of algal colonies and finally they disappeared, and non-marine (Calhoun) muds were deposited. To the west, however, the seas were still present, and marine lime was still forming. Thus, the upper beds of the Ervine Creek to the west are time-equivalent to lower beds of the Calhoun Shale to the east.

Along the line of present outcrop the sea never reached a very great depth, as indicated by the wavy nature of the bedding and the abundance of fossils, which both may be interpreted as indicative of a sea floor where wave agitation was present.

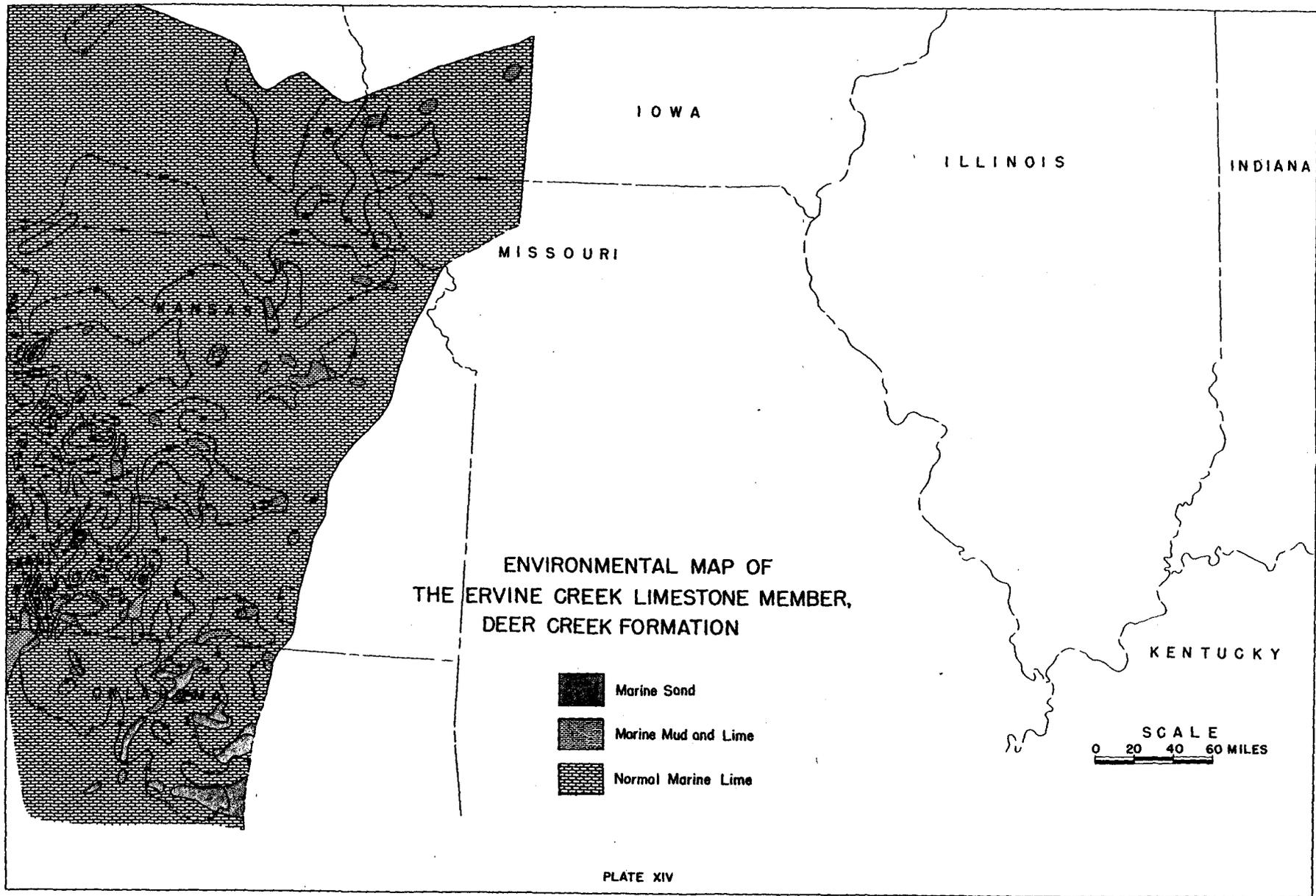


PLATE XIV

Larsh-Burroak Shale Member

Underlying the Ervine Creek Limestone is a widespread marine, black or gray shale, Larsh-Burroak. The Larsh-Burroak shale was originally defined in Nebraska as three units: Burroak Shale, Haynies Limestone, and Larsh Shale. It appears that the Burroak Shale pinches out in northeastern Kansas and the Haynies Limestone becomes an indistinguishable part of the overlying Ervine Creek Limestone (Condra and Reed, 1943).

