Technical Series 6 Kansas Geological Survey

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Contents

Abstract

Regional aspects of the stratigraphy and depositional environments of Chase Group strata were examined throughout Kansas and in southeastern Nebraska based on description and correlation of 196 measured sections. Several important revisions in the stratigraphic nomenclature of the group are proposed and documented: (1) the base of the Schroyer Member of the Wreford Limestone is consistently placed at the base of the cherty limestone section that variously overlies either shale or a thick section of non-cherty limestones in the upper Havensville Member; (2) reinstatement of the name Bruno limestone in reference to a stratigraphically significant carbonate zone within the Blue Springs Member of the Matfield Shale; (3) the Blue Springs–Florence contact is placed at the base of a regionally persistent section of non-cherty limestone and minor interbedded shale in the basal Florence; (4) abandonment of the Barneston Limestone, and elevation of the Florence and Fort Riley each to formation status; (5) recognition of the Cole Creek Member (new name) in reference to the section of non-cherty limestones, and locally, interbedded shales in the basal part of the Florence Formation; (6) inclusion of the Oketo Shale as the upper member of the Florence Formation; (7) recognition that the Gage Member of the Doyle Shale is present in southern Kansas; (8) recognition in south-central Kansas of the non-cherty Santa Fe Lake Member (new name) of the Winfield Limestone as the stratigraphic equivalent of the basal, cherty Stovall Member present in central and northern Kansas; (9) reinstatement of the Luta as the upper member of the Winfield Limestone (thus extracting it from its present inclusion within the Cresswell Member); and (10) recognition that the Cresswell Member of the Winfield Limestone is absent by nondeposition in northern Kansas and Nebraska, where instead, only the Stovall, Grant, and Luta Members compose the formation.

The stratigraphy of the Chase Group defines a hierarchal framework of third-order to progressively higher-frequency, fifth- or sixth-order cycles that document the combined effects of glacio-eustatic forcing, regional to local tectonism along the still-active Nemaha Ridge, and autogenic controls on deposition. Classic midcontinent cyclothems are represented by the fourth or fifth-order cycles in Chase Group strata.

Introduction

Strata of the Chase Group (Permian, Wolfcampian) are exposed from north-central Oklahoma, across east-central Kansas, and into southeastern Nebraska (fig. 1). These outcrops offer an excellent opportunity to examine facies mosaics, inferred paleoenvironments, diagenesis, and sequence-stratigraphic development along the strike of, and to some extent in a dip direction along, the shallow, intracratonic basin in which the rocks were deposited (Mazzullo et al., 1995, 1996). Such studies are critical in defining models with which correlative subsurface strata, particularly those that are host to economic accumulations of fossil fuels, eventually can be compared and interpreted. In this regard, study of Chase Group outcrops is especially relevant to a better understanding of the genesis and geometry of reservoirs in the giant Hugoton-Guymon–Hugoton-Panhandle field in southwestern Kansas and adjoining states, where gas production is mostly from this group of rocks (Pippin, 1970).

Such integrated studies can be done only within a well-constrained stratigraphic framework that is based on the identification and regional correlation of mappable lithologic units across the study area. Basic elements of the stratigraphy of the Chase Group have been studied for more than a century since the pioneering surveys through Kansas of Meek and Hayden (1858, 1859) and Swallow (1866). However, many important issues of stratigraphic terminology, stratotype boundaries, lithofacies development, and regional correlation of lithic units remain unresolved (Chaplin, 1988; Mazzullo et al., 1995).

The principal objective of this paper is to address these issues by describing the stratigraphy and complex lithofacies mosaics of the Chase Group based on outcrop studies throughout Kansas and southeastern Nebraska. Secondary objectives of this paper are to describe some of the more important aspects of paleodepositional environments and cyclicity of these rocks. More incisive studies of diagenesis, sequence stratigraphy, possible factors controlling cyclicity, and correlation of exposed Chase Group strata into the subsurface are the focus of continuing studies and will be presented in future papers.

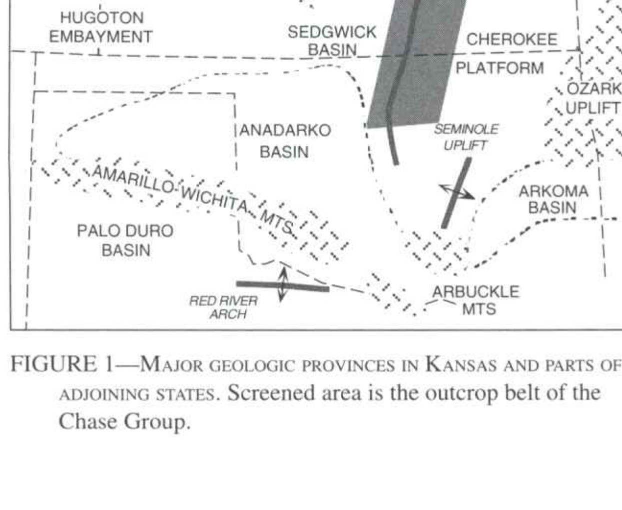


FIGURE 1—MAJOR GEOLOGIC PROVINCES IN KANSAS AND PARTS OF ADJOINING STATES. Screened area is the outcrop belt of the Chase Group.

