KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 82-20

DEPOSITIONAL HISTORY AND DIAGENESIS OF THE VIOLA LIMESTONE IN SOUTH-CENTRAL KANSAS

by

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Depositional History and Diagenesis of the Viola Limestone in south-central Kansas

by

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Submitted to the Department of Geology and the
Faculty of the Graduate School of the University
of Kansas in partial fulfillment of the requirements
for the degree of Master of Science with a major in Geology.

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ABSTRACT

The Viola Limestone is a Middle to Upper Ordovician carbonate sequence present in the subsurface of Pratt and Barber counties in south-central Kansas. A subsurface study of the Viola, based on cores, cuttings, and sample logs was undertaken to 1) determine the depositional environment and diagenetic history of the Viola in south-central Kansas, 2) examine the relationship between mineralogy, depositional environment, diagenesis, and structure in the study area, and 3) evaluate the petrographic accuracy of Bornemann's (1979) lithofacies map which was constructed using average geophysical well-log responses from neutron, density, and sonic logs. Bornemann (1979) used digitized log traces and an interactive computer program for well-log analysis, thereby enabling speedy analysis of a subsurface area. Although some variations did occur in the exact locations of his lithofacies boundaries, Bornemann's (1979) lithofacies map had similar trends and patterns to the lithofacies map produced in this study through the conventional use of core and cuttings.

In this study the Viola Limestone was divided into four mappable units. The basal and upper limestones, units 1 and 3, are composed of crinoid packstones and grainstones. A lower cherty dolomitic limestone, unit 2, is composed of cherty, dolomitic, mixed-skeletal wackestones and cherty dolomitic mudstones; and an upper cherty dolomitic limestone, unit 4, is composed of mixed-skeletal wackestones, intraclast wackestones, and dolomitized mudstones.

The facies were deposited on a submerged carbonate shelf, in three broad environmental belts that lay roughly parallel to the Central Kansas arch: 1) a moderate to high energy, open-marine environment that was the

site of deposition of the crinoid packstone-grainstone facies; 2) a semi-restricted low-energy environment where the mixed-skeletal wackestone facies was deposited; and 3) a very restricted environment closest to the arch, where the cherty, dolomitized mudstones were deposited.

ACKNOWLEDGMENTS

I would like to acknowledge my thesis committee, Dr. Brady-chairman, Dr. Doveton, and Dr. Kaesler for critically reviewing this manuscript; the Kansas Geological Survey for providing support in every aspect of the preparation of this thesis; Marathon Oil Company for their drafting and photographic work; and Marvin Woody for editing the intial drafts and providing moral support throughout this research.

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INTRODUCTION

The Viola Limestone is a Middle Ordovician carbonate formation separated by unconformities from the underlying Simpson Group and the overlying Maquoketa Shale (Fig. 1). It consists of interbedded limestones, dolomites, and cherty dolomitic limestones, which were deposited in open-marine to very restricted conditions on a large carbonate shelf that extended from Ohio to Idaho and as far south as Louisiana (Lyons, 1966). Petrography of the Viola has been studied in detail in southern Oklahoma (Wengerd, 1948; Mairs, 1966) and Arkansas (Freeman, 1965). The Viola is entirely subsurface in the study area, which includes Pratt and Barber counties as well as portions of adjacent counties in south-central Kansas (Fig. 2).

Studies of subsurface formations have traditionally relied on sample logs prepared from borehole cuttings and cores to describe the gross variations in geometry and lithologic character of the rocks. Although cores furnish the most complete information, they are generally limited in availability and serve only as a check on other sources of data (Bornemann, 1979). Bornemann (1979) developed a technique for subsurface lithofacies analysis using average geophysical well-log responses from neutron, density, and sonic logs. He calculated porosity and three mineralogical components (calcite, dolomite, and silica) for the Viola in Pratt, Barber, Kiowa, and Comanche counties in south-central Kansas. After plotting the mineral fractions on a compositional triangle, Bornemann subdivided the Viola on the basis of lithology and constructed a suite of lithofacies maps. These maps, in conjunction

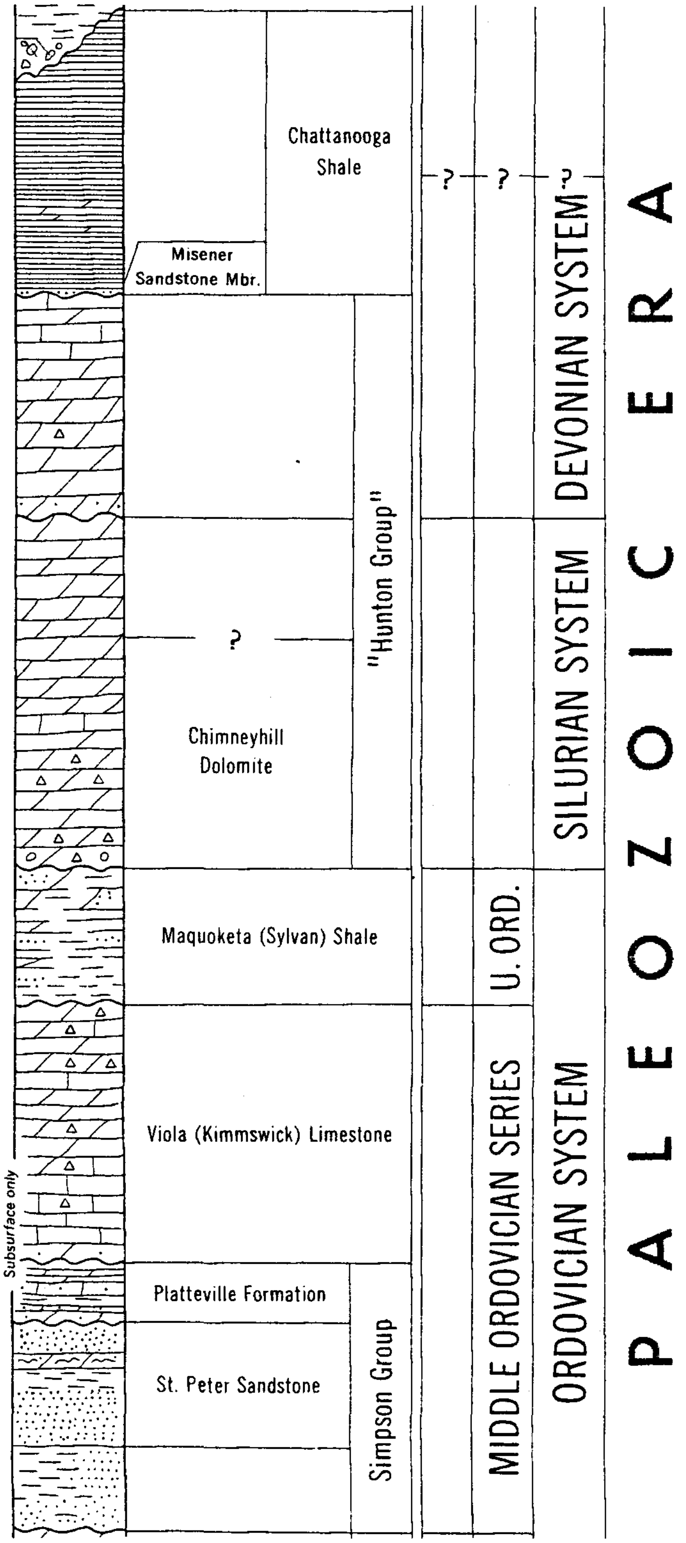

Figure 1 Stratigraphic column of the Ordovician, Silurian, and Devonian Systems in Kansas (from Zeller, 1968).

with a set of structure maps, were analyzed with respect to the structural, depositional, and diagenetic history of the Viola. This method used digitized log traces and interactive computer programs for well-log analysis and enabled speedy analysis of a subsurface area.

Geophysical well-logs provide remote-sensing measurements of the physical properties of subsurface rocks and require direct lithologic observations to monitor interpretations. Descriptions of cuttings and cores provide the necessary lithologic observations to assess lithofacies maps produced from geophysical logs. The work on which this thesis is based was undertaken to 1) provide those necessary lithologic observations, consisting of descriptions of lithofacies and diagenetic alterations, and interpretation of the depositional history, 2) evaluate the petrographic accuracy of Bornemann's lithofacies map, and 3) determine the significance of any major trends and patterns on the lithofacies map with regard to depositional facies, diagenesis, and structure.

METHODS OF STUDY

Ten cores of the Viola Limestone in Barber and Pratt counties (fig. 2) in south-central Kansas were slabbed and examined. Descriptions included depositional texture, grain size, mineral and constituent composition, diagenetic features, and sedimentary structures. The rocks were classified using the depositional texture classification of Dunham (1962). Critical areas of the cores were thin sectioned (133) for more detailed examination. These were stained with alizarin red-S and potassium ferricyanide following procedures described by Dickson (1965) to distinguish ferroan carbonate and to differentiate calcite from dolomite.

The location and number of cores described in this study were determined by their availability in the core library of the Kansas Geological Survey. None of these cores provided complete sections, and well cuttings from the same wells were used to supplement the cores. The cuttings were examined, and ninety-four thin sections were made at selected intervals for more detailed descriptions similar to those of the core thin sections.

Sample logs prepared by J. C. Davies and Ruth Bell Steinberg compared favorably with core and cutting descriptions produced by the author. These sample logs were used to determine the distribution of the facies in areas lacking core coverage. For ease of comparison with the computer generated lithofacies map produced by Bornemann (1979), the facies were classified as residual chert, limestone, dolomite, or cherty dolomitic limestone lithofacies using the triangle in figure 3.

Distribution of the facies was mapped using these four classifications, and from this, a lithofacies map, representing the dominant lithofacies present, was produced.

	Company well	County	Section Township Range	Location	Depth meters (feet)
✗ 1	Sinclair-Prairie 1 Degeer	Barber	34 32S 15W	NE NW NE	1508-1551 (4948-5087)
✗ 2	Sinclair 1 Alice Gentry	Barber	1 33S 15W	NE C NE	1571-1594 (5106-5231)
✓ 3	Sinclair-Prairie 1 M. Binning	Barber	26 32S 13W	SE SE SW	1454-1481 (4769-4860)
✓✗ 4	Lario 2 Randles	Barber	34 32S 12W	C NE NE	1417-1447 (4649-4746)
5	I.T.I.O. 1 George	Barber	12 33S 10W	C SE SW	1433-1458 (4702-4782)
✗ 6	Carter 1 Lytle	Barber	6 32S 14W	C NE NW	1435-1473 (4709-4832)
✗ 7	Sinclair-Prairie 1 A. Oldfather	Barber	18 31S 18W 14 ?	NE NE SW	1349-1389 (4426-4556)
✗ 8	Sinclair 4 G. Oldfather	Barber	7 31S 14W	SW NW SE	1319-1357 (4328-4453)
9	Bridgeport 1-I Brown	Pratt	25 29S 13W	NE C NW	1361-1400 (4465-4592)
✓ 10	Sinclair-Prairie 1 Blurton	Pratt	22 28S 12W	NE SE NW	1309-1343 (4294-4407)

Table 1 Location of cores used in this study.

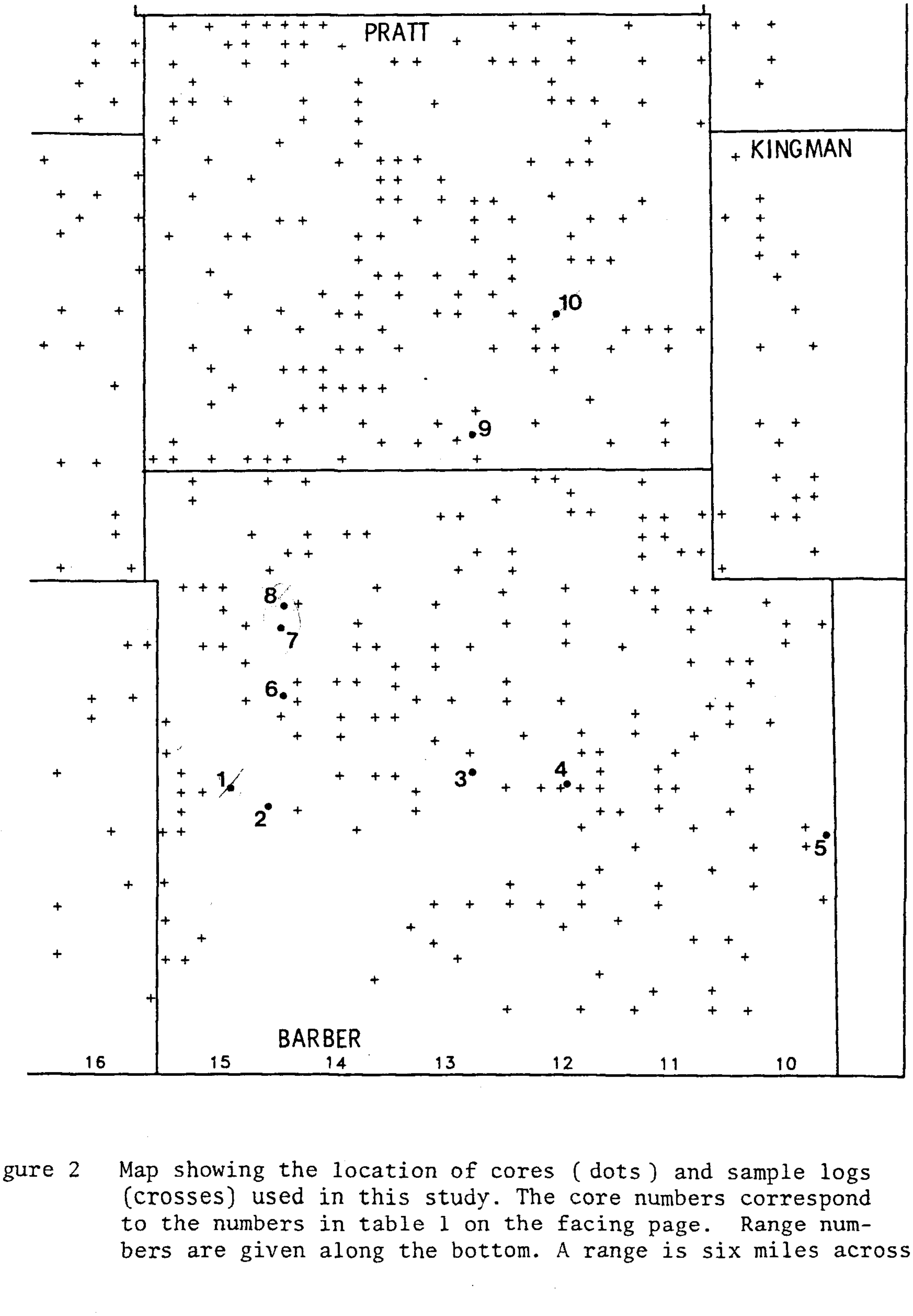

Figure 2 Map showing the location of cores (dots) and sample logs (crosses) used in this study. The core numbers correspond to the numbers in table 1 on the facing page. Range numbers are given along the bottom. A range is six miles across.

