Core studies of the Viola limestone in Barber and Pratt counties, south-central Kansas

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Introduction

St. Clair (1981) made detailed examinations of slabbed Viola core and thin sections from ten wells in Barber and Pratt counties in a thesis study of petrography, lithofacies, and diagenesis. Locations of the cored wells are shown in fig. 1 and listed in table 1. Core from Sinclair-Prairie Degeer #1 NENWNE sec. 34, T. 32 S., R. 15 W. are presented in this workshop. The cores collectively sample all the major subdivisions of the Viola in this two-county area, with the exception of the residual chert facies. In the following text, descriptions and interpretations are based on the full set of ten cored wells. However, most of the features described can be observed in the core samples from the Degeer #1 well.

Stratigraphy

The Viola limestone of south-central Kansas consists of limestones, dolomites, and cherts. Although several geologists such as Taylor (1947) and Ver Wiebe (1948) subdivided the Viola into informal lithologic units, Lee (1943) concluded that the Viola could not be zoned on a regional basis. Adkison (1972) made a detailed study of the structure and stratigraphy of the Viola across the Sedgwick Basin and traced some individual units across limited areas. St. Clair (1981) concluded that the Viola in Barber and Pratt counties could be subdivided into four mappable units, which were informally named the basal limestone (unit 1), the lower cherty dolomitic limestone (unit 2), the upper limestone (unit 3), and the upper cherty dolomitic limestone (unit 4).