Study Area

Geologic Setting and Stratigraphic Framework

The Chase Group is exposed for about 230 mi (370 km) in a more-or-less continuous, northeast-trending outcrop belt from Payne and Logan counties in Oklahoma, through 17 counties in Kansas, and then northward into Gage, Pawnee, and Richardson counties in Nebraska (fig. 1). Exposures throughout Kansas and in Nebraska comprise the study area described in this paper (fig. 2).

Deposition of the Chase Group in the study area occurred on the relatively stable, slowly subsiding midcontinent craton (Peterson, 1980; Rascoe and Adler, 1983; Rascoe, 1988; Mazzullo, 1995) which, during the Early Permian, included parts of the Cherokee Platform; the Forest City, Salina, Sedgwick, and Central Nebraska basins; and the buried Nemaha Ridge (fig. 1)(Merriam, 1963). This area was situated about 7-10° north of the paleoequator according to the global maps of Scotese and McKerrow (1990) and Golonka et al. (1994). The Nemaha Ridge was mildly tectonically active at times during the Pennsylvanian and Permian, and locally, appears to have affected deposition of these strata in Nebraska and Kansas (Nelson and Lumm, 1984; Burchett, 1988; Carlson, 1989a,b; Stander, 1989; Steeples, 1989; Heckel, 1994). Late Wolfcampian tectonism along the Nemaha Ridge is believed to have affected deposition of the Chase Group in Kansas (Mazzullo et al., 1995). The Nemaha Ridge and associated faults remain seismically active to the present (DuBois and Wilson, 1978; Burchett et al., 1985; Stander, 1989; Steeples, 1989; Marshak and Paulsen, 1996).

The Chase Group as currently recognized (fig. 3) is assigned to the upper Wolfcampian, and is correlated to the uppermost Sakmarian to Artinskian of Russia. According to D. Boardman (personal communication, 1996), the Sakmarian–Artinskian boundary occurs at the base of the Florence limestone. The Chase Group is immediately underlain by cyclically deposited carbonates and shales of the Council Grove Group and is overlain by dominantly terrestrial siliciclastics and evaporites of the Sumner Group (fig. 3)(Merriam, 1963; Zeller, 1968). According to Mazzullo et al. (1995, 1996), strata of the Chase Group that crop out in Kansas are a maximum of about 400 ft (122 m) of interbedded marine carbonates and marine to terrestrial siliciclastics. The group thins regionally to the south where, in north-central Oklahoma, it comprises 300–334 ft (92–102 m) of similar lithologies that grade farther south to terrestrial red beds (Shelton et al., 1985; Chaplin, 1988, 1994). A similar change in lithologies is present in the subsurface along the west side of Hugoton and Guymon–Hugoton fields in the Hugoton embayment (Pippin, 1970; Rascoe and Adler, 1983; Parham, 1993; Parham and Campbell, 1993). The Chase Group also thins to the north, being from about 239 to 275 ft (73–84 m) thick in Nebraska according to Condra and Upp (1931) and Burchett (1988). Its northern, pre-Mesozoic erosional

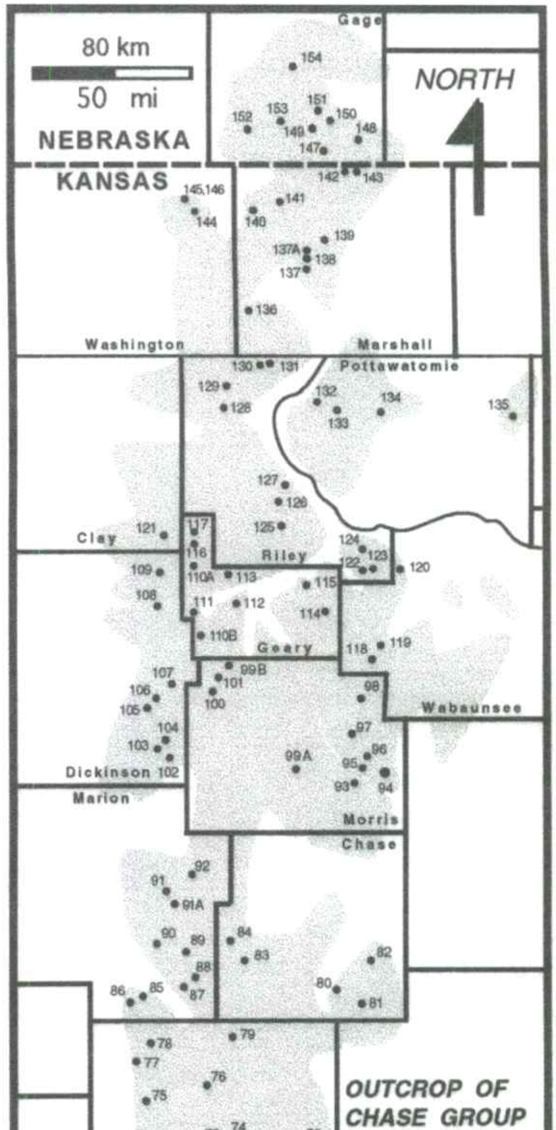


FIGURE 2—Outcrop belt of the Chase Group in Kansas and southeastern Nebraska, showing locations of measured sections referenced to the Appendix and text by numbers.