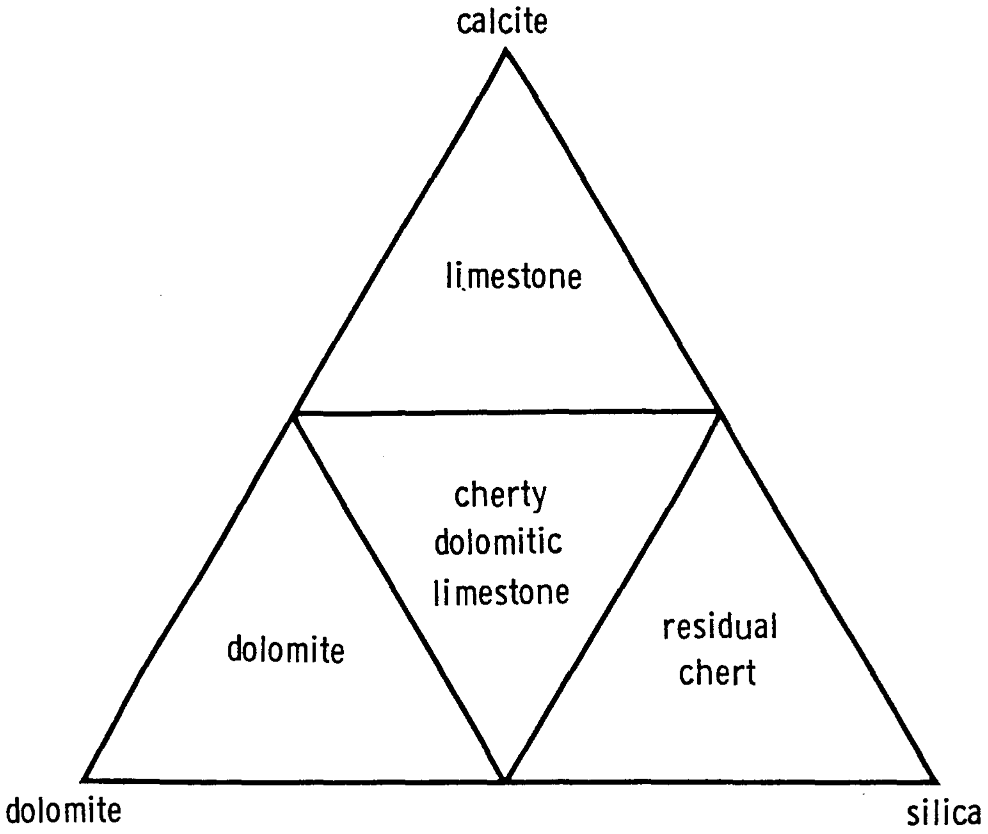

Figure 3 Classification triangle.

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GEOLOGIC SETTING AND STRATIGRAPHY

The study area is approximately 7500 square kilometers (2160 sq. miles) and includes Pratt and Barber counties as well as portions of adjacent counties. The primary structural element is the Pratt Anticline, which divides the Sedgwick Basin to the east from the Hugoton Embayment to the west. To the north the area is bounded by the Central Kansas Uplift (figure 4).

Ordovician paleogeography and sedimentation in the Midcontinent were predominantly controlled by the extent to which epicontinental seas covered the Transcontinental Arch and the position of the North American plate relative to the earth's latitudinal belts (Ross, 1976). During deposition of the Viola, the Transcontinental Arch and Canadian Shield were largely inundated, and normal-marine conditions prevailed in south-central Kansas where carbonate sedimentation was dominant.

The Middle Ordovician Viola Limestone represents the Trentonian Stage (Witzke, 1980) in south-central Kansas. It is roughly equivalent to the Red River of the Williston Basin (Witzke, 1980); the Kimmswick of Missouri, Illinois, and Arkansas (Lee, 1943); and the Galena of Iowa and Nebraska (Ireland, 1966). It represents one section of a broad epicontinental sea that existed over the midcontinent region during one of the most widespread inundations in North American history (Ross, 1976).

The Viola Limestone at its type locality in the Arbuckle Mountains was originally described by Taff (1904) as including all of the beds between the Simpson Group and the Maquoketa or Sylvan Shale. It extends into the subsurface of Kansas where it unconformably overlies

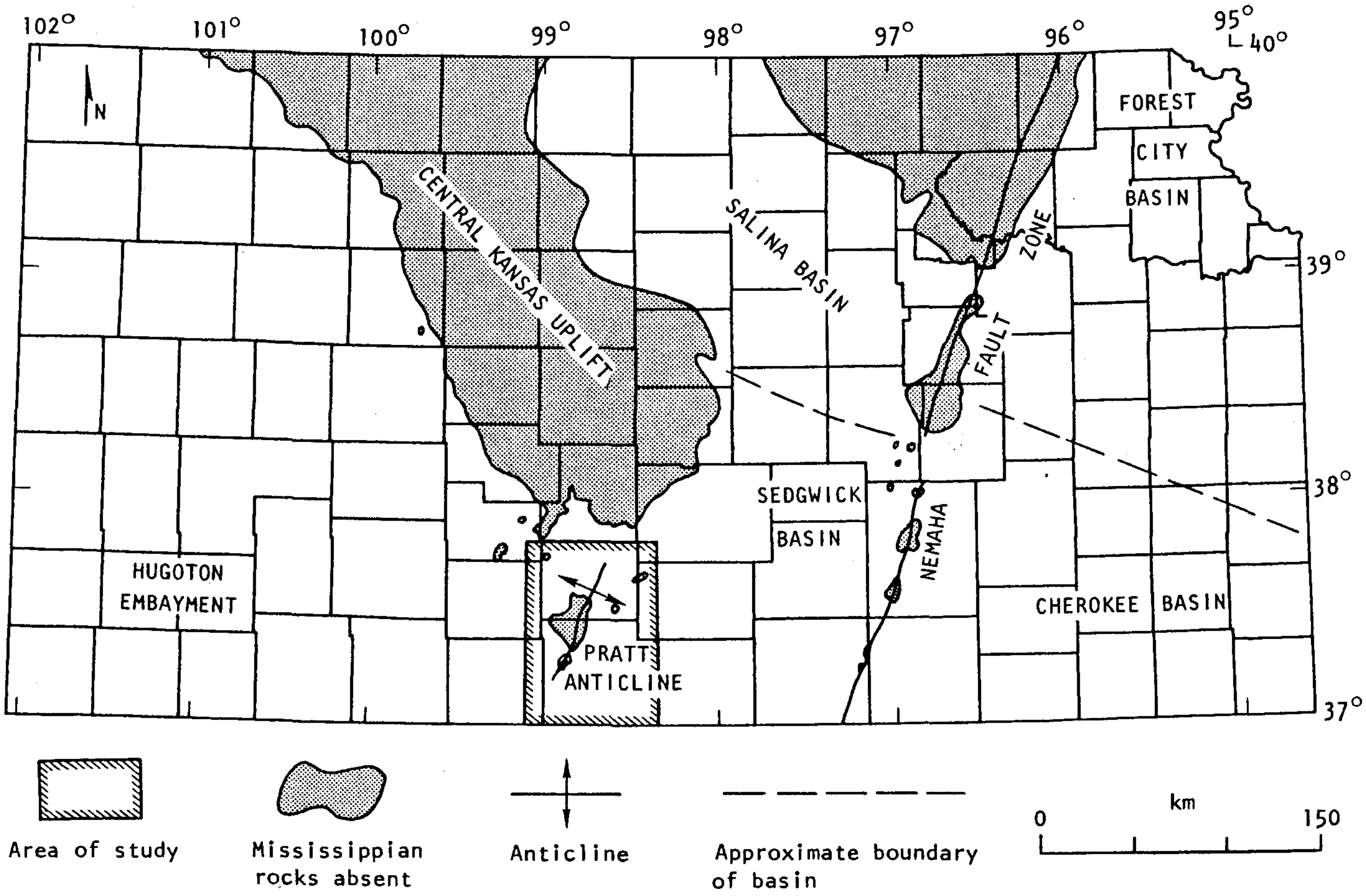

Figure 4 Map showing the major structural features in the subsurface of Kansas and location of the study area (after Adkison, 1972).

the Simpson Group in south-central Kansas. The Viola was originally overlain by the Maquoketa Shale in Pratt and Barber counties. This formation, however, has been almost entirely stripped from the study area by pre-Mississippian erosion.

The Viola ranges in thickness from 25 to 50 meters (75 to 150 feet) in the study area. I divided it into four mappable units, which are referred to as the basal limestone, the lower cherty dolomitic limestone, the upper limestone, and the upper cherty dolomitic limestone; units one through four respectively (fig. 5 and 6). Unit 1, the basal limestone, ranges in thickness from 1.5 to 7.6 meters (5 to 25 feet) and is composed of crinoid packstones and grainstones. It forms an almost continuous sheet across the study area (fig. 7) and has a characteristic log response that is useful for determining the boundary between the Viola and the underlying Simpson Group. Unit 2, the lower cherty dolomitic limestone, was originally present throughout the study area but has since been removed by erosion over areas on the Pratt Anticline (fig. 7). It ranges in thickness from 3.0 to 31.7 meters (10 to 104 feet) and consists of dolomitic, mixed-skeletal wackestones and dolomitic mudstones. The upper limestone, unit 3, is present today only in the southwestern half of the study area (fig. 7), having been removed by erosion in the northeast. It ranges in thickness from 1.2 to 9.8 meters (4 to 32 feet) and consists of crinoid packstones and grainstones. Unit 4, the upper cherty dolomitic limestone, ranges in thickness from 1.2 to 14.6 meters (4 to 48 feet) and consists of mixed-skeletal wackestones with some dolomitic intraclast wackestones and dolomitic mudstones over the Pratt Anticline. It presently exists only