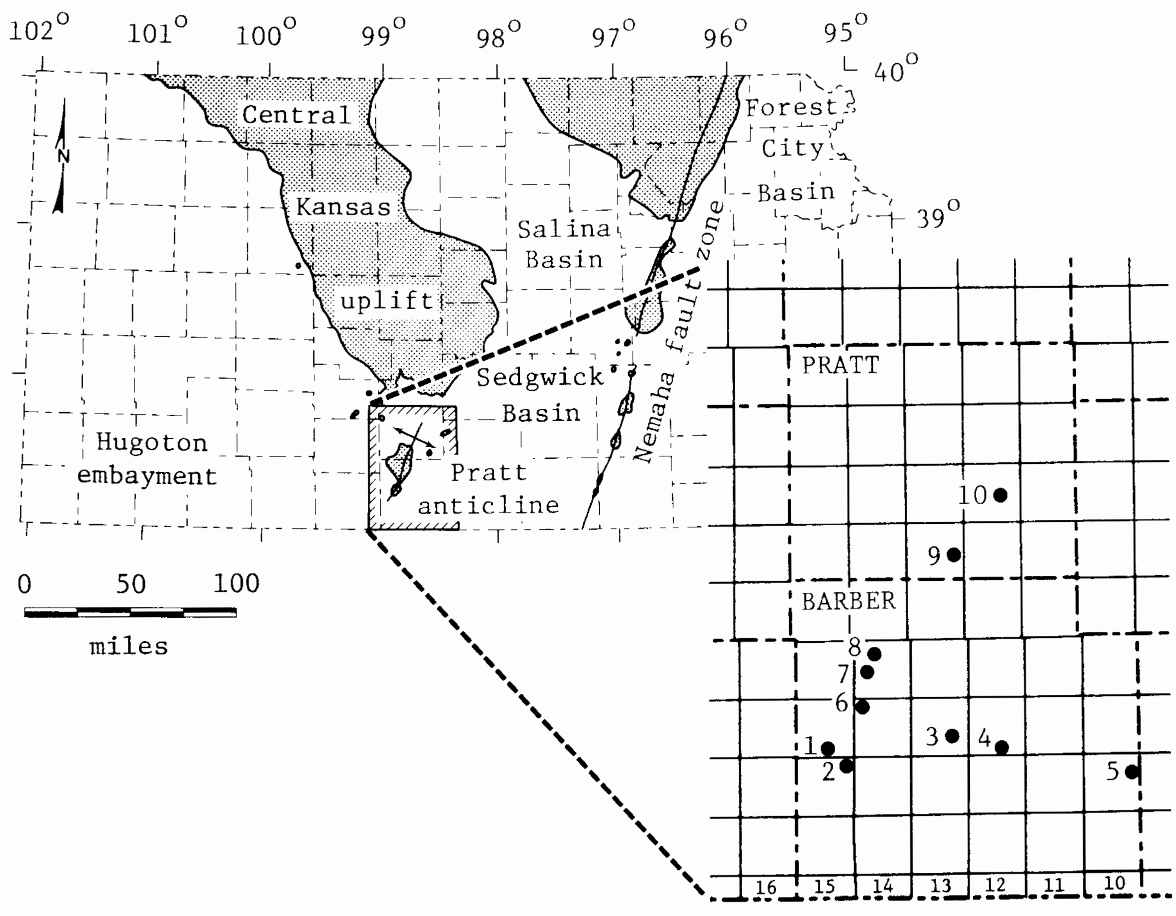
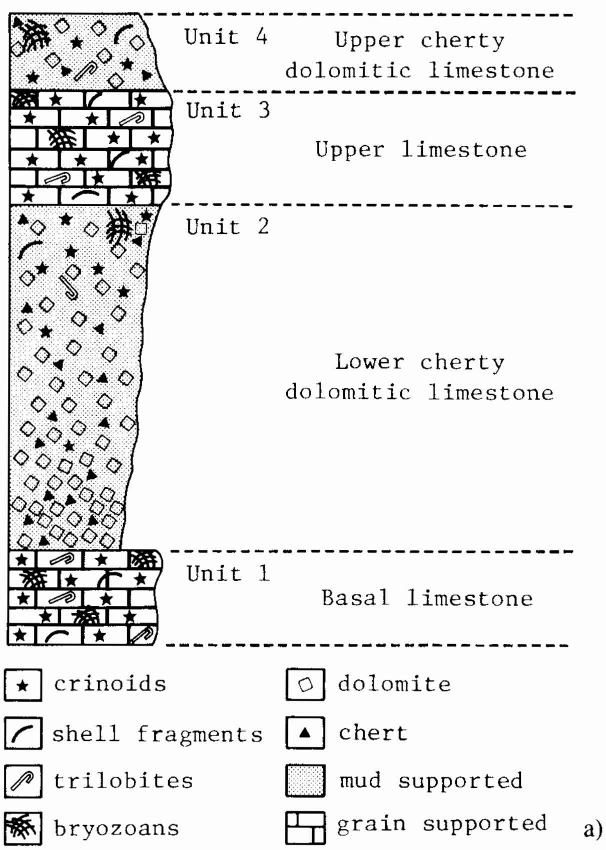


FIGURE 1—Map showing location of study area and wells listed in table 1.

TABLE 1—List of wells and locations shown in fig. 1.

Name	County	Location	Depth of cored interval
1. Sinclair-Prairie 1 Degeer	Barber	NENWNE34, 32S, 15W	1508-1551 (4948-5087)
2. Sinclair 1 Alice Gentry	Barber	NECNE1, 33S, 15W	1571-1594 (5106-5231)
3. Sinclair-Prairie 1 M. Binning	Barber	SESESW26, 32S, 13W	1454-1481 (4769-4860)
4. Lario 2 Randles	Barber	CNENE34, 32S, 12W	1417-1447 (4649-4746)
5. I.T.I.O. 1 George	Barber	CSESW12, 33S, 10W	1433-1458 (4702-4782)
6. Carter 1 Lytle	Barber	CNENW6, 32S, 14W	1435-1473 (4709-4832)
7. Sinclair-Prairie 1 A. Oldfather	Barber	NENESW18, 31S, 14W	1349-1389 (4426-4556)
8. Sinclair 4 G. Oldfather	Barber	SWNWSE7, 31S, 14W	1319-1357 (4328-4453)
9. Bridgeport 1-I Brown	Pratt	SESESW25, 29S, 13W	1361-1400 (4465-4592)
10. Sinclair-Prairie 1 Burton	Pratt	NESENW22, 28S, 12W	1309-1343 (4294-4407)