The Burroak Shale is named for beds near the Burroak school in E 1/2 Sec. 21, Tsp. 71 N., Rge. 43 W., Fremont County, Iowa, (Condra and Reed, 1937). It was previously named Mission Creek Shale.

The Larsh Shale was named by Condra (1927) from the Larsh farm, two and one half miles east and one and one quarter miles north of Union, Nebraska.

In Oklahoma beds correlated with this unit are unnamed. They include the shales and local sandstones occurring between the Deer Creek and Plummer limestones (see Fig. 1).

In Nebraska, Iowa, Missouri, and northeastern Kansas the Larsh-Burroak Shale consists of an upper bed of gray to yellow clayey shale and a lower bed of black fissile shale. The upper bed rarely contains fossils, and the lower bed contains only conodonts.

The shale is absent in parts of central Kansas and Oklahoma where no deposition occurred during this interval. It reaches a maximum thickness of 27 feet in Oklahoma along the outcrop, but averages 5 feet or less.

Rather widespread marine conditions with restricted circulation existed during Larsh-Burroak time (see Plate XV). In Nebraska, Iowa, Missouri, and eastern Kansas large areas were sites of black mud deposition. The causes for the restricted circulation which allowed the accumulation of the black muds are problematical. It may be that these areas were deeper depressions in the sea floor where the bottom waters were unaffected by currents or they may have been shallow areas restricted from the open sea by some physical barrier. To the south and west normal marine muds were forming more generally. Local sand deposits formed where currents built up bars.

In Nebraska, Iowa, and Missouri there were small areas where lime was deposited over the black shale. Elsewhere normal marine mud was still forming.

Rock Bluff Limestone Member

The Rock Bluff Limestone is a massive, vertically jointed bed of dark blue limestone containing fusulinids, brachiopods, and pelecypods. Its type locality is in the Missouri River bluffs northeast of Rock Bluffs, Nebraska (Condra, 1927).

It averages 2 feet in thickness and ranges from a feather edge to 20 feet in south central Kansas and Oklahoma.

During this interval (Plate XVI) normal marine conditions prevailed throughout the area studied. A few isolated areas were sites of marine mud or sand deposition, and in a few places no deposition occurred during this interval.