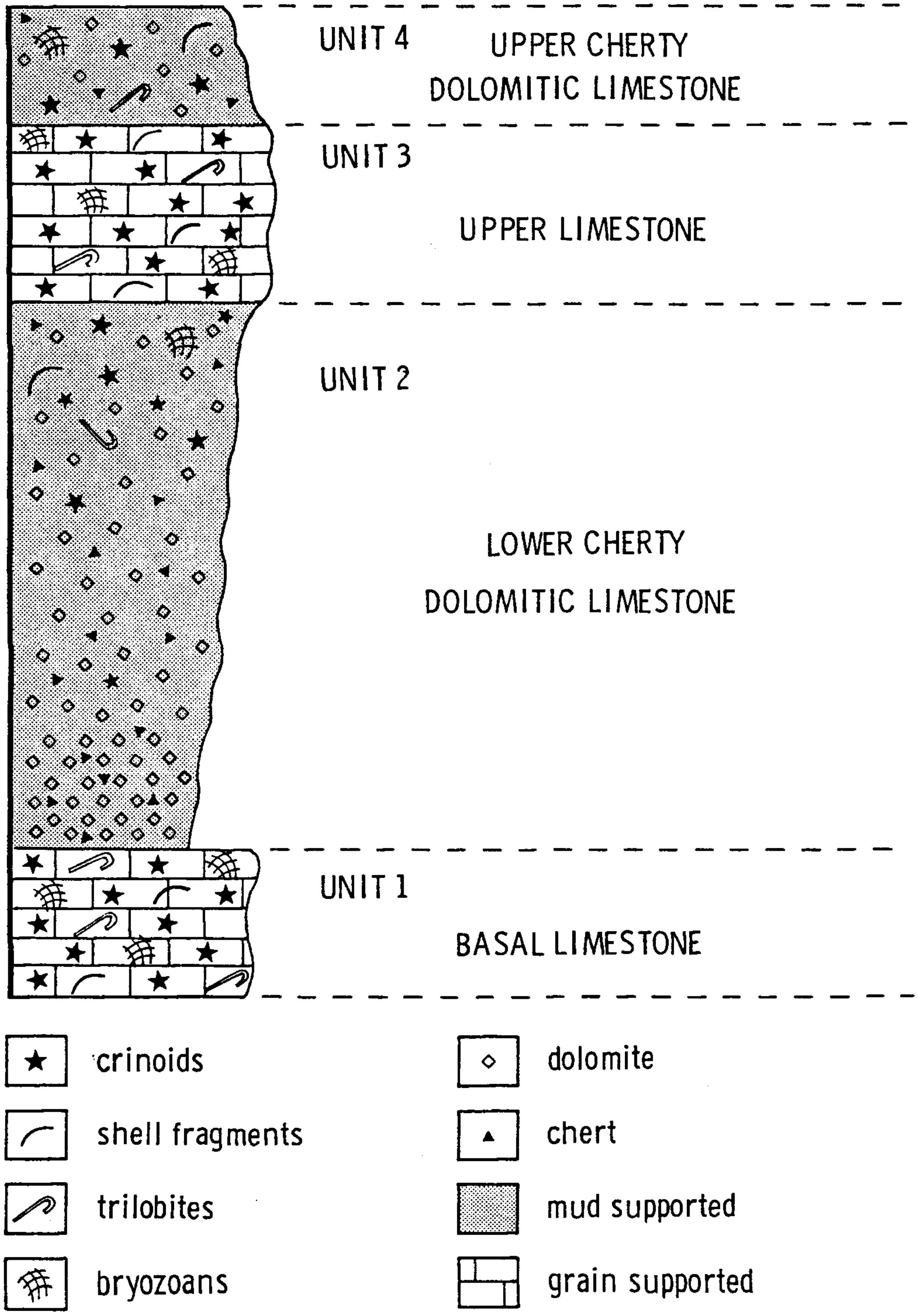

Figure 5 Generalized stratigraphic section of the Viola Limestone in south-central Kansas.

Figure 6. Photograph of slabbed core showing the four units of the Viola Limestone. Depth increases from left to right and from top to bottom. The core is from 1 Degeer.

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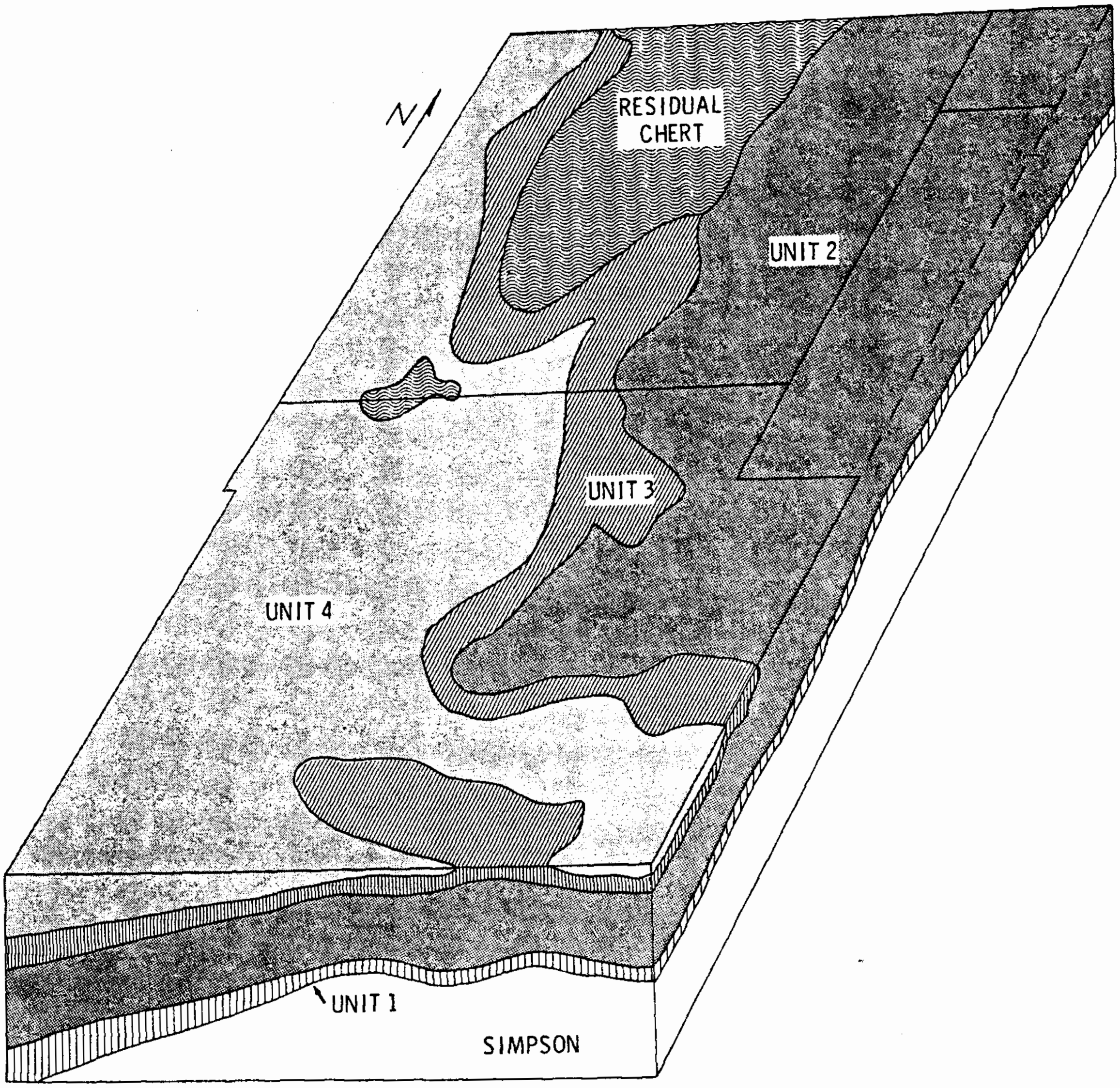

Figure 7 Block diagram of the study area showing the present distribution of units 1 - 4 and the location of the residual chert.

in the western and southern part of the study area, having been removed by erosion to the east and north (fig. 7).

LITHOFACIES

The Viola Limestone in south-central Kansas consists of crinoid packstones and grainstones, cherty dolomitic mixed-skeletal wackestones, dolomitic intraclast wackestones, and cherty dolomitic mudstones. Each facies consists of rocks with similar sedimentary characteristics that suggest a distinct depositional environment. The crinoid packstones and grainstones are light-gray to white, are moderate to well sorted, contain very little mud, and consist predominantly of crinoids, with some trilobites, brachiopods, and bryozoans. The skeletal wackestones, which are light-green to gray, also commonly contain crinoids, trilobites, brachiopods, and bryozoans; but they are less abundant and less diverse. They may also contain ostracodes, sponge spicules, and pellets. The matrix of the wackestones is commonly partially or totally dolomitized, and chert nodules are fairly common. The dolomitic intraclast wackestones are laminated green and light-gray dolomites that contain green intraclasts. The cherty dolomitic mudstones are light-brown to dark-gray, fine- to coarse-grained dolomites with chert nodules up to 8.5 cm (3.3 inches) in length. They commonly contain a small percentage of calcite, present as fine-grained neomorphic spar between the dolomite rhombs.

where?

<u>Unit 1</u> and <u>Unit 3</u> - The basal and upper limestones are very similar and will be described together. They are both represented by the crinoid packstone-grainstone facies (fig. 8). Other fossil fragments include predominantly brachiopods, bryozoans, and trilobites, with a few

Figure 8. Crinoid packstone-grainstone facies of units 1 and 3.

A) Core photograph

B) Photomicrograph - Note the abundant syntaxial cement on the crinoids, the micritic rims on the trilobites, and the dolomite rhombs in the bryozoans. The bar scale is 1 mm.

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mollusks, ostracodes, sponge spicules, and unidentified phosphatic fossils. Pellets and intraclasts are rare. The interparticle areas are largely filled with optically continuous calcite overgrowths on the crinoids, with minor amounts of bladed cement on the other fossil fragments. Lime mud is present, but only rarely does it occur in large enough quantities to prevent extensive cementation by syntaxial overgrowths on the crinoids. The fossil fragments have sufficient grain contacts to form a supporting framework, and in some cases, pressure solution has resulted in embayed and sutured grain contacts.

The fossils vary in their state of preservation. The crinoids, which are the best preserved, may be partially replaced by dolomite or silica and may display peripheral micritization due to algal or fungi borings (Bathurst, 1966). The trilobites generally are slightly abraded and show the most extensive peripheral micritization. Brachiopods are usually fairly broken up and abraded and are most commonly silicified, while bryozoans show the least preservation and are often completely recrystallized or dolomitized.

Adkison (1972) reported cross-bedding in the basal limestone, but none was recognized in samples in the study area. Green shale stringers occur in places, as do lenses of fine-grained dolomite (fig 9). These lenses may be up to 1 cm (0.39 inch) thick and were probably originally lime mud. Large intraclasts, up to 2.5 cm (1 inch) long, which were ripped up from these lenses, may also occur.

Aside from the dolomitized mud lenses, dolomite also occurs as well-developed rhombs ranging in size from 0.08 to 0.26 mm (0.003 to 0.01 inch). They are found replacing inter- and intraparticle lime mud

Figure 9. Photomicrograph of a dolomite lense. Note the lack of syntaxial rims on the crinoids, in the upper part of the photograph, which are surrounded by a fine grained matrix. The bar scale is 1 mm.

Figure 10. Photomicrograph of chert nodule showing ghosts of a bryozoan, crinoid, and shell fragment. The bar scale is 1 mm.

Figure 9

Figure 10

19a

and may also replace fossils. The amount of dolomite increases as the original amount of lime mud increases. This is probably due to the greater ease of dolomitization of the original aragonitic or high-magnesium calcite mud (Cloud, 1962). Also, since the lime mud impedes the complete filling of interparticle areas by syntaxial overgrowths, the rocks with greater amounts of lime mud may have been more porous than those with little mud, thereby aiding dolomitization.

Chert nodules are rare in this facies. When they do occur, they are composed of a mixture of cryptocrystalline and microcrystalline quartz, chalcedony, and abundant calcite inclusions. Their long axis may be up to 5 cm (2.0 inches) and is oriented roughly parallel to bedding. The nodules contain numerous fossil ghosts of trilobites, brachiopods, bryozoans, crinoids, and ostracodes and have a mottled light-brown, gray, and white coloration (fig. 10). The contact between nodules and the carbonate matrix is abrupt. The chert nodules are found in those samples with the highest original lime-mud content and consequently the most extensive dolomitization.

<u>INTERPRETATION</u> The fossil diversity and abundance, together with the minor amounts of mud and moderate abrasion of the fossils, indicate this facies represents deposition in an open-marine environment with normal salinity and moderate- to high-energy conditions.

<u>Unit 2</u> - This unit was not well sampled so detailed descriptions of only a few core were possible. A pale-green or light-gray, argillaceous, cherty, dolomitic mixed-skeletal wackestone occurs at the top of this unit (fig. 11). The matrix, which was probably originally aragonitic

Figure 11. Dolomitic mixed-skeletal wackestone facies at the top of unit 2.

A) Core photograph

B) Photomicrograph - The matrix of this sample has been completely dolomitized. Note the lack of syntaxial rims on the crinoids and the partial silicification of the brachiopod fragment (arrow). The bar scale is 1 mm.

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and high-magnesium calcite mud, by analogy to modern shallow water carbonates (Cloud, 1962), has since been partially or completely dolomitized. The dolomite exists as well-formed rhombs from 0.08 to 0.26 mm (0.003 to 0.01 inch) in size and as very fine-grained anhedral crystals. The dolomite rhombs may exhibit as many as five different stages of growth, illustrated by alternating layers of ferroan and non-ferroan dolomite or by dust rings that formed on the surface of the crystals between growth stages. Fine-grained neomorphic calcite spar may exist between the dolomite rhombs. According to Mossler (1971) this indicates that early dolomitization probably preceded alteration of the matrix to low-magnesium calcite.

The fossils in this facies include crinoids, bryozoans, trilobites, brachiopods, sponge spicules, phosphatic brachiopods, ostracods, and unidentified phosphatic skeletal fragments. Only a few of these are present in a single sample. Other constituents include phosphatic pellets and peloids, which are probably recrystallized skeletal fragments. Originally calcareous fossils generally are still calcite, but they may be partially silicified to chalcedony or microcrystalline quartz. The brachiopods and crinoids are most commonly silicified. Some fossils are dolomitized, usually the crinoids, which may be replaced by a single crystal of dolomite (fig. 12) or by many tiny rhombs. Bryozoans whose zooecia have been filled with mud also tend to be partially replaced by dolomite.