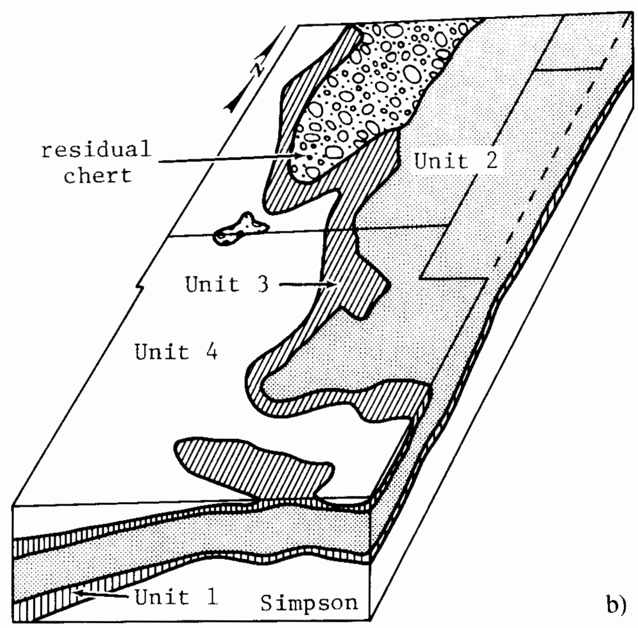


FIGURE 2—a) Generalized stratigraphic section of the Viola Limestone in south-central Kansas. b) Block diagram of the eastern half of the study area showing the present distribution of the Viola subdivisions. Basal limestone = 1; lower cherty dolomitic limestone = 2; upper limestone = 3; and upper cherty dolomitic limestone = 4.

The petrographic characteristics and fossil contents of these units are summarized graphically as a composite section in fig. 2, together with a block diagram to show their subsurface distribution, based on studies of both limited core and cuttings from an extensive well control.

Petrographic summaries and interpretations of lithofacies units

Basal limestone

The basal limestone forms an almost continuous sheet across the study area and has a characteristic "tight-lime" (low-porosity) log response that is useful for locating the boundary between the Viola and the underlying Simpson Group. The units can be summarized as a crinoid packstone-grainstone facies limestone. Fossil fragments other than crinoids most commonly include brachiopods, bryozoans, and trilobites, and less commonly 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. 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 occasionally display peripheral micritization due to algal or fungal borings (Bathurst, 1966). The trilobites generally are slightly abraded and show the most extensive peripheral micritization. Brachiopods are usually highly fragmented and abraded and are most commonly silicified, while bryozoans show the least preservation and are often completely recrystallized or dolomitized.

Adkison (1972) reported crossbedding 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. These dolomite lenses may be up to 1 cm thick and probably were originally lime mud. Large intraclasts, up to 2.5 cm 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. They are found replacing inter- and intraparticle lime mud and also may 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 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 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. 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.

Lower cherty dolomite limestone

This unit was originally present throughout the study area but has since been removed by erosion over areas on the Pratt anticline. It ranges in thickness from 0 to 104 ft and consists of dolomite mixed-skeletal wackestones and dolomitized mudstones.