limit in Nebraska is concealed beneath Pleistocene glacial deposits (Burchett, 1988). The eastern edge of the outcrop belt, particularly in Kansas, is defined by the erosionally backstepping, Flint Hills escarpment. Paleoshorelines, and updip gradation into terrestrial siliciclastics, are postulated to have existed north of the outcrop in Nebraska and east of the outcrop in Kansas.

Data Base and Methods of Study

This study is based on a total of 196 measured sections of outcropping Chase Group strata in the study area, 188 of which are in Kansas and eight of which are in Nebraska. Locations of the 160 most informative and stratigraphically complete of these sections, referenced by number, are shown in fig. 2. Very poor and incomplete exposures precluded measurement of outcrop sections in Lyon and Nemaha counties in Kansas, and in Richardson and Pawnee counties in Nebraska. Detailed descriptions of the 160 measured sections, including specific geographic locations and other pertinent information useful in locating and accessing these outcrops, are included in the Appendix to this paper. In addition to newer exposures, we examined nearly all of the outcrops, where they still exist, that were described initially by earlier workers such as Hay (1893, 1896), Prosser (1894, 1895, 1897a,b, 1902), Prosser and Beede (1904), Beede and Sellards (1905), Beede (1908), Fath (1921), Bass (1929), Condra and Upp (1931), Moore (1936), Jewett (1941), Moore et al. (1951b), O'Connor et al. (1953), Walters (1954), Hattin (1957), Mudge et al. (1958), Byrne et al. (1959), Scott et al. (1959), Walters and Bayne (1959), Bayne (1962), and Lutz–Garihan and Cuffey (1979). All unit stratotypes (type localities and/or type areas) that were proposed by previous workers also were examined.

Grp	Formation	Member
SUMNER	WELLINGTON FM.	MILAN HUTCHINSON CARLTON HOLLENBERG
CHASE	NOLANS LS.	HERINGTON PADDOCK KRIDER
	ODELL SH.	undivided
	WINFIELD LS.	CRESSWELL GRANT STOVALL
	DOYLE SH.	GAGE TOWANDA HOLMESVILLE
	BARNESTON LS.	FORT RILEY OKETO FLORENCE
	MATFIELD SH.	BLUE SPRINGS KINNEY WYMORE
	WREFORD LS.	SCHROYER HAVENSVILLE THREEMILE
COUNCIL GROVE	SPEISER SH.	undivided
	FUNSTON LS.	undivided
	BLUE RAPIDS SH.	undivided
	CROUSE LS.	undivided
	EASLY CREEK SH.	undivided
	BADER LS.	MIDDLEBURG HOOSER EISS
	STEARNS SH.	undivided
	BEATTIE LS.	MORRILL FLORENA COTTONWOOD
	ESKRIDGE SH.	undivided
	NEVA LS.	undivided

FIGURE 3—Currently recognized stratigraphy of the Chase Group (from Zeller, 1968) and the Council Grove Group (from Baars et al., 1994).

In the field, strata were described on a bed-by-bed basis in terms of lithology, thickness (in feet and inches, converted later to metric units), bedding characteristics, color (fresh and weathered), sedimentary and biogenic structures, macrofossils present, and diagenetic attributes. Lithology of carbonate rocks was described using the classification of Dunham (1962). In the text of this paper we use the term shale to refer to siliciclastic claystones and/or silty claystones with fissile texture. In order to avoid confusion with carbonate mudstones (e.g., lime mudstone, dolomudstone), which are always specifically referred to as such in the text, siliciclastic claystones without fissility (i.e., with blocky texture) are referred to as mudrocks instead of mudstones. The term (siliciclastic) mudstone is used only when citing descriptions of stratal sections from published sources. A current trend among some sedimentologists is to view mudrocks, with their blocky texture, as paleosols (e.g., Miller and West, 1993; Miller et al., 1996), and it is apparent that some such rocks indeed are paleosols (e.g., Retallack, 1988). However, not only is blocky texture common in paleosols, but it may also result from the admixture of clayey sediment with carbonate (e.g., cement or fine particulates) and/or silt, and through bioturbation and haloturbation. Hence many mudrocks, particularly those that are fossiliferous and display no imprint of past soil-forming processes, are not paleosols. We therefore use the terms shale and mudrock in a purely descriptive sense throughout this paper; interpretation of their depositional environments are presented separately.