The chert nodules in the mixed-skeletal wackestones may be up to 5.2 cm (2.04 inches) long. They are light-gray or white and are

Figure 12. Photomicrograph of dolomitized crinoids (arrows). The bar scale is 1 mm.

Figure 13. Photomicrograph of multiply zoned dolomite rhombs. The rims are alternating layers of ferroan and nonferroan dolomite. The bar scale is 1 mm.

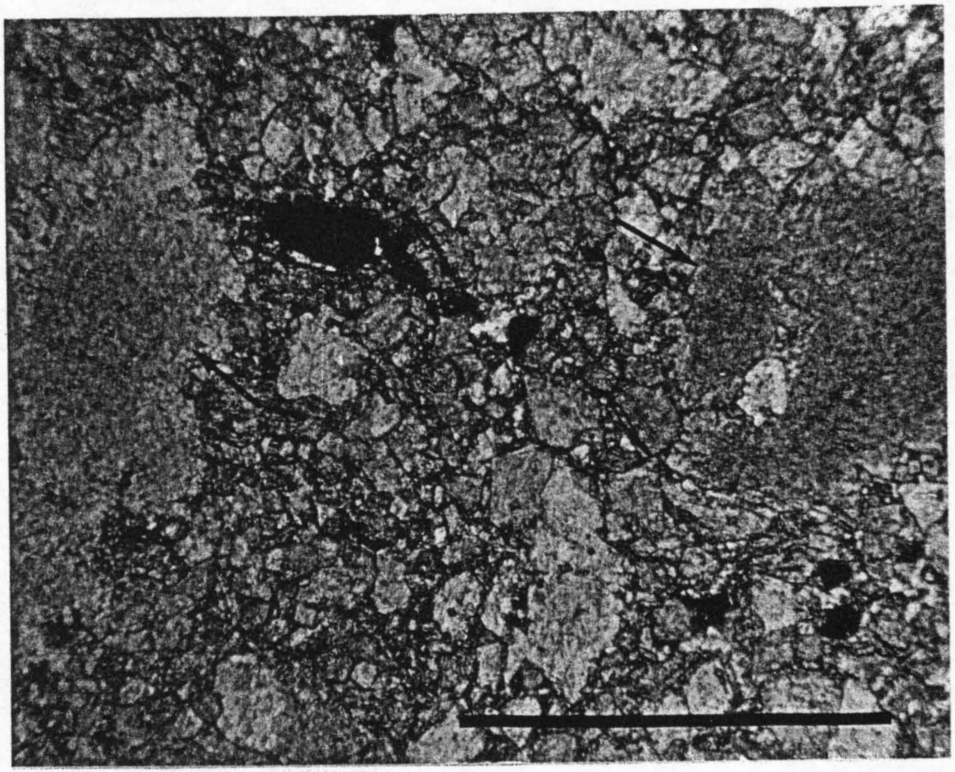

Figure 12

Figure 13

composed of cryptocrystalline quartz. The contact between the chert nodules and the carbonate matrix is usually sharp.

Below the mixed-skeletal wackestone, unit 2 consists of green to light-brown or gray, argillaceous, cherty dolomitic mudstones, which are commonly laminated (fig. 14) or mottled. The dolomite is very fine- to medium-grained and occurs as rhombs or subhedral crystals. Many of the dolomite crystals are multiply zoned with concentric outlines of alternating ferroan and nonferroan dolomite (fig. 13). Ferroan saddle dolomite (Radke and Mathis, 1979) occurs as a cement partially filling the remaining voids (fig. 15). Ferroan saddle dolomite is a variety of dolomite that has a warped crystal lattice (Radke and Mathis, 1979).

Crinoids, brachiopods, trilobites, bryozoans, and ostracodes are rarely present. Most of the crinoids are replaced by large single crystals of dolomite. The other fossils are associated with chert nodules and are either partially or totally silicified depending on how complete chert-nodule formation has been.

Laminations occur as alternating layers of medium- and fine-grained crystals, which may reflect original sediment size differences. Burrows are common and may be filled by dolomite rhombs of a different size from those in the undisturbed sediment. Aside from these features, the size distribution of dolomite crystals is relatively uniform, implying recrystallization from a sediment with a relatively uniform grain size, such as lime mud.

The chert nodules are white or gray with white borders. They may be greater than 8.5 cm (3 inches) in length and are composed of cryptocrystalline quartz. Some chert nodules display ghosts of fossils that

Figure 14. Laminated, dolomitic mudstone facies of unit 2.

A) Core photograph - Note the burrows (arrows).

B) Photomicrograph - The bar scale is 1 mm.

Figure 15. Photomicrograph of ferroan saddle dolomite. Note the curved crystal faces. The bar scale is 1 mm.

Figure 16. Photomicrograph of curved bands of cryptocrystalline quartz (arrows). Note that silicification is most intense at the outermost band. The bar scale is 1 mm.

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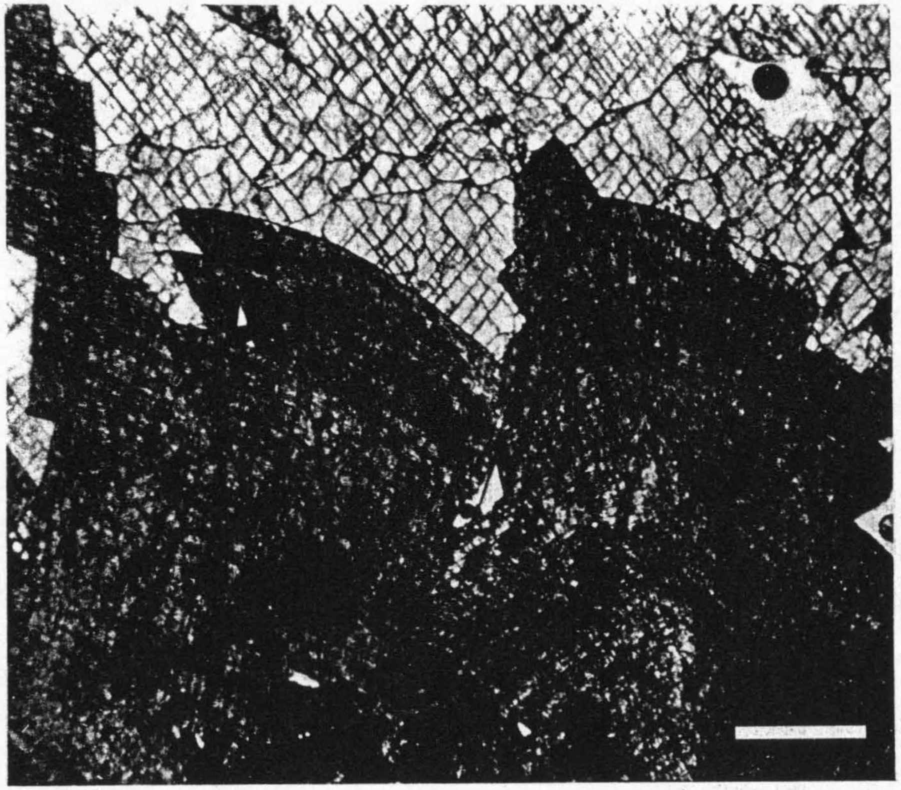

Figure 15

Figure 16 ⟶

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are not present in the dolomitized matrix. This may be interpreted as either preservation of the original texture and composition of the sediment in the chert nodule or preferential silicification around fossils. The uniform texture of the dolomite and the occurrence of partial silicification in the vicinity of fossils supports the latter theory. The fossils were probably washed in and created a localized environment favorable to silicification.

INTERPRETATION While dolomitization could have obliterated any fossil remnants in the lower part of this unit, the uniform grain size of the dolomite implies recrystallization of sediment with relatively uniform grain size, such as aragonitic and high-magnesium calcite mud. The few fossils in this lower section were probably washed in during periods of slightly higher energy conditions. The laminations are current generated. The currents may have had rythmic or cyclic energy conditions that produced alternating layers of large and small grains. The lower section of unit 2 was deposited in a very restricted environment where few macro-organisms could survive and which was subject to currents of variable intensity through time.

The low diversity and lack of abundant fossils in the mixed-skeletal wackestone facies at the top of this unit implies deposition in a semirestricted, low-energy environment, probably seaward of the mudstone facies, where circulation with the open ocean would be sufficient to provide the proper nutrients and salinity to sustain life.

fall ?

In general, unit 2 represents a relative rise in sea level resulting in deposition of mixed-skeletal wackestones over the very restricted dolomitic mudstones.

Unit 4 - Pale-green or light-gray, mixed-skeletal wackestones (fig. 17) were deposited in the southern part of the study area. Their matrix was probably originally aragonitic and high-magnesium calcite mud, which has since been either completely replaced by dolomite or recrystallized to neomorphic calcite spar with minor replacement dolomite.

The dolomite matrix consists of micritic to very fine-grained anhedral crystals and fine-grained clear rhombic crystals. Ferroan dolomite occurs only as a very coarse-grained, void-filling, saddle dolomite cement.

Where the matrix is neomorphic calcite spar, it may consist entirely of extremely fine-grained crystals, or it may be fine- to medium-grained, subhedral crystals. Sometimes it has a texture similar to that of the dolomite matrix of unit 2, with extremely fine-grained anhedral crystals mixed with very fine- to fine-grained calcite rhombs. In places clear, fine-grained, rhombic dolomite occurs in these samples.

Fossils in these mixed-skeletal wackestones include crinoids, brachiopods, trilobites, bryozoans, ostracodes, mollusks, and sponge spicules. Other constituents include peloids, which are probably fossils that have been micritized beyond recognition, and phosphatic pellets. Generally no more than three constituents are present at any given location, and there are usually only one or two varieties. Crinoids are the most common, followed by trilobites and ostracodes.

Figure 17. Mixed-skeletal wackestone facies of unit 4.

A) Core photograph

B) Photomicrograph - The matrix in this sample has been partially dolomitized. The bar scale is 1 mm.

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Figure 18. Dolomitic intraclast wackestone facies of unit 4.

A) Core photograph - The arrows point to the intraclasts.

B) Photomicrograph - Note the difference in grain size between the intraclasts (dark) and the matrix (light). The bar scale is 1 mm.

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Syntaxial overgrowths on the crinoids, when present, are poorly developed. The fossils are usually calcite but may be partially or completely replaced by cryptocrystalline quartz. The crinoids are also commonly replaced by single crystals of dolomite.

In general, the degree of dolomitization of the original matrix increases as the number of fossils decreases. This could imply that the environment became more restricted, possibly by a sharp increase or decrease in salinity, that may have also promoted penecontemporaneous dolomitization.

Chert nodules in the mixed-skeletal wackestones are white or gray with white borders, are composed of cryptocrystalline quartz, and may be more than 6.5 cm (2.55 inches) in length. When formation of nodules is complete, nodules have abrupt contacts with the carbonate matrix. In a number of samples, incomplete chert-nodule formation is evidenced by curved bands of cryptocrystalline quartz (fig 16), with the most intensive silicification occurring at the outer edges of the bands. If the silica replaced a calcite matrix, the calcite crystals are often rimmed with micritic dolomite. The amount of dolomite increases toward the center of the developing nodule. Quartz also occurs as a drusy, void-filling cement. It is very fine- to fine-grained with the crystal size increasing away from the edge of the void.

North of the mixed-skeletal wackestones, along the edge of the Pratt Anticline, unit 4 is represented by dolomitic intraclast wackestones (fig.18) and laminated dolomitic mudstones. These lithologies are green and gray or pale-green and white.

The dolomite consists of very fine-grained to coarse-grained subhedral to rhombic crystals. The larger rhombs display alternating layers of nonferroan and ferroan dolomite. The mudstones and wackestones may have laminations, with alternating layers of medium- and coarse-grained rhombs or very fine- and fine-grained subhedral crystals. The intraclasts may be more than 2 cm (0.79 inch) in length and are composed of very fine-grained dolomite. They tend to be more ferroan then their coarser-grained matrix. The difference in crystal size in the laminations and between the intraclasts and matrix may represent variation in original sediment size or, in the case of the intraclasts, different times of dolomitization. The intraclasts, which are very fine-grained, may have been penecontemporaneously dolomitized, possibly before transport, whereas the matrix was dolomitized in a later diagenetic event.

INTERPRETATION The low diversity and abundance of fossils in the mixed-skeletal wackestones implies deposition in a semirestricted, low-energy environment. This facies was deposited landward of the moderate- to high-energy environment of the crinoid packstone-grainstone facies. The degree of restriction, as reflected in the diversity and abundance of fossils, varied over the study area.

Dolomitic intraclast wackestones and laminated dolomitic mudstones occur along the edge of the ancient Pratt Anticline. The alternating laminations of medium- and coarse-grained rhombs may be a product of currents if the rhomb sizes reflect variations in the original sediment grain sizes. The intraclasts were probably derived from currents reworking the fine-grained beds on the bottom of the very shallow sea.

The lack of fossils in this facies implies that salinity or other environmental conditions were not suitable to sustain macro-organisms.