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

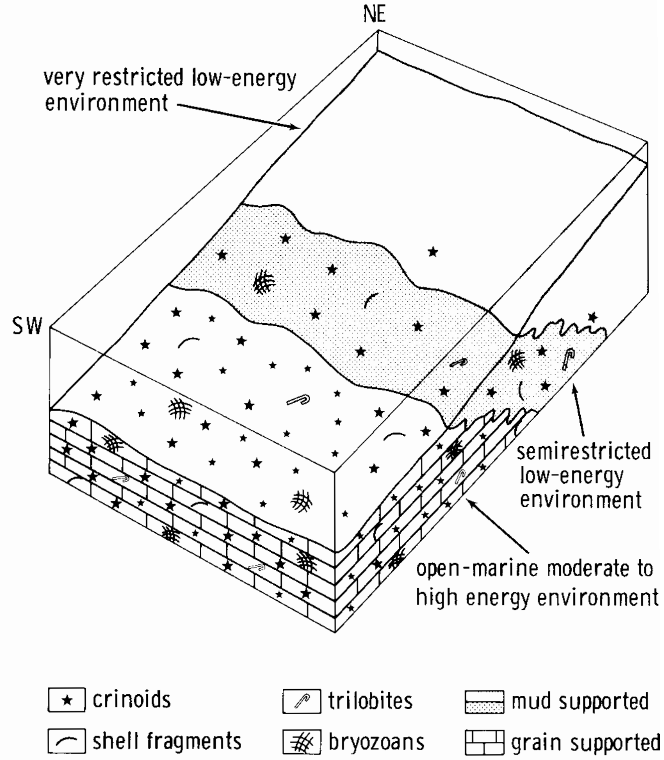


FIGURE 3—Generalized model for depositional environments in the Viola Limestone in south-central Kansas.

Crinoids, brachiopods, trilobites, bryozoans, and ostracodes rarely are present. Most of the crinoids are replaced by large single crystals of dolomite. The crinoids were recognized as "ghosts" within the dolomite crystals. 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 in length and are composed of cryptocrystalline quartz. Some chert nodules display ghosts of fossils that 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.

A pale-green or light-gray, argillaceous, cherty, dolomitic mixed-skeletal wackestone occurs at the top of this unit