Rock samples from every unit described in the field (see the Appendix) were returned to the laboratory and routinely slabbed, polished, etched in 10% dilute hydrochloric acid, and re-examined under a high-power (8-50×) binocular microscope for more precise characterization of lithology, identification of component particles, and major diagenetic attributes. Samples were stained with Alizarin red-S to distinguish calcite, dolomite and quartz, and many were subsequently X-rayed, to verify mineralogy, on a Philips XRG-3100 diffractometer utilizing Cu K-alpha radiation. The amount of insoluble residue was calculated, after digestion in dilute hydrochloric acid, to determine specific lithology of many rock samples (e.g., calcitic shale, shaly limestone, etc.) following the classification of Pettijohn (1975). Selected siliciclastic rocks were disaggregated in an ultrasonic bath and examined to identify dominant particle size and possible microfossil content.

History of Study of the Chase Group

Stratigraphic Studies of Outcrops

Subsequent to Meek and Hayden's (1858, 1859) initial descriptions in Kansas, Swallow (1866) defined the stratigraphy of that part of the lower Permian succession that is the Chase Group of present usage, but he did not apply formal stratigraphic names to the section. Later work by Hay (1891, 1893, 1896), in the Republican-Smoky Hill-Kansas River valleys in northern Kansas and areas to the immediate south, did not result in any substantive changes in the stratigraphy, except for his introduction in 1893 of the name "Wreford limestone" in place of Swallow's 1866 designation of beds 58 through 62. The Chase Formation was originally defined by Prosser (1895) from exposures in Chase County, Kansas; in their 1934 report, Moore et al. had elevated the section to group status. After having examined outcrops from Nebraska to southern Kansas, Prosser (1894, 1895, 1897a,b,c, and 1902) and Prosser and Beede (1904) eventually defined the Chase Formation, and later the Chase Stage, as including those currently recognized formations from the Wreford Limestone (referred to earlier as the Strong flint) to the Winfield Limestone (formerly the "Marion concretionary limestone"); the overlying beds of their Marion Formation were assigned to the Sumner Stage (Prosser, 1902; Prosser and Beede, 1904)(fig. 4). This stratigraphy was followed by Adams et al. (1903) and Beede and Sellards (1905), although later, Beede (1908) considered the Chase Stage to be overlain by the Marion Stage which included, in its lower part, the Luta limestone, Enterprise Shale, and Herington Limestone (fig. 4). The Chase and Marion stages were assigned to the Lower Permian based on biotic studies by some of the aforementioned earlier workers, an assignment that was confirmed by Prosser (1897c, 1905), Beede and Sellards (1905), Beede (1909), and later, by Ross (1963).

Studies in Butler County, Kansas, by Fath (1921) and in Cowley County, Kansas, by Bass (1929) described some details of facies changes in Chase Group strata in these areas, and resulted in Fath's recognition of the Towanda Limestone. One of the most important regional studies of the Chase Group was that of Condra and Upp (1931), who named many of the members now recognized within this section in Kansas and Nebraska. In their classification they returned to the older stratigraphic terminology of Prosser (1902) and Prosser and Beede (1904) in assigning the Odell, Krider, and Paddock (then, newly defined units within the Enterprise Shale) and overlying Herington Limestone to the Marion Formation of the Sumner Group