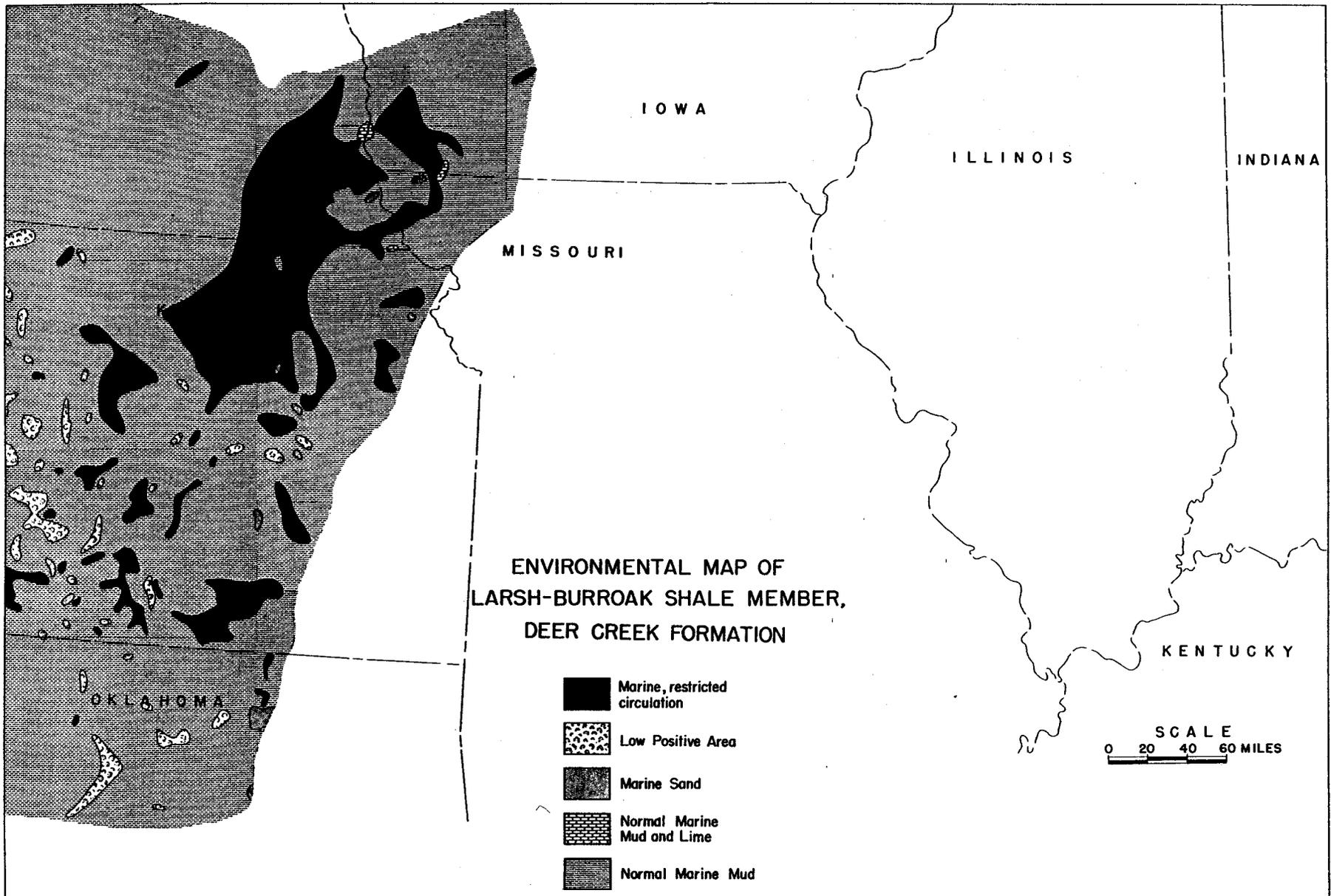


PLATE XV

Oskaloosa Shale Member

The Oskaloosa Shale Member of the Deer Creek Formation was named by Moore (1936) for beds near Oskaloosa, Kansas. It is a yellowish-gray sandy shale with a rather restricted geographical area.

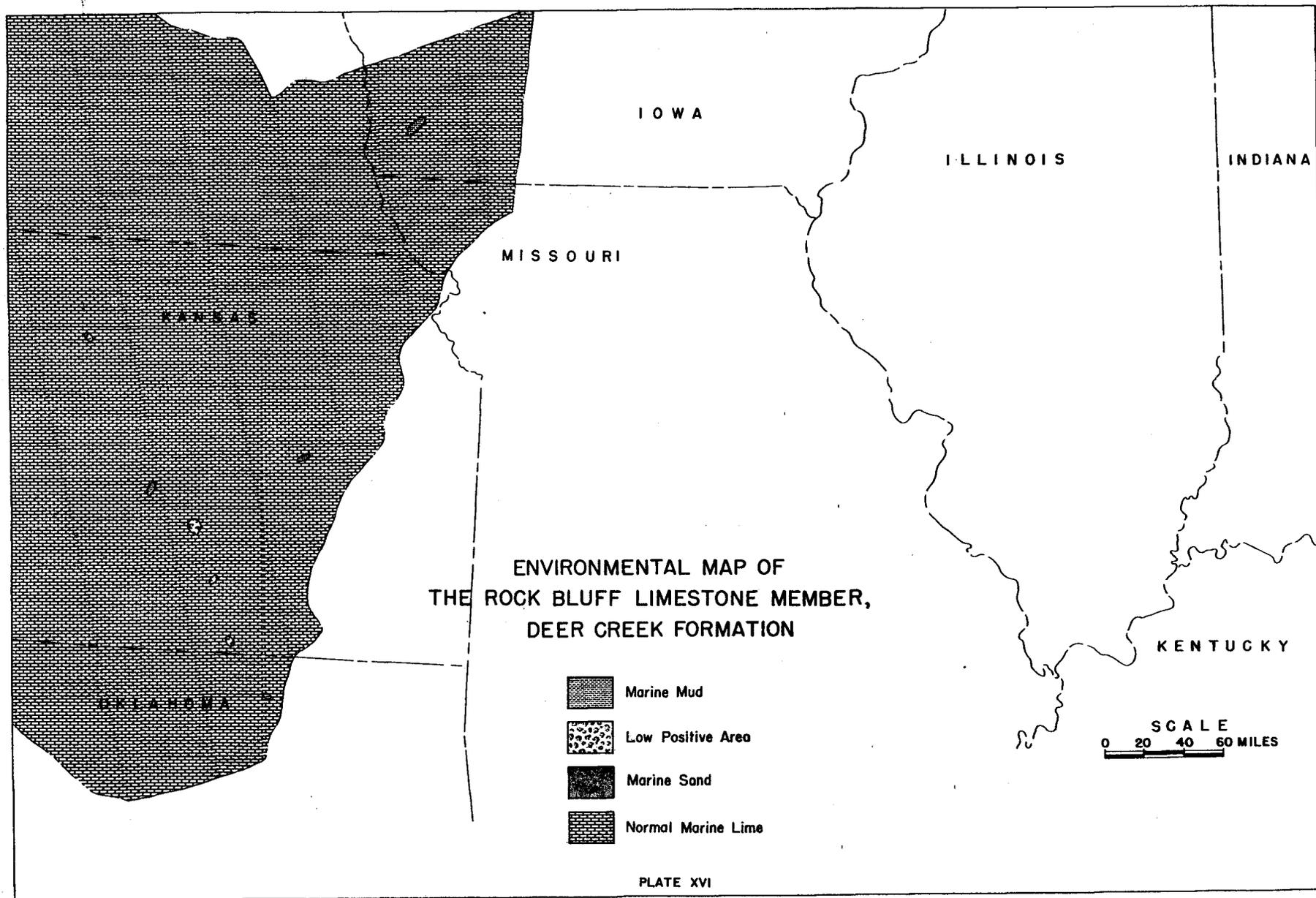
It reaches a maximum thickness of 20 feet in parts of eastern and south central Kansas and in Oklahoma along the outcrop belt. In Nebraska and northwest central Kansas it is absent.