Residual Chert The Viola is partly or entirely residual chert in the area over the Pratt Anticline. The chert is the residue remaining after extensive solution of the Viola in Late Devonian, Late Mississippian, and Late Pennsylvanian times (Adkison, 1972). It is predominantly white or gray and is generally smoothly textured and opaque to subopaque, although it may be tripolitic or spongy. Overall, most of the residual chert is similar to the chert found in carbonates unaffected by solution (Adkison, 1972). No cores of the residual chert were available, and the preceding description was taken from Adkison (1972).

DIAGENESIS

The carbonate rocks of the Viola Limestone have been altered by a number of diagenetic processes, which began in early postdepositional time and continued through deeper burial. Diagenetic features considered here include cementation, silicification, dolomitization, and micritization.

CEMENTATION Three types of cement are present in the crinoid packstone-grainstone facies of the Viola Limestone in south-central Kansas. They may also be found in the mixed-skeletal wackestone facies where localized grain-supported textures exist. The types are a bladed cement, a syntaxial rim cement, and a drusy, void-filling cement.

A cloudy, bladed cement up to 0.08 mm (0.003 inch) in length may coat trilobites, brachiopods, bryozoans, and rarely crinoids (fig. 19). This style of cementation indicates that it was precipitated in a water-saturated pore system and is analogous to early cements found in the modern shallow submarine realm (Bricker, 1971; Land, 1970; Folk, 1974).

In the crinoid packstone-grainstone facies most of the original pore space has been filled by syntaxial rim cement on the crinoid fragments. The rim cement commonly abuts the surface of polycrystalline fossil fragments or the initial bladed cement when it is present. Pray (Bathurst, 1975) coined the term 'competitive cementation' to account for those situations where cements which nucleated on different particles, most notably single-calcite-crystal echinoderms versus polycrystalline fossil grains, occupy different volumes of the original

Figure 19. Photomicrograph of bladed cement (arrow) on bryozoan, crinoid, and brachiopod fragments. The large crystals (S) are syntaxial cement. The bar scale is 1 mm.

Figure 20. Photomicrograph of syntaxial overgrowths on a crinoid fragment surrounded by a micritic matrix. The bar scale is 1 mm.

Figure 19

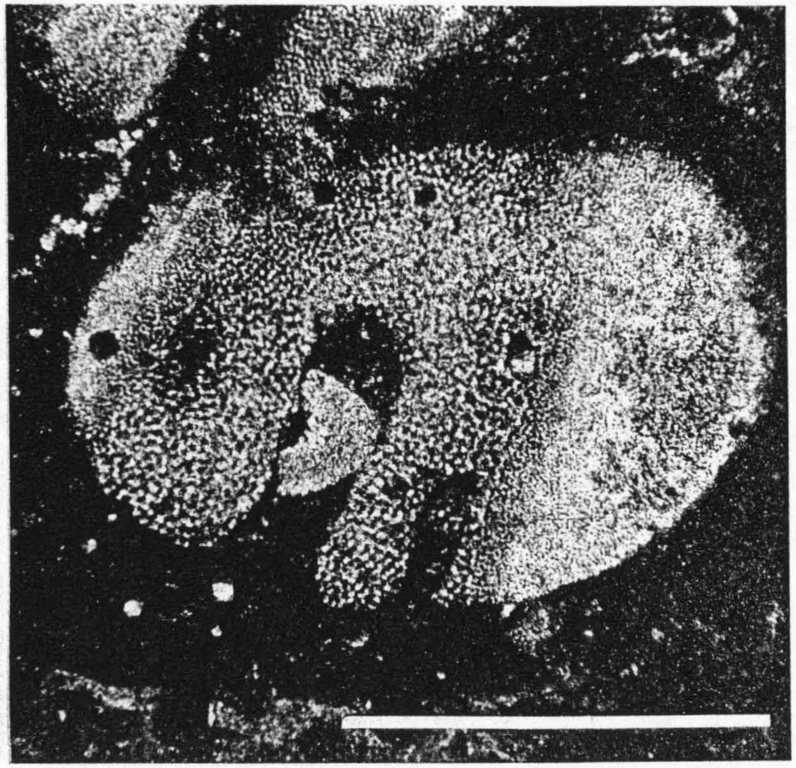

Figure 20

porosity. He concluded that the rate of growth of cement on large single, crystals is greater than on a polycrystalline substrate of micron-sized crystals.

The overgrowths commonly have an outer rim of ferroan calcite representing the last stage of cementation. According to Burgess (1979), ferroan calcites are probably precipitated in the phreatic zone where interstitial water has a low Eh. Syntaxial cements in general are indicative only of relatively early cementation and do not suggest a specific diagenetic environment (Burgess, 1979). It is conceivable that initial rim cementation began in the shallow subtidal environment with the final pore filling event occurring after uplift into the phreatic zone.

Lucia (1962) and Evamy and Shearman (1965) noted that the growth of syntaxial rim cement is prevented where the surface of the echinoderm is coated with micrite or is enclosed in a micrite matrix. The crinoids in the mixed-skeletal wackestones may have irregular overgrowths (fig 20) despite the surrounding micrite matrix. One possible explanation for this feature is that overgrowths developed on the seafloor before burial by the mud matrix (Burgess, 1979; Bathurst, 1975). Another possibility is that overgrowths replaced or displaced the lime-mud matrix during formation.

A drusy cement is found filling the molds of dissolved fossil fragments, in geopetal structures (fig. 21), and within the zooecia of bryozoans. The crystals may be either elongate normal to the void walls or equidimensional. This cement is the least common of the three types in the crinoid packstone-grainstone and mixed-skeletal wackestone

Figure 21. Photomicrograph of drusy cement filling a geopetal structure. The bar scale is 1 mm.

Figure 22. Photomicrograph of dolomite rhombs within a chert nodule. The bar scale is 1 mm.

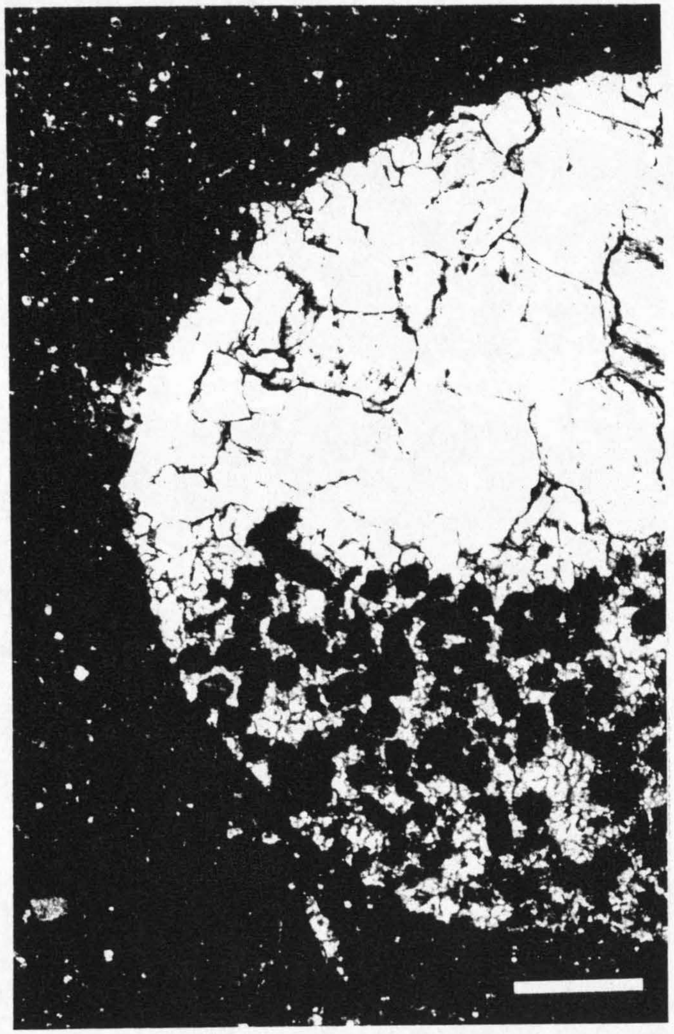

Figure 21

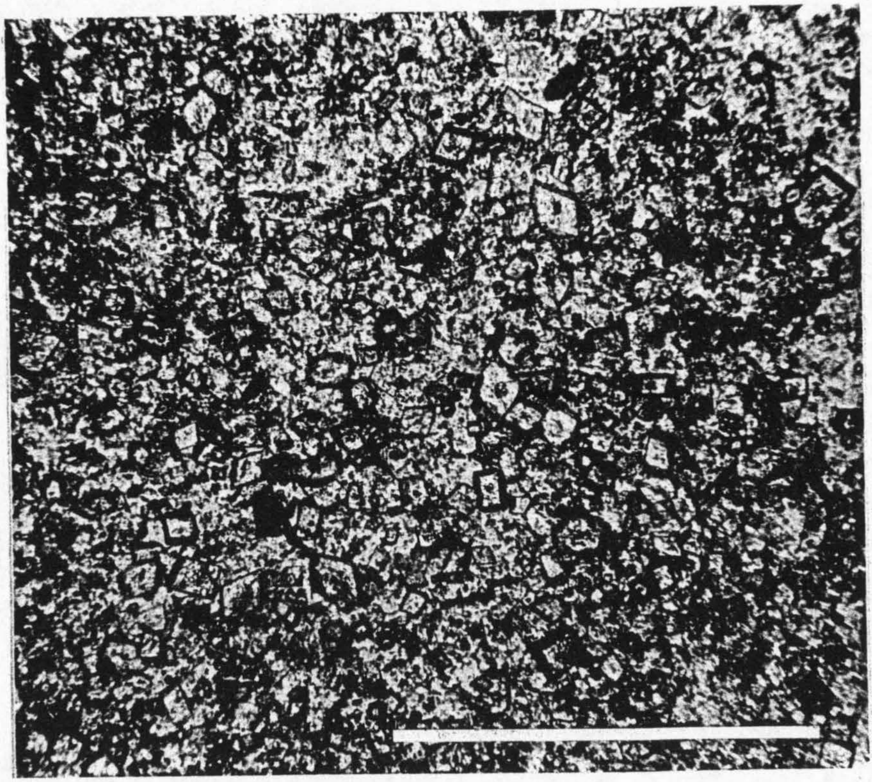

Figure 22

37a

facies.

Calcite cements also occur in the dolomitic mudstone facies, although rarely. Calcite cementation is generally the last diagenetic event and the cements are found filling the remaining voids. The crystals are relatively large and may have undulatory extinction and curved crystal faces.

SILICIFICATION Authigenic silica occurs in the form of chert nodules, silica cement, and selectively replaced fossil fragments. Apart from the mixed-skeletal wackestones and mudstones, in which chert nodules are common, occurrences are comparitively rare.

The chert nodules are composed of cryptocrystalline quartz and may be more than 8.5 cm (3 inches) in length. Their long axis is essentially parallel to bedding, and bedding laminations may extend through them (fig. 23). They are often draped by supratenuous folds (fig. 24) (Dietrich *et al*., 1963), which are produced by differential compaction over the nodules.

Where the matrix is dolomite, dolomite rhombs may occur within the chert nodules (fig. 22). According to Dietrich *et al*. (1963) this represents dolomitization interrupted by silicification. The silica selectively replaced calcite and aragonite but not dolomite, thereby preserving the features of the dolomite developed up to that time.

Where formation of chert nodules is not complete and the matrix is predominantly calcite, the degree of dolomitization increases abruptly upon entering the partially silicified area, suggesting a relationship between chert-nodule and dolomite development. In these

Figure 23. Chert nodule with bedding laminations extending through it (arrow).

Figure 24. Supratenuous folds draping a chert nodule (arrow).