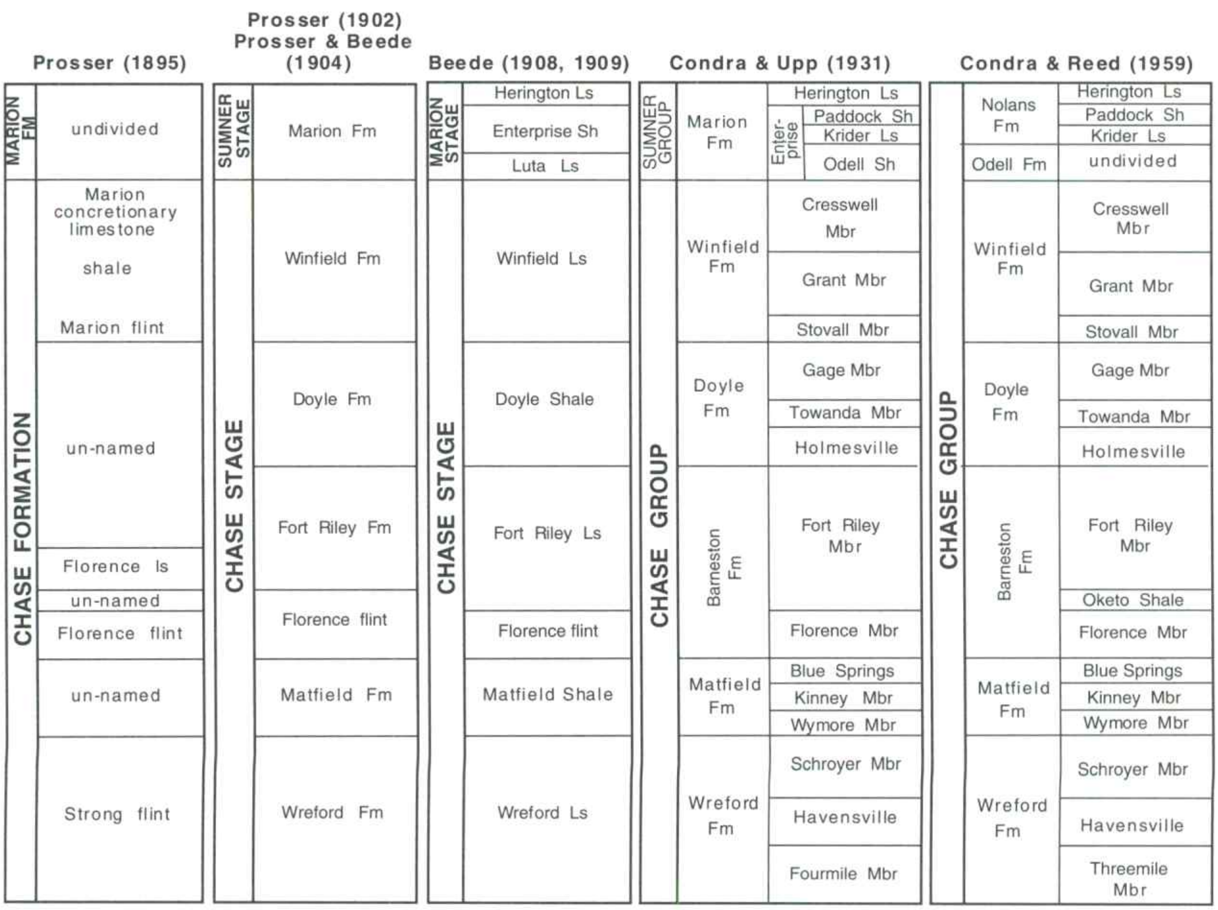


FIGURE 4—Abridged history of stratigraphic terminology of the Chase Group in Kansas and Nebraska.

(fig. 4). Condra and Reed (1943, 1959) later included the beds from the base of the Wreford to the top of the Herington within the Chase Group, which was the stratigraphic terminology adopted by Moore et al. (1951a), and which currently is recognized in Kansas (Zeller, 1968, fig. 3). Subsequent studies in various Kansas counties by Moore et al. (1934, northern counties), Jewett (1941: Riley and Geary), Moore et al. (1951b: Chase), O'Connor et al. (1953: Lyon), Walters (1954: Marshall), Mudge et al. (1958: Morris), Byrne et al. (1959: Marion), Scott et al. (1959: Pottawatomie), Walters and Bayne (1959: Clay), and Bayne (1962: Cowley) generally followed, and in some instances (Moore et al., 1934), slightly modified the stratigraphic terminology of these strata.

The specific contributions of these workers to the evolution of stratigraphic terminology of the Chase Group are discussed in the following sections.

Sedimentologic and Biotic Studies

In addition to providing useful stratigraphic information, several notable papers have been published on the sedimentology, paleontology, and paleoecology of strata of the Chase Group that crop out in Kansas and adjoining states. Cyclicity in these strata was described by Jewett (1933), Moore (1936, 1950, 1959), Elias (1937, 1964), Hattin (1957), Lutz–Garihan and Cuffey (1979), Busch et al. (1985), Busch (1988), Boardman and Heckel (1989), Boardman and Nestell (1993), Miller and West (1993), Mazzullo and Teal (1994), Archer (1995), Archer et al. (1995), Boardman et al. (1995), Mazzullo et al. (1995, 1996), Chaplin (1996), and Miller et al. (1996). General aspects of the sedimentology and mineralogy of a near-surface core of the Chase Group from Riley County were examined by Twiss (1991). Twiss and Underwood (1988) earlier had described gross aspects of the stratigraphy and mineralogy of the Barneston Limestone exposed at some localities in north-central Kansas. Shelton et al. (1985) and Chaplin (1988, 1994, 1996) examined carbonate-to-siliciclastic facies changes in the Chase Group from southern Kansas into Oklahoma.

Fossil flora in the rocks were described by Sellards (1908) and Elias (1936), fusulinids in the Wreford and Barneston by Thompson (1954) and Sanderson and Verville (1970, 1988), fusulinids in the Barneston by Toomey (1992), and bryozoans in the Wreford by Cuffey (1967) and others. The biota of the Luta limestone was examined by Boos (1929), and Hattin (1957) and Lutz–Garihan and Cuffey (1979) described regional aspects of sedimentation and paleoecology in the Wreford, including the occurrence of supposed reefs in the Threemile Member. Elias (1964) and Moore (1964) summarized details of the paleontology and depositional facies of the entire Chase Group in Kansas. Toomey and Mitchell (1986) described biota and depositional facies in the Winfield-to-Herington section in southern Kansas and northern Oklahoma, and Toomey (1992) examined similar aspects of the Barneston Limestone in Oklahoma from outcrops and cores. Boardman and Heckel (1989), Ritter (1991), Boardman and Nestell (1993), and Boardman et al. (1995) described cyclicity and biota, including conodonts, in the lower Chase Group throughout large areas of the midcontinent. The relevance of these contributions to the present study will be discussed in subsequent sections of this paper.