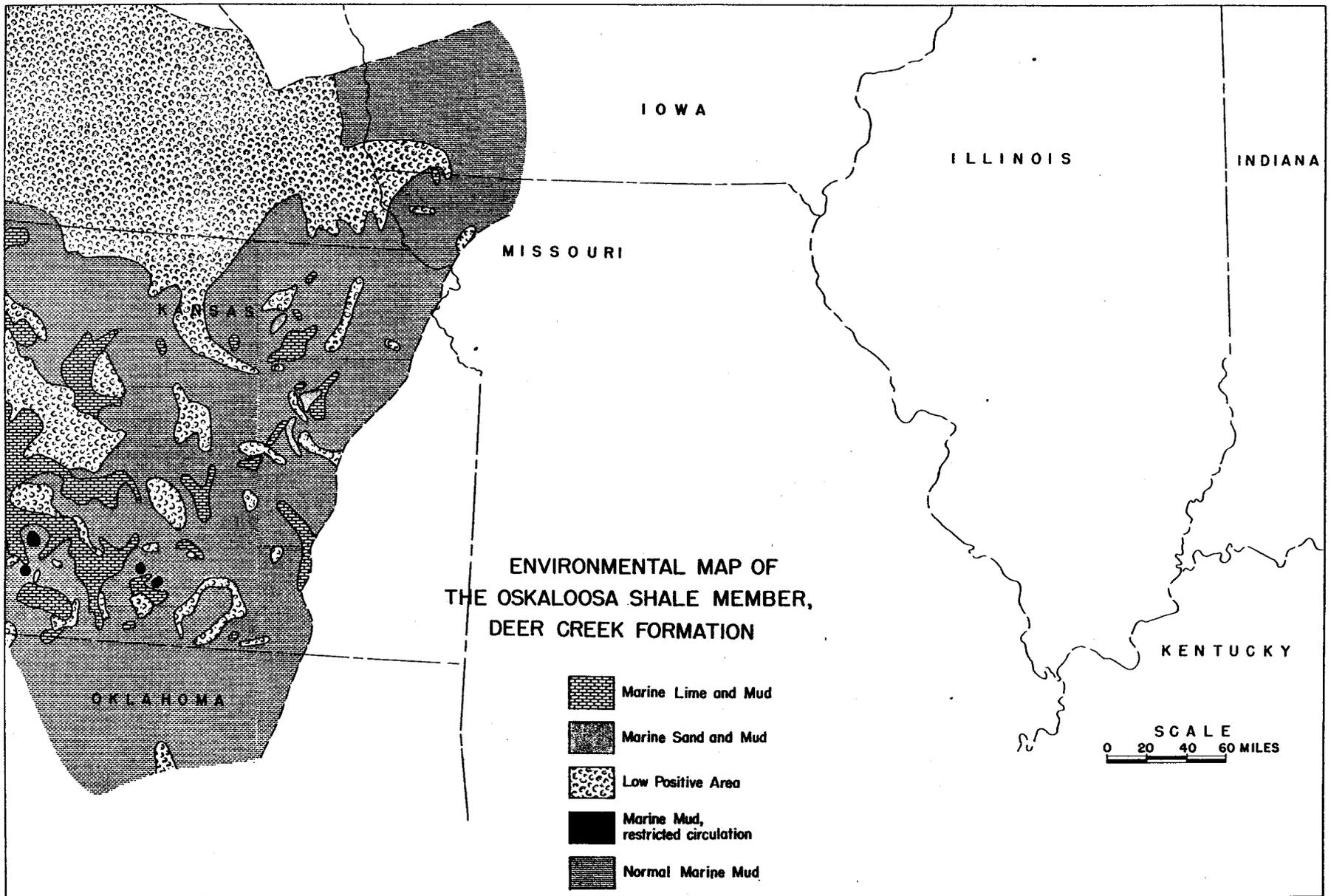
In places a thin bed of nodular or algal limestone occurs. Fossils are not common in the shale, but it occasionally contains brachiopods and pelecypods.