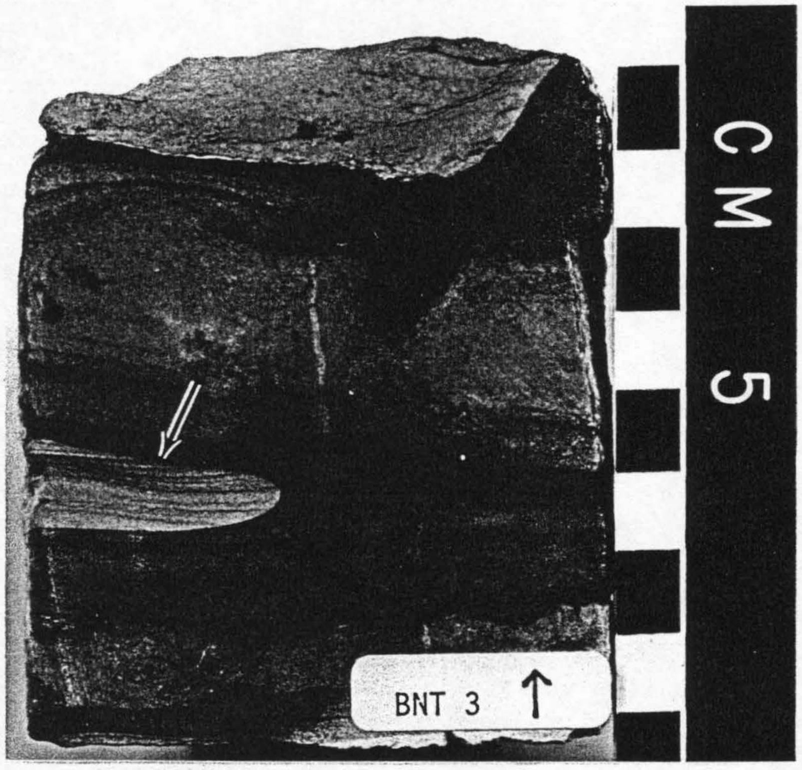

Figure 23

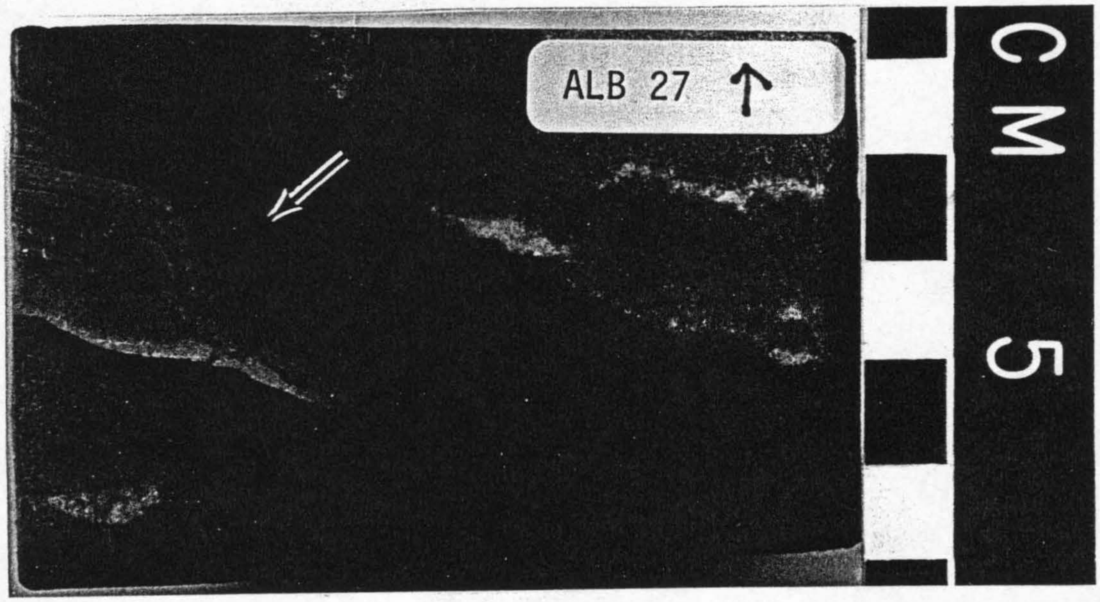

Figure 24

samples calcite fossils and rhombs are the most resistant to dolomitization and are often surrounded by fine-grained, anhedral dolomite. According to the theory of chert nodule maturation (Wise and Weaver, 1974), porosity exists within a growing chert nodule, allowing the development of dolomite in this localized diagenetic environment. Baker and Kastner (1981) also found that the transformation of opal-CT (Jones and Segnit, 1971) to quartz favors the formation of dolomite. This may also explain the existence of dolomite rhombs in the chert nodules of rocks with dolomite matrixes.

Selective replacement of fossil fragments by silica occurs in both the wackestone and packstone-grainstone facies. The silica may be cryptocrystalline quartz or chalcedony. Crinoids and brachiopods are the first fossils to be silicified. Replacement of the fossil fragments may occur on a very fine scale, preserving the microstructure of the original shell.

Drusy void-filling quartz cement occurs filling fractures in the mudstones. The silica occurs as microcrystalline quartz with the longer axis oriented roughly perpendicular to the walls of the void. Cryptocrystalline quartz also replaced cement between fossil fragments.

Formation of chert nodules and selective replacement of fossils or cement are not diagnostic of particular diagenetic environments. Chert will apparently form wherever there is sufficient biogenic opal to act as a source (Wise and Weaver, 1974). Knauth (1979) proposed that many nodular cherts in limestones formed in the mixed meteoric-marine system. If chertification and dolomitization occurred at approximately the same time (Dietrich et al., 1963), then a mixed meteoric-marine model would explain both chert nodule formation and dolomitization of the Viola Limestone in south-central Kansas.

The preference of chert nodules for the skeletal wackestones and mudstones over the packstones and grainstones may indicate a greater local source of silica. It may also be controlled by the greater permeability and porosity of these facies, thereby allowing silica-rich pore fluids to pass through them with greater ease.

DOLOMITIZATION Dolomitization is the most common diagenetic process to affect the Viola in the study area. The dolomite may replace other minerals or it may occur as a cement. While most of the dolomite appears to have had a late diagenetic origin, it is conceivable that some penecontemporaneous dolomitization occurred in the very restricted environment where the mudstones were deposited.

The late diagenetic replacement dolomite occurs mostly as subhedral to rhombic crystals, 0.08 to 0.43 mm (0.003 to 0.015 inch) in size. They may have cloudy centers with clear rims or be concentrically zoned with alternating ferroan and nonferroan dolomite layers. The variation in the amount of ferrous iron incorporated into the dolomite lattice could be due to either variations in the Eh or pH of the dolomitizing fluids (Burgess, 1979) or variations in the ferrous-iron content of those fluids.

The wackestones and mudstones are the most intensely dolomitized. In the wackestones the fossils are usually calcite, although the crinoids may be replaced by single crystals of dolomite. There is little dolomitization in the crinoid packstone-grainstone facies. Where present, it occurs as large rhombs replacing the fossils or as smaller rhombs and micrite replacing whatever mud may have been originally deposited. The degree of dolomitization increases as the amount of mud between the fossils increases.

The absence of evaporitic minerals, their pseudomorphs, or large formations of collapse breccias that would indicate the former presence of evaporites, precludes dolomitization of the subsurface sediment by reaction with hypersaline brines (Dunham and Olson, 1978). This together with the probable presence of the Viola within the mixed meteoric-marine zone at least twice during the Late Silurian to Early Devonian, while erosion was removing the overlying Maquoketa Shale and Hunton Limestone, supports dolomitization in the mixed meteoric-marine zone as proposed by Hanshaw et al. (1971), Badiozamani (1973, Dorag model), Folk and Land (1975, schizohaline model), and others. The areas of greatest dolomitization correspond to the positive structure residuals of a second order trend surface mapped by Bornemann (1979). This may reflect a longer period of residence in the mixed meteoric-marine zone for rocks in these areas.

Adams and Rhodes (1960) noted that when dolomitizing fluids passed through rocks with differing degrees of permeability, the more porous rocks were favored, and impervious limestone lenses were bypassed. This would account for the differing degrees of dolomitization between the wackestone and mudstone facies and the crinoid packstone-grainstone facies. The crinoid packstones and grainstones would have been cemented before the time of dolomitization, thereby restricting the flow of dolomitizing fluids through these rocks. Within this facies dolomitization is greatest along mud lenses and stylolites, which are more permeable.

In the lower restricted zone, unit 2, the degree of dolomitization increases down section. This corresponds to an increase in the degree of restriction, probably caused by an increase or decrease in salinity, of the depositional environment. The increase in dolomite may reflect an increase in permeability, or it might be caused by late diagenetic dolomitization of penecontemporaneously dolomitized sediment, with a resultant increase in the degree of dolomitization.

Existing models for dolomitization emphasize that penecontemporaneous dolomite can form in both subtidal (Irwin, 1965; Behrens and Land, 1972) and supratidal (Illing et al, 1965; Shinn et al, 1965) environments if the necessary chemical and physical factors favorable for the development of Mg-rich hypersaline waters exist. Most of these models require the extensive deposition of evaporite minerals before dolomitization can occur. A few Holocene shallow water hypersaline environments that have the potential to produce dolomite without deposition of more soluble evaporite minerals have been found in Shark Bay, Australia (Logan and Cebulski, 1970), and on the Great Bahama Bank (Black, 1933; Smith, 1940; Newell, 1959; Cloud, 1962). These areas are characterized by nearly vertical isosalinity layers of increasing concentration landward (Harris, 1973). Irwin (1965) suggests a possible model for penecontemporaneous dolomitization in epeiric seas, in which the great widths of shelves and their low slopes were sufficient in themselves to restrict or eliminate circulation, thereby allowing dolomite formation. The combination of the present-day models for dolomitization without evaporite deposition and Irwin's theoretical model of decreasing circulation landward, with the possible formation of nearly vertical isosalinity layers of increasing concentration landward, make it conceivable that penecontemporaneous dolomitization occurred in the very restricted facies at the base of unit 2.

Void-filling dolomite cement occurs in a few mudstones in the Viola. The cement is usually ferroan saddle dolomite. Saddle dolomite is a variety of dolomite that has a warped crystal lattice. It is characterized by curved crystal faces and cleavage and sweeping extinction (Radke and Mathis, 1979). Choquette (1971) suggests that curved crystal faces and pronounced undulatory extinction be considered possible general characteristics for epigenetic (post-lithification) cement. Radke and Mathis (1979) propose that saddle dolomite has potential as a geothermometer, being indicative of elevated temperatures (60-150 C). It occurs as the last stage of dolomitization in the Viola Limestone in south-central Kansas.

MICRITIZATION Peripheral micritization of skeletal grains occurs within the Viola. Totally micritized peloids are rare.

Micritized rims are on the scale of a few microns in thickness and may affect all types of fossils, though they most commonly occur on trilobites and only rarely on crinoids. Occasionally the central unaffected area of the grain has been dissolved and later filled with void filling cement.

Micritization is generally accepted to be the result of algal and fungal borings (Bathurst, 1966). Purdy (1968) was skeptical of this method of micritization and suggested that not all degrading neomorphism occurs in this manner. He offered an alternative suggestion that the decomposition of indigenous organic matter resulted in the simultaneous replacement of both the original organic and the clay sized carbonate particles by micrite.

DEPOSITIONAL HISTORY

The Viola Limestone in south-central Kansas was deposited in an extensive epicontinental sea that covered a large part of North America during Middle to Late Ordovician time (Ross, 1976). Shaw (1964) and Irwin (1965) proposed facies patterns for deposition in epicontinental seas with low seafloor slopes. They postulated that environments would develop as broad adjacent bands parallel to the paleoshoreline. The widths of the bands are dependent on the slope of the seafloor, with narrower bands developing in areas of greater slope.

The widespread distribution of facies in the Viola implies deposition in extensive belts, though not on the scale of hundreds of miles as proposed by Irwin (1965) for deposition on seafloors with slopes of less than one foot per mile. There is also no known shoreline present in the area during Viola time. There was, however a submerged arch trending northwest from the Chautauqua Arch towards the Central Kansas Uplift (Adkison, 1972). This arch shall hereafter be referred to as the Central Kansas Arch (fig. 26) following Rich (1933), and includes the pre-Mississippian elements of the Chautauqau and the Ellis Arches. The Ellis Arch is the pre-Mississippian structure, which was ancestral to the Central Kansas Uplift (Jewett, 1951). The general depositional setting calls for an open-marine environment shallowing towards this arch with semirestricted and very restricted environments developing as water depths decreased with a concomitant decrease in circulation and a probable increase in salinity (fig. 25).