Stratigraphic Framework

In this section we describe, in ascending order, the systematic stratigraphy of each of the formations and their component members within the Chase Group with regard to locations of original unit stratotypes when so defined, formation and/or member boundaries, and characteristic lithology and paleontology. In these descriptions, rock colors refer to those of fresh surfaces. Stratigraphic revisions and designation of principal reference sections for several units are proposed and formally documented following the Code on Stratigraphic Nomenclature (North American Commission on Stratigraphic Nomenclature, 1983) in instances where original stratotypes were either not specified, were poorly defined, or are no longer well exposed. Regional stratigraphic relationships and major elements of depositional facies of each formation throughout Kansas and southeastern Nebraska are discussed and illustrated in the second part of this paper.

Wreford Limestone

History of Terminology

The name Wreford Limestone was originally used by Hay (1893, and again in 1896) in informal reference to the cherty limestones exposed in several quarries around the then-existent town of Wreford in Geary County, Kansas; in an earlier publication (Hay, 1891) the name had been misspelled as "Walford." In none of these publications did Hay provide a specific type locality or stratotype description of this unit. Prosser (1894) suggested that the name "Ogden flint" could instead be applied to this unit if the name Wreford proved to be undesirable. Later, Prosser (1895) instead proposed the name "Strong flint" for this unit which, although named for exposures on Crusher Hill about 1.5 mi (2.4 km) west of Strong City in Chase County, Kansas, was for some reason described from exposures about 2 mi (3.2 km) northeast of the town of Council Grove in Morris County, Kansas. Prosser (1902) eventually accepted the name Wreford, and then, formally abandoned the name "Strong flint" (Prosser and Beede, 1904).

Despite the fact it was never formally defined, and a stratotype description was not specified by Hay (1891, 1893, 1896), the name Wreford nevertheless has since become widely accepted in Kansas and Nebraska. The Wreford is very poorly exposed, and its upper and lower contacts are mostly obscured, in the abandoned quarries around the former town of Wreford. Therefore, a principal reference section is proposed for this unit at the roadcuts along I–70 in the NE sec. 34 (south side of the road) and the adjoining SE sec. 27 (north side of the road) in T. 11 S., R. 6 E., Geary County, Kansas (fig. 5). Prior permission from the Kansas Department of Transportation to examine roadcuts along the interstate is recommended, and often required, by the highway patrol. The designated location is 8 mi (12.9 km) northeast of the former town of Wreford, the original type area, and is the closest exposure of a complete Wreford section in the general vicinity. Hattin (1957) mentioned supposed Wreford outcrops only 1 mi (1.6 km) northwest of Wreford, located specifically at the roadcuts along US–77 just south of the bridge over the Smoky Hill River. This roadcut, however, does not expose the Wreford, but rather, a continuous section from the upper part of the Matfield to the lower Fort Riley.

The entire Wreford is well exposed along I–70 (fig. 5B,C [our measured section number 113]), where it is about 38 ft (11.6 m) thick and comprises, in ascending stratigraphic order, 11.5 ft (3.5 m) of the cherty Threemile Member, 18 ft (5.5 m) of the Havensville Member, and 8.5 ft (2.6 m) of the mostly cherty Schroyer Member (fig. 6). The basal contact of the Wreford here is placed at the lowest occurrence of hard, resistant, light-colored (yellow), cherty limestone in the Threemile Member above the gray, fossiliferous shale and mudrock of the Speiser. This lower limestone, 2 ft 8 inches (0.8 m) thick, is overlain by about 9 inches (23 cm) of fossiliferous, yellow-gray mudrock in the lower part of the Threemile (fig. 6). Together both units are, notwithstanding thickness changes, regionally persistent and readily recognized marker beds throughout the state (see, e.g., Jewett, 1941; Hattin, 1957). The upper contact of the formation is placed at the base of the unfossiliferous, green, silty shale of the basal Wymore Member of the Matfield Shale. Throughout much of Kansas, the uppermost beds of the Wreford (top of the Schroyer Member) are non-cherty limestones, typically biopackstone to grainstone, with a prominent unconformity at the top (Mazzullo et al., 1995, 1996).

Cherts in the Wreford section here, as well as throughout the study area, typically are nodular to bedded, and vary in color from dark-gray (commonly laminated in the lower half of the Threemile) to light-gray, and locally, orange-yellow; the lighter colors result from weathering. Where fossiliferous, the cherts typically contain the same types of fossils as those that occur in the surrounding limestones.