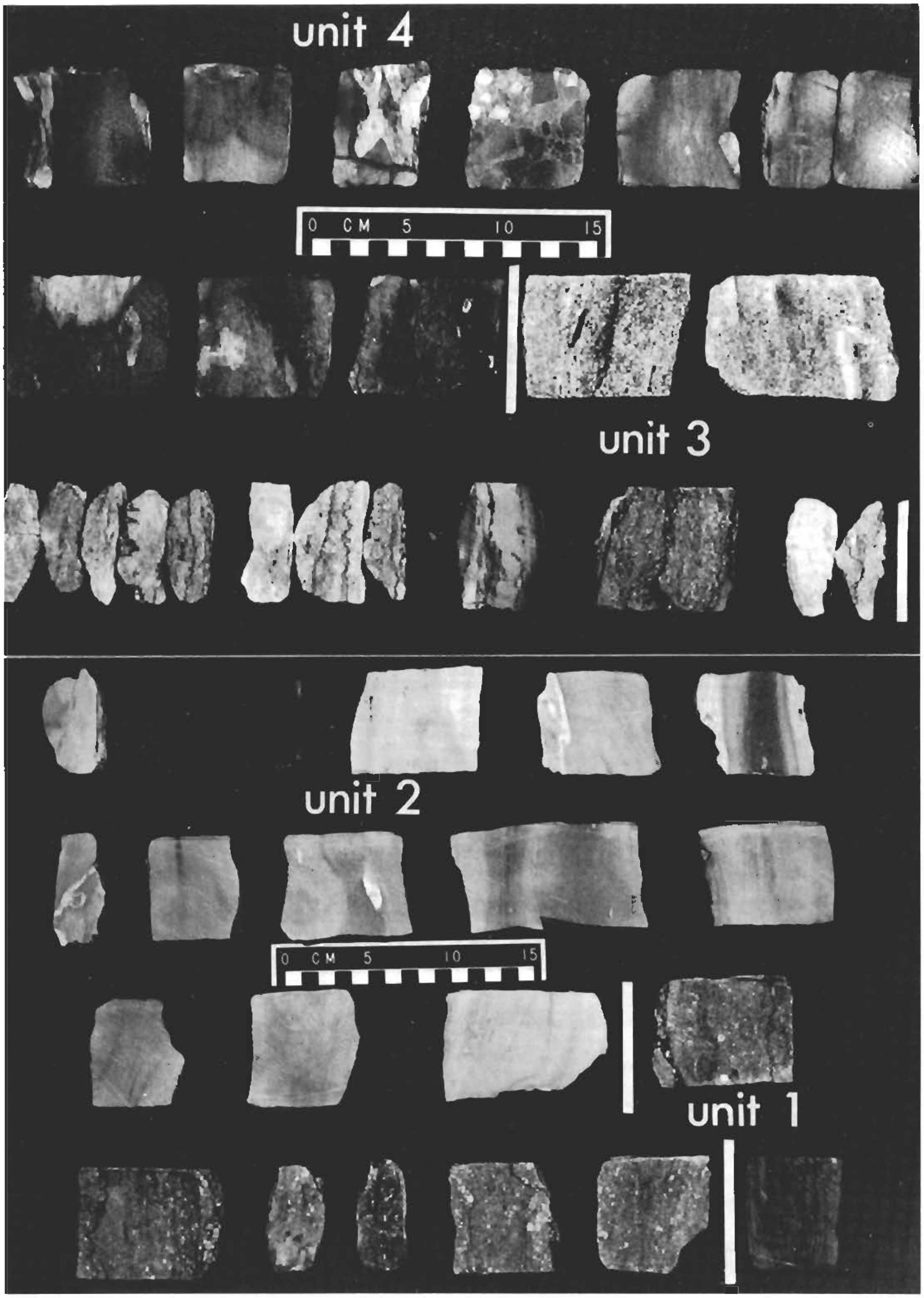


FIGURE 4—Slabbed core of Viola Limestone from Degeer No. 1 (sec. 34, T. 32 S., R. 15 W.). Basal limestone = 1; lower cherty dolomitic limestone = 2; upper limestone = 3; and upper cherty dolomitic limestone = 4. Stratigraphic depth increased from top to bottom and from left to right.

in some cores. The matrix, which was probably originally aragonitic 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 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 nonferroan and ferroan dolomite. Fine-grained neomorphic calcite spar may exist between the dolomite rhombs.

The fossils in this facies include crinoids, bryozoans, brachiopods, trilobites, phosphatic brachiopods, sponge