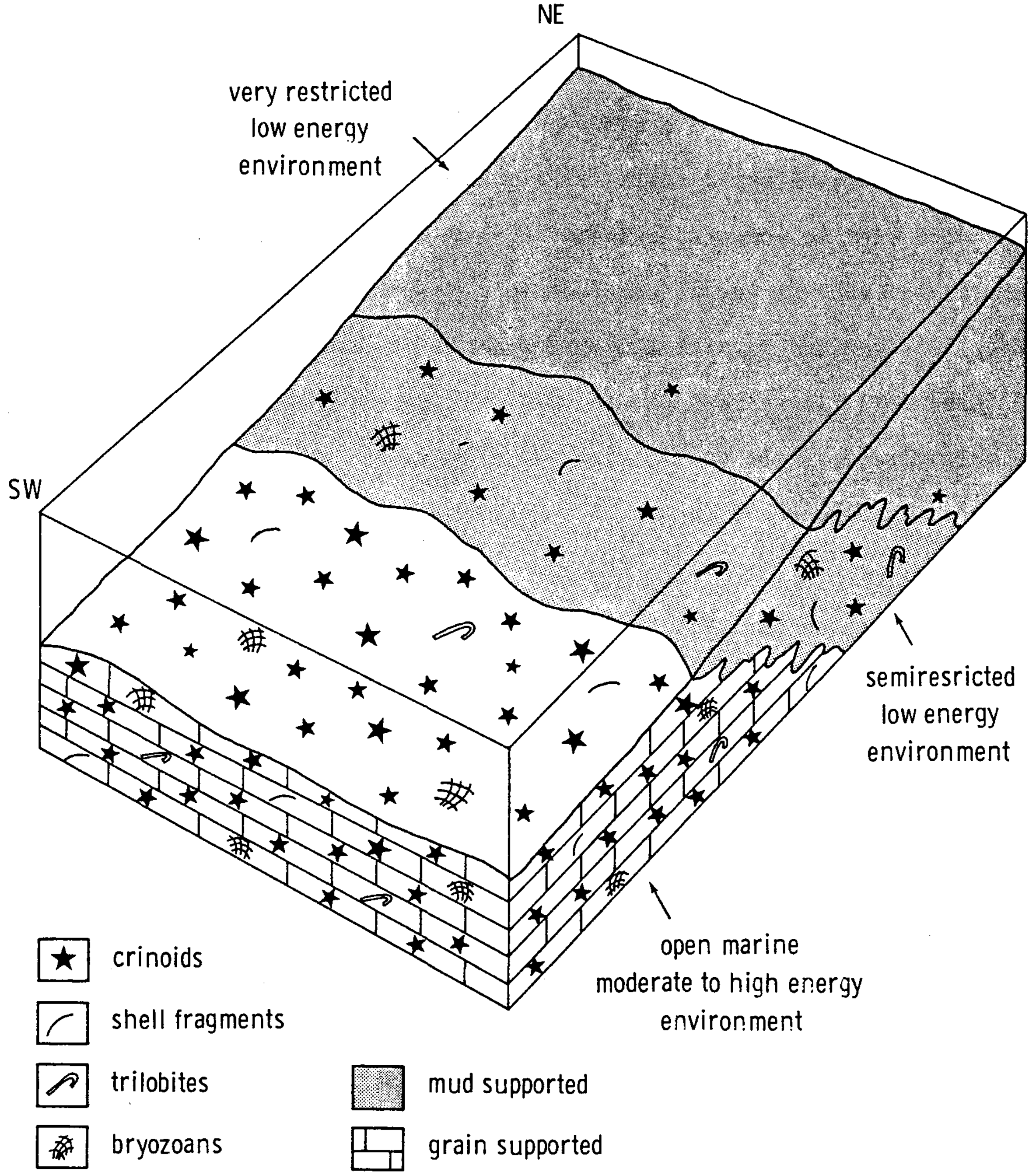

Figure 25. Generalized depositional model for the Viola in south-central Kansas. The crinoid packstone-grainstone facies was deposited in the open marine environment, the mixed-skeletal wackestones were deposited in the semirestrited environment, and the dolomitic mudstones were deposited in the very restricted, low energy environment. The Central Kansas Arch would be off to the norhteast.

The basal crinoid packstone-grainstone facies of unit 1, was unconformably deposited on the Simpson after a marine transgression. It represents deposition in a moderate- to high-energy, open-marine environment with normal salinity. The general thinning of this unit northeastward supports the idea of a gradual shallowing in this direction, which presumably continued throughout deposition of the Viola. Taylor (1947) proposed an unconformity at the top of the basal limestone in north-central Kansas, and while the possibility of an unconformity in this position exists in the study area, it cannot be documented conclusively.

Shaw (1964) stated that vertical successions of environments displayed in autochthonous rocks deposited in epeiric seas are reflections of a lateral sequence that existed at any given time. Accordingly, the mudstones at the base of the lower cherty dolomitic limestone, unit 2, represent an environment that was laterally equivalent to the crinoid packstone-grainstone facies, upon which the mudstones were deposited. The environment of deposition of the mudstones was in the lee of the crinoid packstone-grainstone facies. Conceivably, the mudstones were separated from the packstones and grainstones by a less restricted environment such as that which produced the mixed-skeletal wackestones which occur at the top of this unit.

In cores, the transition from the open-marine environment of the crinoid packstone-grainstone facies to the very restricted environment of the mudstones is abrupt. The actual contact, however, is nowhere represented in the cores. The rapid transition may reflect an unconformity, marine regression, or seafloor uplift that occurred after the deposition of the crinoid packstone-grainstone facies. The semirestricted mixed-skeletal wackestone facies which, separated the open-marine crinoid packstone-grainstone facies from the very restricted mudstone facies is absent in the transition of unit 1 to unit 2. Therefore, the possibility that the transition represents progradation of the restricted facies over the open-marine facies is unlikely.

The depositional environment of the mudstone facies was characterized by abnormal salinity or the absence of life-sustaining nutrients. Shaw (1964) postulated that because of presumed shallow slopes in epeiric seas, friction would have dampened the effects of normal, diurnal tides. Shallowness of the sea would have prevented the development of great nutrient-laden currents like those in modern oceans (Belak, 1980). Under such conditions, lack of adequate circulation would have created areas of increasing restriction as the sea shallowed toward the Central Kansas Arch. Excessive evaporation in this area, without replenishment with fresh waters, could result in the development of progressively higher salinities toward the arch, beyond the limits of tidal exchange. This model indicates an environment that is restricted through both a lack of life-sustaining nutrients and abnormally high salinities. Abnormally low salinities or a variable salinity is also conceivable if extensive rains provided enough fresh water to dilute the system or cause seasonal fluctuations in salinity.

After the abrupt marine regression or seafloor uplift that preceded deposition of the mudstones at the base of unit 2, a gradual marine transgression occurred, which resulted in the deposition of mixed-skeletal wackestones over the mudstones. The skeletal wackestones were deposited under semirestricted, low-energy conditions, probably between the depositional belt of the mudstone facies and that of the crinoid packstone-grainstone facies.

The marine transgression continued, culminating in the deposition of the crinoid packstone-grainstone facies of unit 3. During this period moderate- to high-energy, open-marine conditions again prevailed in the study area.

The deposition of the mixed-skeletal wackestones of unit 4 over the crinoid packstones and grainstones of unit 3 resulted from either progradation of facies belts seaward during a stillstand in sea level or development of the Pratt Anticline, forcing the belts seaward. Whichever occurred, the depositional slope was probably steeper than it was during earlier deposition of the Viola, resulting in less restricted conditions behind the crinoid packstone-grainstone facies and narrower depositional belts. The semirestricted, low-energy environment of deposition of the mixed-skeletal wackestones shallowed toward the Pratt Anticline, resulting in increased restriction, and in the deposition of intraclast wackestones and laminated mudstones along the slopes of the anticline.

After deposition of the Viola, the area was subaerially exposed resulting in an unconformable contact between the Viola and the Maquoketa Shale (Adkison, 1972).

STRUCTURE

Studies by Lee (1956), Merriam (1963), and Adkison (1972) concluded that the structural configuration of Kansas has remained virtually stable since the beginning of the Middle Pennsylvanian. Tectonic events that noticeably affected the Viola in south-central Kansas took place between the Middle Ordovician and the Middle Pennsylvanian. The first of these occurred after deposition of the St. Peter Sandstone (Lee, 1956). At this time the Central Kansas Arch (fig. 26) began developing (Lee, 1943; Lee _et_ _al_., 1946; Adkison, 1972). The continued uplift of this structural feature and the concommitant formation of the North Kansas Basin and the Southwest Kansas Basin, following deposition of the St. Peter, was intermittant and occurred during both periods of sedimentation and periods of emergence (Lee, 1956). The influence of this early structure on Viola deposition is evidenced by the increased restriction due to shallowing in a northeast direction across the study area. Its influence on postdepositional diagenesis is indicated by the extensive dolomitization that occurred along the flanks of this arch after the Viola was uplifted into the mixed meteoric-marine zone.

Although Adkison (1972) considered formation of the Pratt Anticline (fig. 26) to be mainly of Early Pennsylvanian age, lithologic evidence in the study area suggests that it exists as at least a submerged high during deposition of unit 4. Further uplift before deposition of the Chattanooga Shale is strongly suggested by the extensive karst topography formed on the Viola and the contemporaneous development of the similarly extensive Viola residual chert (Adkison, 1972).

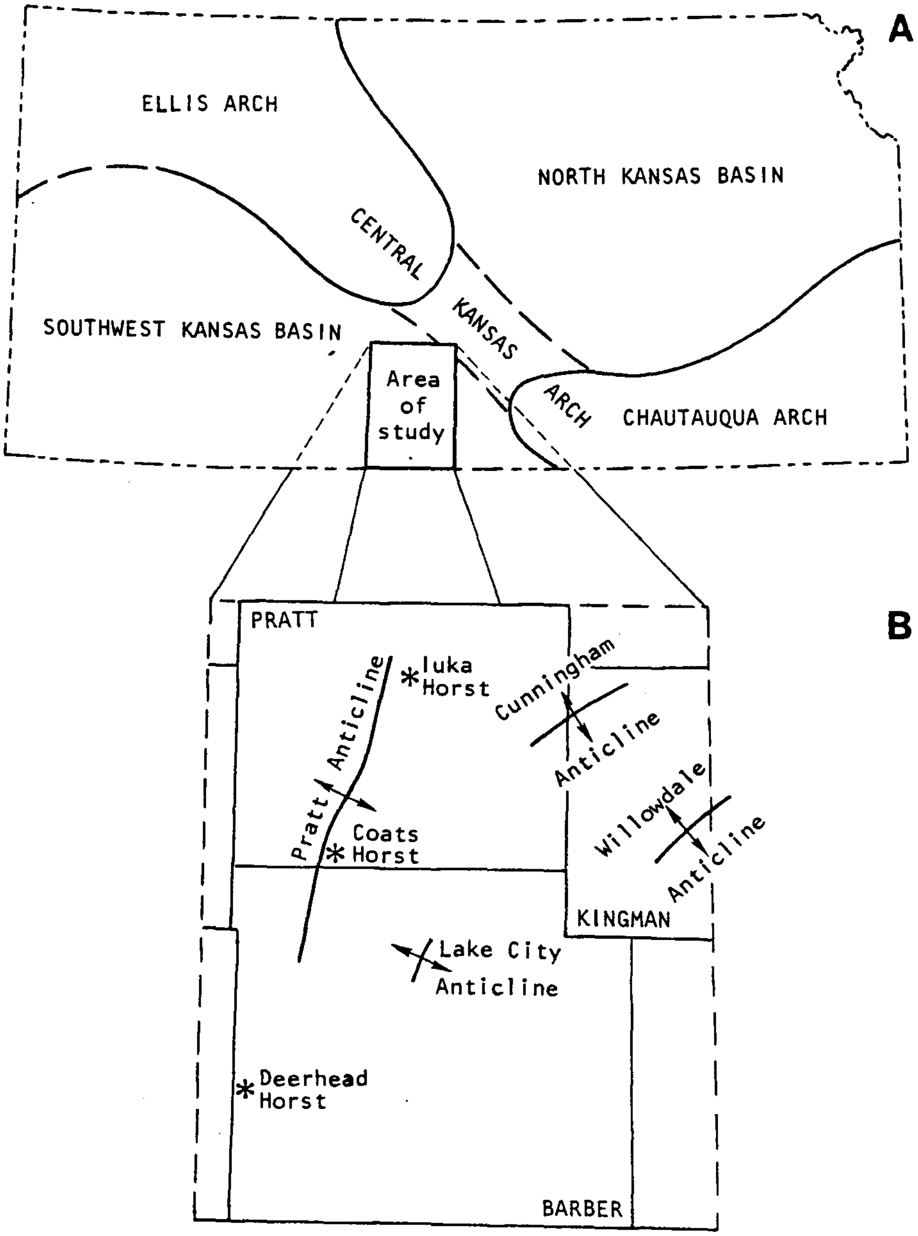

Figure 26 A) Major structural trends during deposition of the Viola Limestone.

B) Minor structural features in the study area.

According to Rutledge and Bryant (1937), the Cunningham Anticline, which extends from the southwest corner of T.28 R.11 to T.26 R.6 (fig. 26), formed at the time of the Wichita orogeny in the Early Pennsylvanian. Some of the most extensive dolomitization of the Viola in south-central Kansas is associated with this and the Willowdale Anticline (Merriam, 1963) in T.29 R.9, indicating that they formed either during or before dolomitization, perhaps beginning their upward movement even earlier than the Wichita orogeny. Also during Early Pennsylvanian time, fault bounded blocks in T.27 R.13, T.29 R.14, and T.33 R.15 were activated. These were named the Iuka Horst, Coats Horst, and Deerhead Horst, respectively, by Bornemann (1979). Dolomitization is not associated with these uplifted blocks. This implies that some dolomitization occurred between the time of formation of the Cunningham and Willowdale Anticlines and the block faulting of the horsts. Both of these events had ended by Early Pennsylvanian time and contribute to the structural grain of south-central Kansas, which exhibits trends striking generally northeast or southwest. These trends are thought to correspond to readjustments of tectonic trends in the Precambrian basement (Rich, 1933).

ANALYSIS OF THE LITHOFACIES MAPS

The lithofacies maps in figs. 27 and 28 are based on dominant mineralogy. In this study the facies were analysed as to mineralogy and classified using the triangle in figure 3 as limestone, dolomite, residual chert, and cherty dolomitic limestone. The limestone section represent the crinoid packstone-grainstone facies, while the dolomite and cherty dolomitic limestone sections represent the mixed-skeletal wackestones and mudstones. Therefore, because of the nature of its construction, the lithofacies map produced in this study can also be interpreted to some degree as a dominant facies map. The limestone region on the map (fig. 27) corresponds to where both the basal and upper limestones, unit 1 and 3 are present and reach their greatest thickness and to where unit 4, the upper cherty dolomitic limestone, is least dolomitized. The cherty dolomitic limestone and dolomite regions correspond to that portion of the study area where the upper limestone, unit 3, and the upper cherty dolomitic limestone, unit 4, were eroded or not deposited, and where the mixed-skeletal wackestones and cherty dolomitic mudstones of the lower cherty dolomitic limestone, unit 2, are the dominant facies. The distribution of the limestone, cherty dolomitic limestone, and dolomite regions on the lithofacies map roughly parallels the proposed depositional belts present during Viola time (fig.25) and the Central Kansas Arch.