Threemile Member

This member of the Wreford Limestone was originally named the Fourmile Limestone by Condra and Upp (1931) from exposures along Fourmile Creek in Richardson County, Nebraska, which are no longer well exposed. Because of prior usage this name was abandoned, and the name Threemile Limestone Member was proposed by Moore et al. (1934) for exposures in the valley of Threemile Creek, southwest of the town of Ogden, in Riley County, Kansas. This type area is located on the Fort Riley Military Reservation and is accessible when not in use for military exercises. Specific type location and stratotype descriptions unfortunately were not given by Moore et al. (1934). The name Threemile again appeared in Moore and Elias (unpublished open-file report) and was cited at a field-trip stop in a Kansas Geological Society guidebook (Moore, 1936).

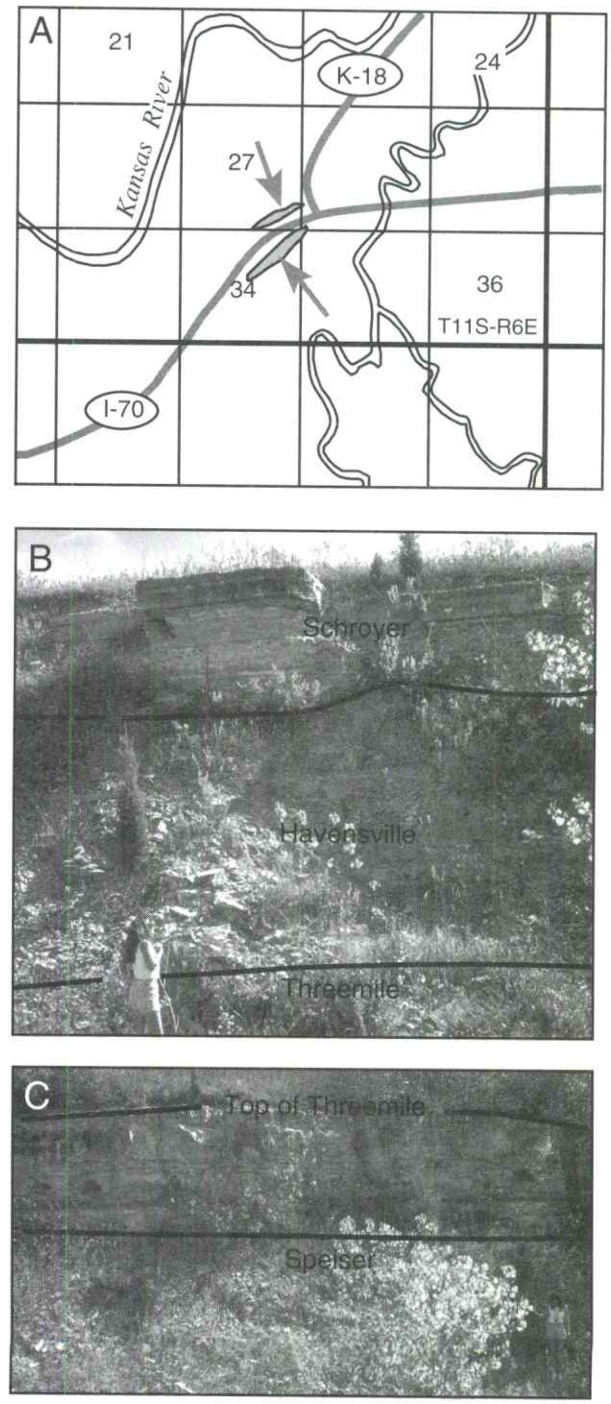


FIGURE 5—A) Location of principal reference sections of the Wreford Limestone, and Threemile and Havensville Members in Geary County, Kansas. B and C) Photographs of the Speiser to Schroyer section at this locality.

Despite the fact that this unit was improperly described and documented, the name Threemile is well established in the stratigraphic literature. Exposures in the type area are now mostly poorly exposed and subject to periodic inaccessibility because of military restrictions. Hattin (1957) suggested that a suitable reference section for the Threemile might be a quarry that he located in the NW SW sec. 11, T. 11 S., R. 6 E., which is along Threemile Creek and also on the military reservation. At this location we found only a mostly filled, shallow quarry where exposures are very poor, and where only the Matfield and uppermost beds of the Schroyer crop out. We located another old quarry nearby, on the west side of Packers Hill, which is to the immediate west of Campbell Hill Road on the military reservation. In fact, this quarry may actually be the one referred to by Hattin (1957), but it is in the SW sec. 10, T. 11 S., R. 6 E. The Threemile, Havensville, and Schroyer are exposed here, with upper beds of the Speiser exposed in the bar ditch along the road. This quarry also is not a suitable reference section for the Threemile because exposures are relatively poor and are on a near-vertical cliff face, and the basal contact with the Speiser is concealed.