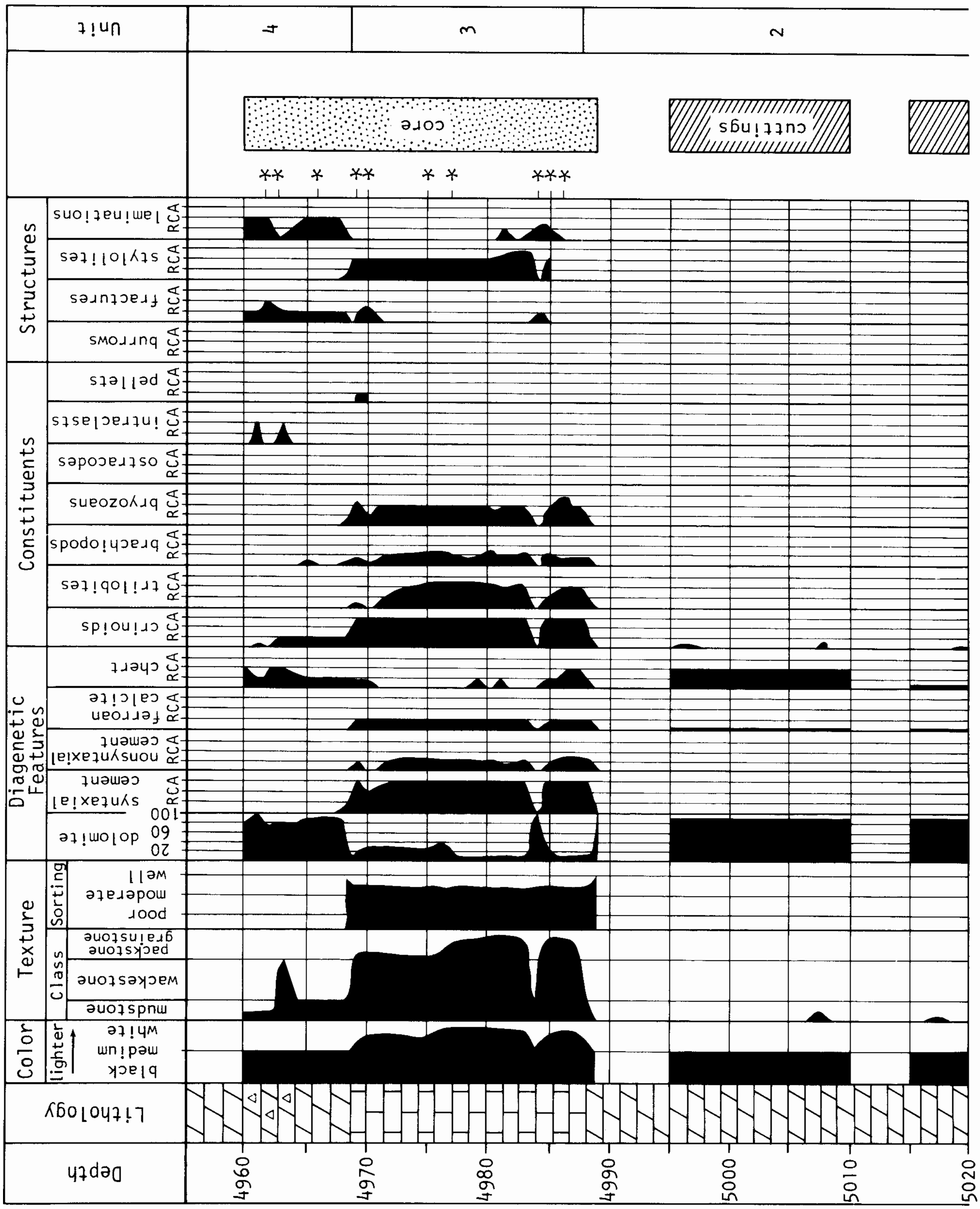
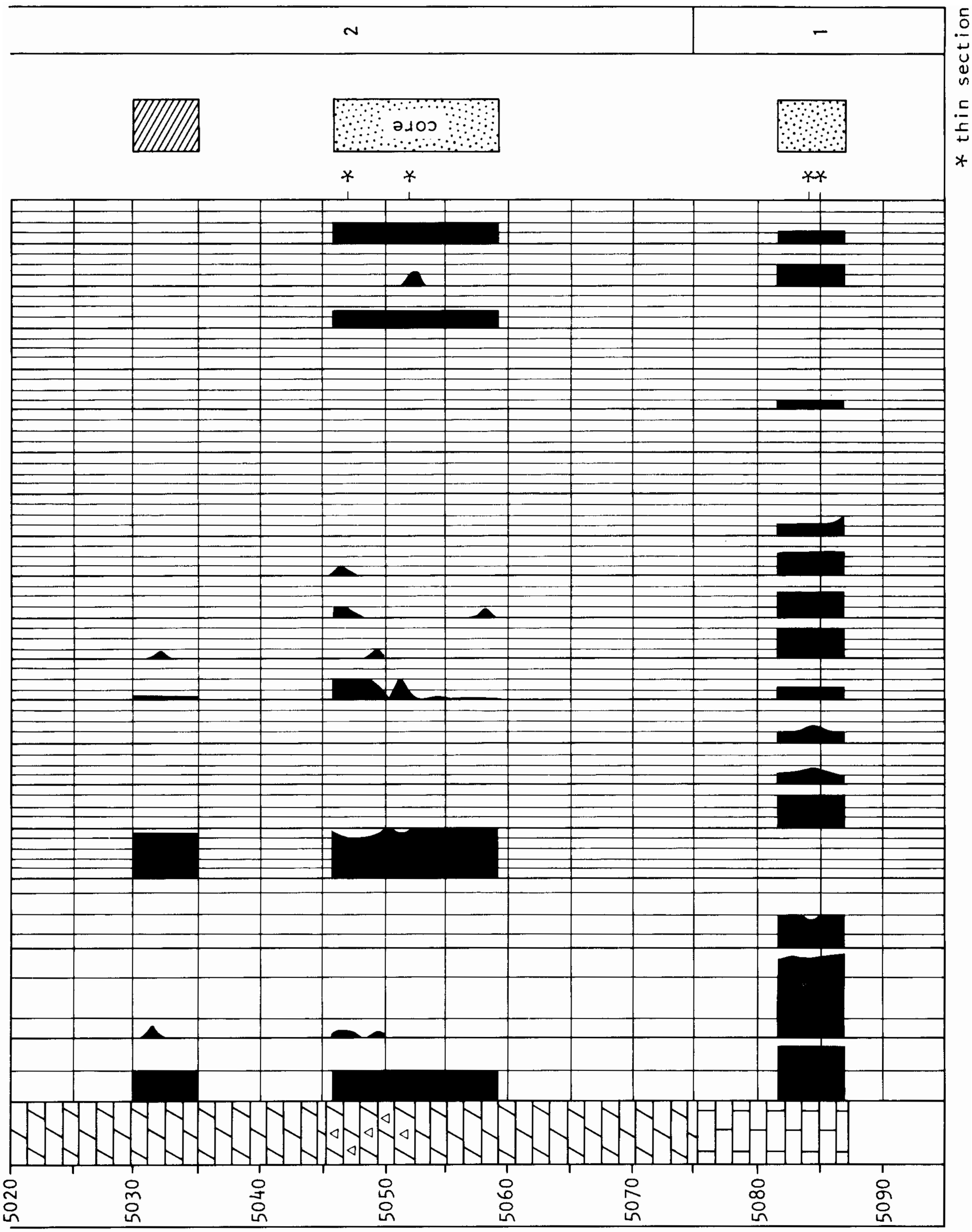