The distribution of the dolomite lithofacies and to a lesser degree the cherty dolomitic limestone lithofacies was controlled by diagenetic events dictated as much by post-Viola structural changes as

▤ Dolomite

▦ Limestone

▩ Cherty Dolomitic Limestone

░ Carbonate + Residual Chert

∴ Residual Chert

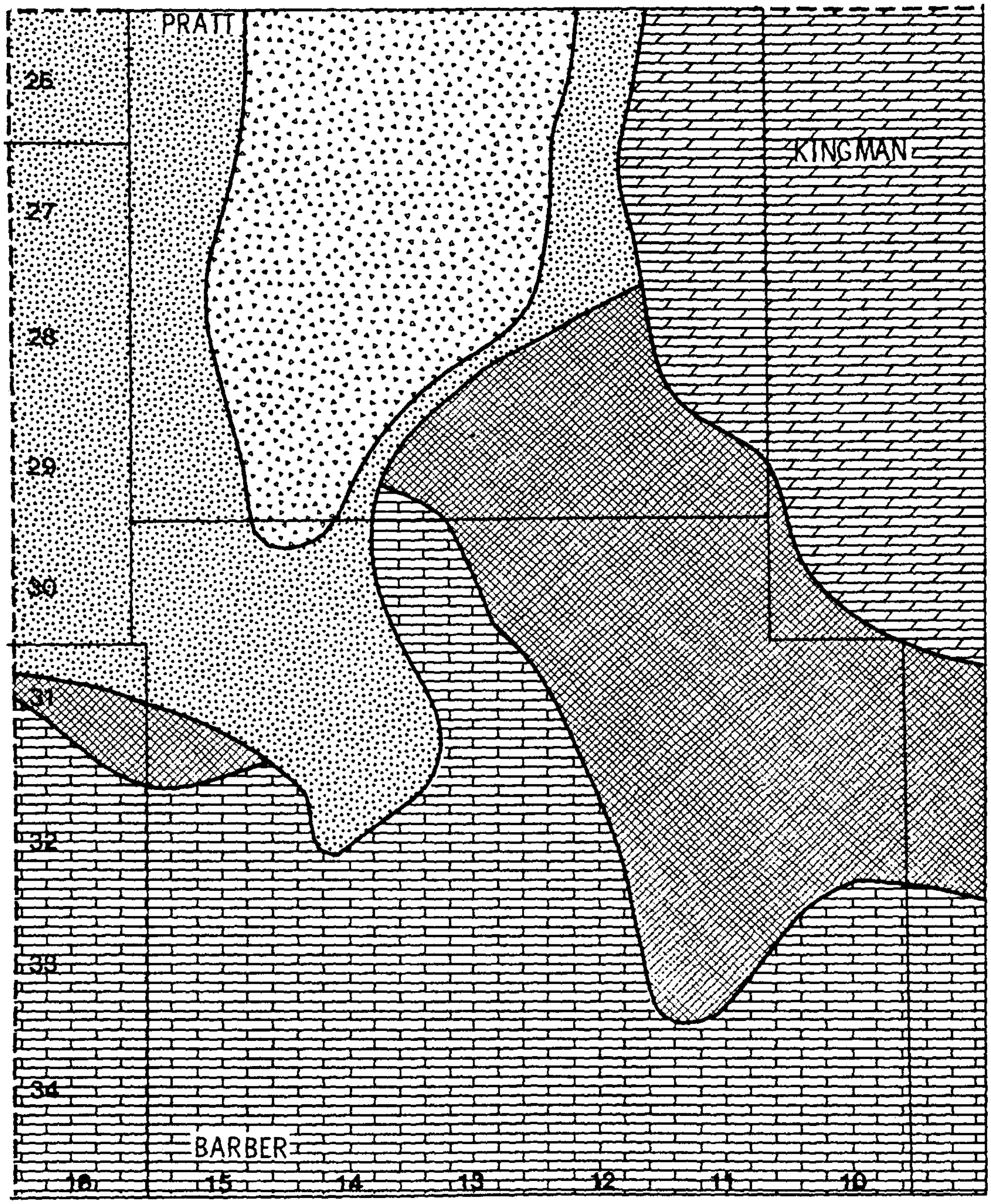

Figure 27 Lithofacies map of the Viola Limestone.

▦ Limestone

▩ Cherty Dolomitic Limestone

░ Carbonate + Residual Chert

▵ Residual Chert

▤ Shaly Carbonate

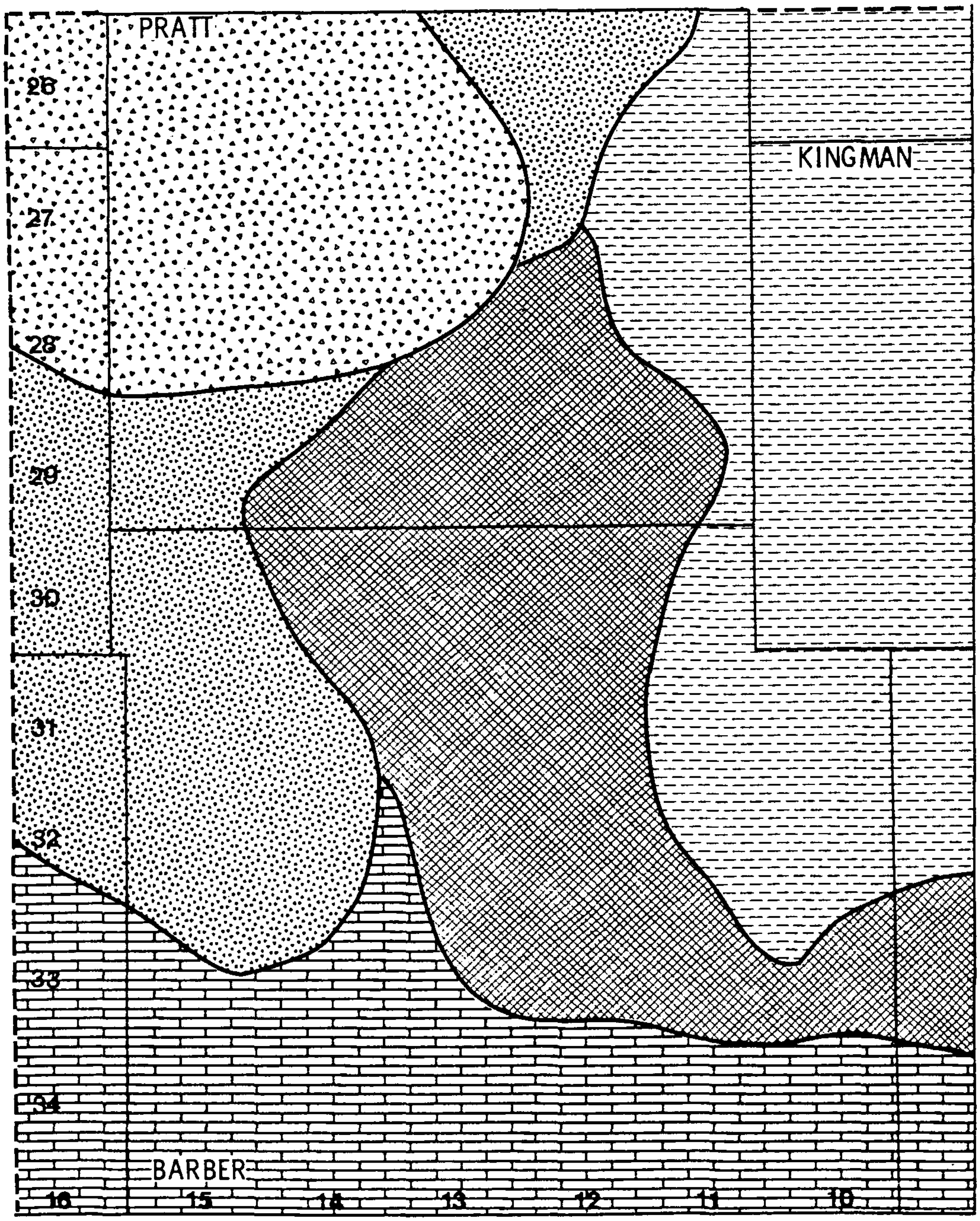

Figure 28 Generalized version of the lithofacies map produced by Bornemann (1979).

by the original facies distribution. The areas of greatest dolomitization correspond to the areas that experienced the longest residence time in the mixed meteoric-marine zone, where dolomitization is proposed to have taken place. To the east, the Central Kansas Arch controlled the degree of dolomitization by controlling the residence time in the mixed meteoric-marine zone. The Cunningham and Willowdale Anticlines (fig. 26) may have also contributed to dolomitization through the same mechanism. To the west, while not evident on the lithofacies map, the Viola on the southern tip of the Pratt Anticline is extensively dolomitized. This structure probably played a role similar to that of the Central Kansas Arch in keeping this area within the mixed meteoric-marine zone.

The Pratt Anticline had an even more significant role in controlling the distribution of residual chert. The areal extent and thickness of the chert is greatest along the axis of the anticline. This is interpreted as due to the greater erosion and karsting experienced by the Viola in this area. Along the flanks of the Pratt, residual chert occurs as scattered patches due to less extensive erosion. This area is represented by the carbonate plus residual chert region on the lithofacies map. The residual chert and carbonate plus residual chert lithofacies were entirely controlled by structural events. They truncate the northwestward trending limestone and cherty dolomitic limestone lithofacies, indicating that the distribution of residual chert was controlled by events that occurred subsequent to the events controlling distribution of the limestone fields.

Using a computer, Bornemann (1979) generated his lithofacies map using digitized well-log traces. A simplified version of his map appears in figure 28. The five lithofacies, limestone, shaly carbonate, cherty dolomitic limestone, residual chert, and carbonate plus residual chert, have a distribution similar to that of their counterparts in the lithofacies map produced in this study. Some variations in the exact locations of the lithofacies boundaries occur. His residual chert plus carbonate region is to the northwest of mine off the axis of the Pratt Anticline, while the carbonate plus residual chert region is westward. The lithofacies that are strongly influenced by the distribution of the depositional facies, that is the limestone, shaly carbonate, and cherty dolomitic limestone lithofacies, are generally southwestward of mine although their overall trend still roughly parallels the proposed depositional belts of the Viola and the Central Kansas Arch. Even with these differences, the computer-generated lithofacies map could be subjected to the same interpretations as those applied to the lithofacies map produced in this study.

Other differences appear in the classification of lithofacies. Bornemann (1979) interpreted the dolomite lithofacies as a shaly carbonate. Since dolomite is a carbonate this interpretation is technically correct if imprecise. It is preferable, however, to distinguish dolomites from limestones since dolomites are commonly more porous and permeable than limestones. Moreover, although the dolomite in this area is slightly argillaceous, to describe it as shaly is to exaggerate the shale content of these rocks.

In general, a computer analysis of digitized well-logs produces a lithofacies map with similar trends and patterns to one produced through the conventional use of cores and cuttings. Its shortcomings lie in its inaccurate location of the different lithofacies. This may be due to the difference in data points or the inability of the computer to apply geologic reasoning in determining its lithofacies distribution.

CONCLUSIONS

1) The Viola Limestone in Pratt and Barber counties can be divided into four mappable units. Basal and upper limestones, units 1 and 3, are composed of crinoid packstones and grainstones. A lower cherty dolomitic limestone, unit 2, is composed of cherty, dolomitic, mixed-skeletal wackestones and cherty dolomitic mudstones; and an upper cherty dolomitic limestone, unit 4, is composed of mixed-skeletal wackestones, dolomitic intraclast wackestones, and dolomitic mudstones.

2) The facies were deposited in three broad environmental belts that lay roughly parallel to the Central Kansas Arch: 1) a moderate- to high-energy, open-marine environment that was the site of deposition of the crinoid packstone-grainstone facies; 2) a semirestricted low-energy environment where the mixed-skeletal wackestone facies was deposited; and 3) a very restricted environment closest to the arch, where the cherty dolomitic mudstones were deposited.

3) Postdepositional alterations included:

a) dolomitization in the mixed meteoric-marine zone and possibly penecontemporaneously along the flank of the Central Kansas Arch;

b) silicification of fossil fragments and probably formation of chert nodules within the mixed meteoric-marine zone;

c) cementation, including syntaxial rim cement on the crinoids and cloudy, bladed cement on the polycrystalline fossil fragments.

4) Diagenesis was fabric selective with dolomitization and chert nodule formation favoring mud-supported textures and cementation favoring grain-supported textures.

5) The Central Kansas Arch existed as a broad submerged saddle during Viola deposition and played an active role in postdepositional dolomitization of the Viola.

6) The Pratt anticline began its upward movement before or during deposition of the upper cherty dolomitic limestone.

7) Structure, diagenesis, and depositional history contributed to the final distribution of lithofacies in the study area.

8) Computer-generated lithofacies maps using digitized log traces were capable of reproducing trends and patterns in lithofacies distribution but did not accurately delineate lithofacies boundaries.

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