This interval does not exhibit the widespread uniformity of environment (see Plate XVII) that is evident during other intervals above. The geographical restriction of this unit is a result of the influence of a large clastic wedge underlying the limestone below it. This wedge (Tecumseh Shale) is similar to the Calhoun and Severy shales and like the Calhoun Shale it had an effect on the configuration of the beds deposited over it.

Just as the upper beds of the Calhoun Shale to the east were deposited contemporaneously with the lower beds of the Hartford Limestone to the west, it appears that the Tecumseh Shale was still forming in the northwest while the marine Oskaloosa shales formed elsewhere.

Where the underlying Ozawkie Limestone is absent, it is impossible to distinguish beds equivalent to Oskaloosa from beds of the underlying Tecumseh Shale. It is assumed that where the Ozawkie Limestone





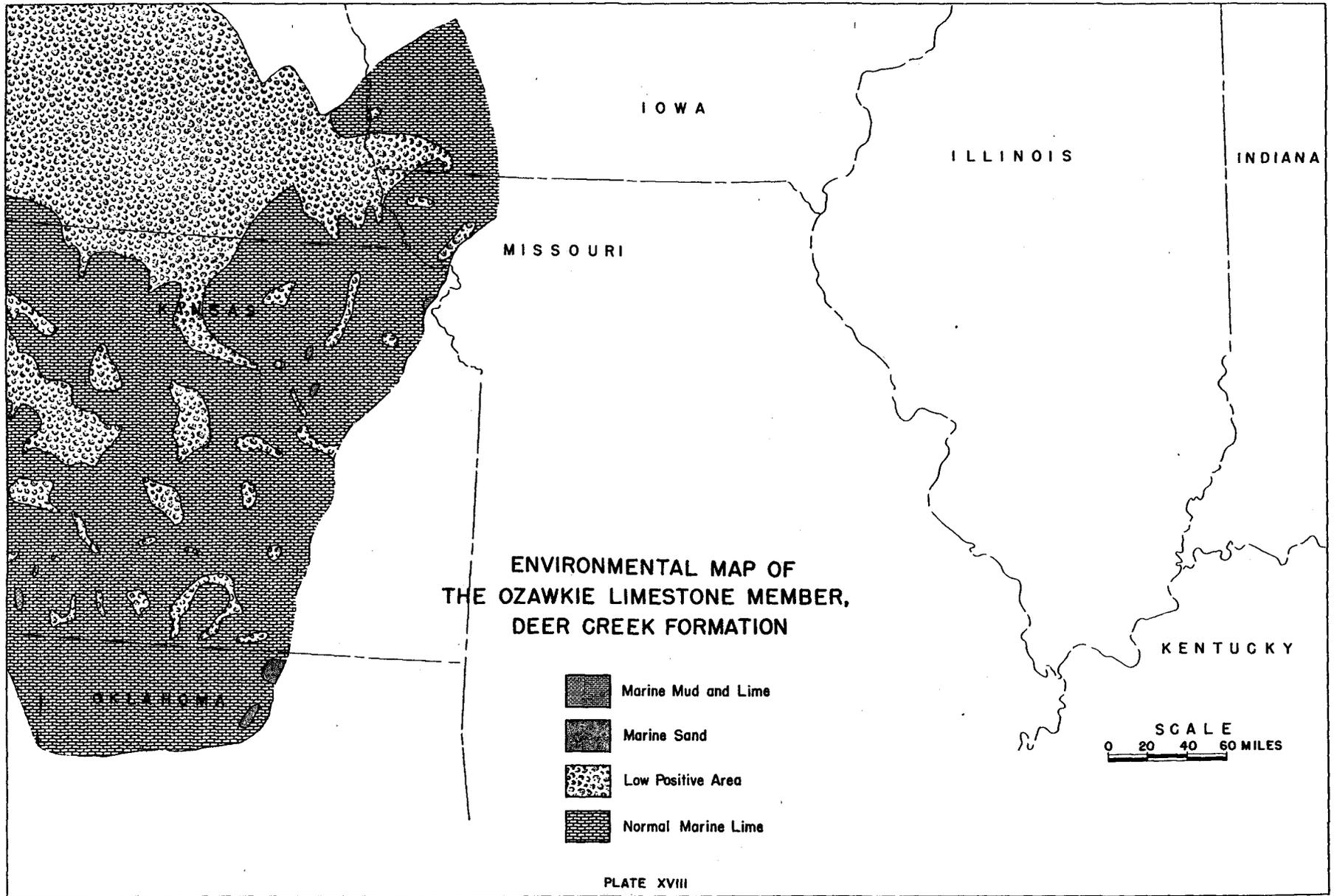
was absent the Oskaloosa Shale above it was also. This assumption is probably valid in general but more detailed study will undoubtedly prove it incorrect in local areas. Since the Rock Bluff Limestone almost entirely covers the area studied, it seems reasonable that the seas of the Oskaloosa interval approached the areal extent of the Rock Bluff to a greater degree than the earlier Ozawkie seas did.