FIGURE 5—Core description of Viola Limestone in Sinclair-Prairie Degeer No. 1 well, NENWNE sec. 34, T. 32 S., R. 15 W., Barber County, Kansas.


2
1
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5020
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spicules, ostracodes, and unidentified phosphatic skeletal fragments. Only a few of these are present in a single sample. Other constituents include nonskeletal phosphatic material 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 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 wackestone may be up to 5.2 cm long. They are light gray or white and are composed of cryptocrystalline quartz. The contact between the nodules and the carbonate matrix usually is sharp.

Upper limestone

The upper limestone is only present today in the southwestern half of the study area, having been beveled by erosion in the northeast. It ranges in thickness from 0 to 32 ft and consists of crinoid packstones and grainstones. In almost all respects, the petrographic characteristics of the upper limestone are extremely similar to the basal limestone.

Upper cherty dolomitic limestone

This unit occurs only in the western and southern part of the area, having been beveled by erosion to the east and the north. It ranges in thickness from 0 to 48 ft and consists of mixed-skeletal wackestones with some dolomitic intraclast wackestones and dolomitic mudstones over the Pratt anticline.

Pale-green or light-gray, mixed-skeletal wackestones were deposited in the southern part of the study area. Their matrix probably was originally aragonitic and high-magnesium calcite mud, which has since either been 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 the lower cherty dolomitic limestone, 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 probably are fossils that have been micritized beyond recognition, and phosphatic material. Generally no more than three constituents are present at any given location, and usually only one or two varieties are present. Crinoids are the most common, followed by trilobites and ostracodes. Syntaxial overgrowths on the crinoids, when present, are poorly developed. The fossils usually are calcite but may be partially or completely replaced by cryptocrystalline quartz. The crinoids also are commonly replaced by single crystals of dolomite and appear as crinoid ''ghosts'' within the dolomite crystals.

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, which also may have promoted penecontemporaneous dolomitization.