During Oskaloosa time much of the area to the north and west was a low positive area where deposition was negligible (see Plate XVII). Quite possibly this was the area of the thicker part of the clastic wedge and it may still have had a deltaic environment. The sea covered the remainder of the area except for isolated islands or very shallow areas where no deposition occurred. To the west normal marine lime formed. To the east marine muds were forming, and, locally, shallow-water algal colonies grew. In eastern Kansas thin beds of marine sand formed where conditions were favorable. Small areas of restricted circulation in south central Kansas allowed the preservation of organic debris in the mud, thereby imparting a black color to the deposits.

Ozawkie Limestone Member

The underlying Ozawkie Limestone is the lowermost member of the Deer Creek Formation. Its type locality is Ozawkie, Kansas, as described by Moore (1936).

It is a brownish-gray massive limestone containing fusulinids, pelecypods, brachiopods and algal remains. In some places oolitic layers



are present. The greatest thickness reached is 30 feet in south central Kansas.

As explained above during this interval much of north central Kansas and Nebraska was a low positive area with little or no deposition (Plate XVIII). To the south and east rather shallow seas covered most of the area and lime was deposited. The shallow nature of the seas is indicated by the presence of algal colonies and oolitic deposits. In isolated spots thin muds were intercalated with the lime deposits. Along the present eastern outcrop in Oklahoma calcareous beach sands accumulated and the waves and currents left eroded limestone pebbles and ripple marks in it.

SUMMARY AND CONCLUSIONS

Conditions were not as uniform throughout the Mid-continent area as one might expect from observations of outcrop data. This is probably because the line of outcrop is more or less perpendicular to the directions of sediment transport and invasion of the sea.

Still, however, conditions were surprisingly uniform for most intervals. Apparently the paleoslope was very gentle and relief was small so that a change in sea level of a few tens of feet would inundate a large part of the midcontinent.

The repetitive nature of the megacycles is a problem which cannot easily be explained. The unique characteristics of many of the limestones and shales in the megacycle and their repetition in the same order in each megacycle indicate that the conditions which formed them were much more complex than a simple series of transgression - regression cycles. These conditions were present through the entire Mid-continent area and probably through an even larger area.

One sediment source was to the northeast in Kansas; the sediment was possibly transported from distant sources across Iowa or northern Missouri and Illinois. Another source was to the south and east in Oklahoma, originating in the newly forming Ouachita Mountains.

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