Chert nodules in the skeletal wackestones are white or gray with white borders, are composed of cryptocrystalline quartz, and may be more than 6.5 cm 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, with the most intensive silicification occurring at the outer edges of the bands. If the silica replaced a calcite matrix, the calcite crystals often are 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 skeletal wackestones, along the edge of the Pratt anticline, this unit is represented by dolomitized intraclast wackestones and laminated dolomitized 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 in length and are composed of very fine grained dolomite. They tend to be more ferroan than 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 of Viola depositional environments

The crinoid packstone-grainstone facies of the basal limestone 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 although the possibility exists in the study area, this 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 represent an environment that was laterally equivalent to the crinoid packstone-grainstone facies over 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 the basal limestone to the overlying unit. 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 freshwaters, 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 also are conceivable if extensive rains provided enough freshwater to dilute the system or to cause seasonal fluctuations in salinity.

After the abrupt marine regression or sea-flow uplift that preceded deposition of the mudstones at the base of the lower cherty dolomitic limestone unit, 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 the upper limestone unit. During this period moderate- to high-energy, open-marine conditions again prevailed in the study area.

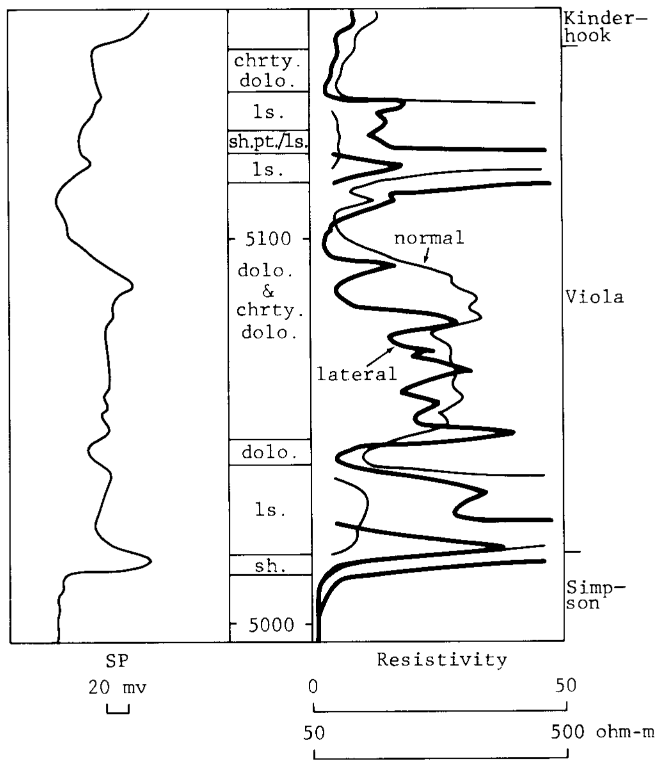

FIGURE 6—Spontaneous potential and resistivity logs for Degeer #1 core sample.

The deposition of the mixed-skeletal wackestones of the upper cherty dolomitic limestone unit over the crinoid packstone and grainstones of the upper limestone 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 wackestone and laminated mudstones along the slopes of the anticline.

A generalized depositional model for the Viola in south-central Kansas is shown schematically in fig. 5 and summarizes the lateral relationships between the facies of the informal stratigraphic subdivisions. In this interpretation, the crinoid packstone-grainstone facies was deposited in an open-marine environment, the mixed-skeletal wackstones were deposited in a semirestricted environment, and the dolomitic mudstones were deposited in a very restricted, low-energy environment. The facies belts roughly paralleled the Central Kansas arch, which is located to the northeast of the model.

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

Workshop core: Degeer #1

The preceding remarks summarize observations made on core drawn from ten wells in the two-county area. Core samples from Degeer #1 provide example specimens from all four Viola unit subdivisions (fig. 4). Graphic logs of texture, diagenetic features, constituents, and structures are shown in fig. 5. Since Degeer #1 is an older well (1947), the associated wireline-log suite is rather restrictive. However, the spontaneous potential and resistivity logs (fig. 6) are sensitive to porosity/permeability variations which are closely keyed with the lithofacies character of each unit. The relatively tight limestone divisions of units 1 and 3 are readily contrasted by their high resistivities with the more porous dolomites of units 2 and 4, which show lower resistivities.

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