We therefore propose a principal reference section for the Threemile Member at the same locality as for the Wreford (fig. 5A), which is our measured section number 113 (fig. 6). The Threemile is 11.5 ft (3.5 m) thick here and conformably overlies the Speiser Shale. The basal 2 ft 8 inches (0.8 m) consist of two beds of very light gray, cherty, sparsely fossiliferous lime mudstone with crinoids, fenestrate bryozoans, and *Composita* spp. Although Sanderson and Verville (1970) supposedly noted the occurrence of the fusulinid *Schwagerina* in correlative lower beds in Chase County, Kansas, we have not yet found fusulinids anywhere in the Threemile. These basal limestones contain abundant chert nodules throughout most of Kansas, but southward from about the latitude of the city of Winfield in Cowley County, chert nodules become rare to absent in the basal part of this section. Instead, the limestones contain abundant, silicified *Composita* (e.g., see measured sections 15 and 22). At the principal reference section, these lower limestone beds are overlain by 7 inches (17.8 cm) of fossiliferous, yellow-gray, calcitic mudrock that grades rapidly upward to 2 inches (5.1 cm) of yellow-gray, shaly biowackestone, both of which contain abundant fenestrate bryozoans and accessory ramose bryozoans, crinoids, *Chonetes* spp., *Derbyia* spp., *Reticulatia* spp., and *Composita* spp. The overlying 6 ft 9 inches (2.1 m) consist of generally thick-bedded, very light yellow, fossiliferous lime mudstone to sparse biowackestone which is cherty in only the top 4 ft (1.2 m). Fossils include crinoids, ramose bryozoans, and brachiopod fragments. The upper 1 ft 4 inches (0.4 m) of the member consist of thin-bedded, yellow-gray, shaly and cherty lime mudstone that grades upward to cherty mudrock, both with crinoids and brachiopod fragments; a

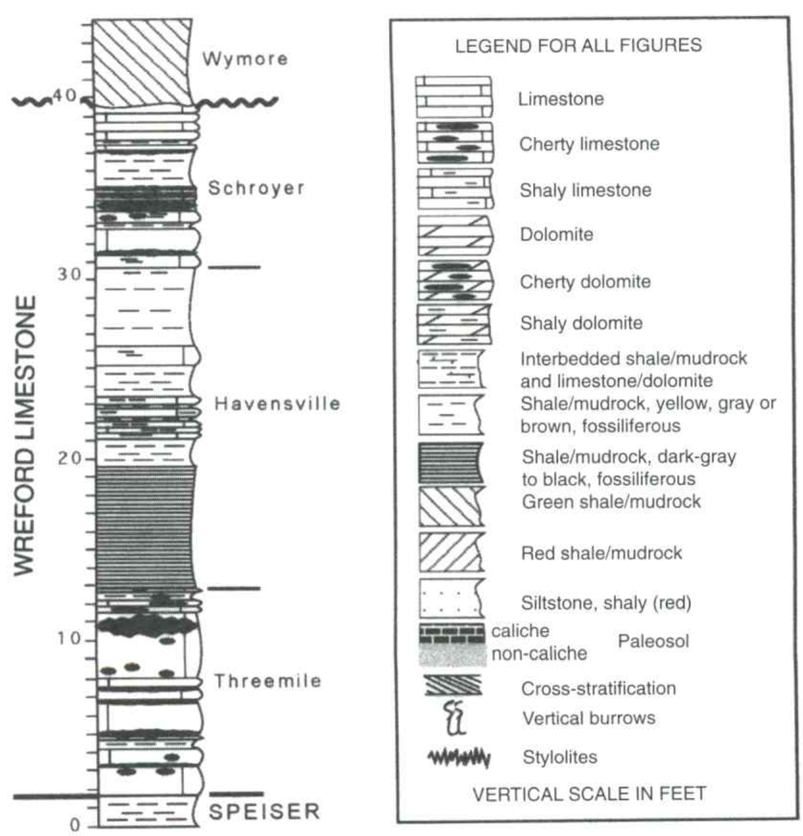


FIGURE 6—Lithostratigraphy of Wreford Limestone at the principal reference section (measured section number 113). Inset is lithologic legend for all ensuing columnar sections and stratigraphic cross sections. All vertical scales are in feet.

thin limestone with chert nodules caps this section (fig. 6). The upper contact with the Havensville Shale at this locality is gradational within a few inches, but is placed at the highest bed of cherty limestone in the section (fig. 6). As discussed later, an additional section of non-cherty carbonate sands overlying these cherty limestones commonly is developed in the upper Threemile farther to the south in Kansas.

Revisions of the Havensville and Schroyer Members

The Havensville Member was formally named and described by Condra and Upp (1931 [their section number 10, p. 34]) at roadside and adjoining gully exposures along K–63, about 2 mi (3.2 km) south of the town of Havensville, in sec. 35, T. 6 S., R. 12 E., eastern Pottawatomie County, Kansas (fig. 7A). According to them, the upper 17–18 ft (5.2–5.5 m)

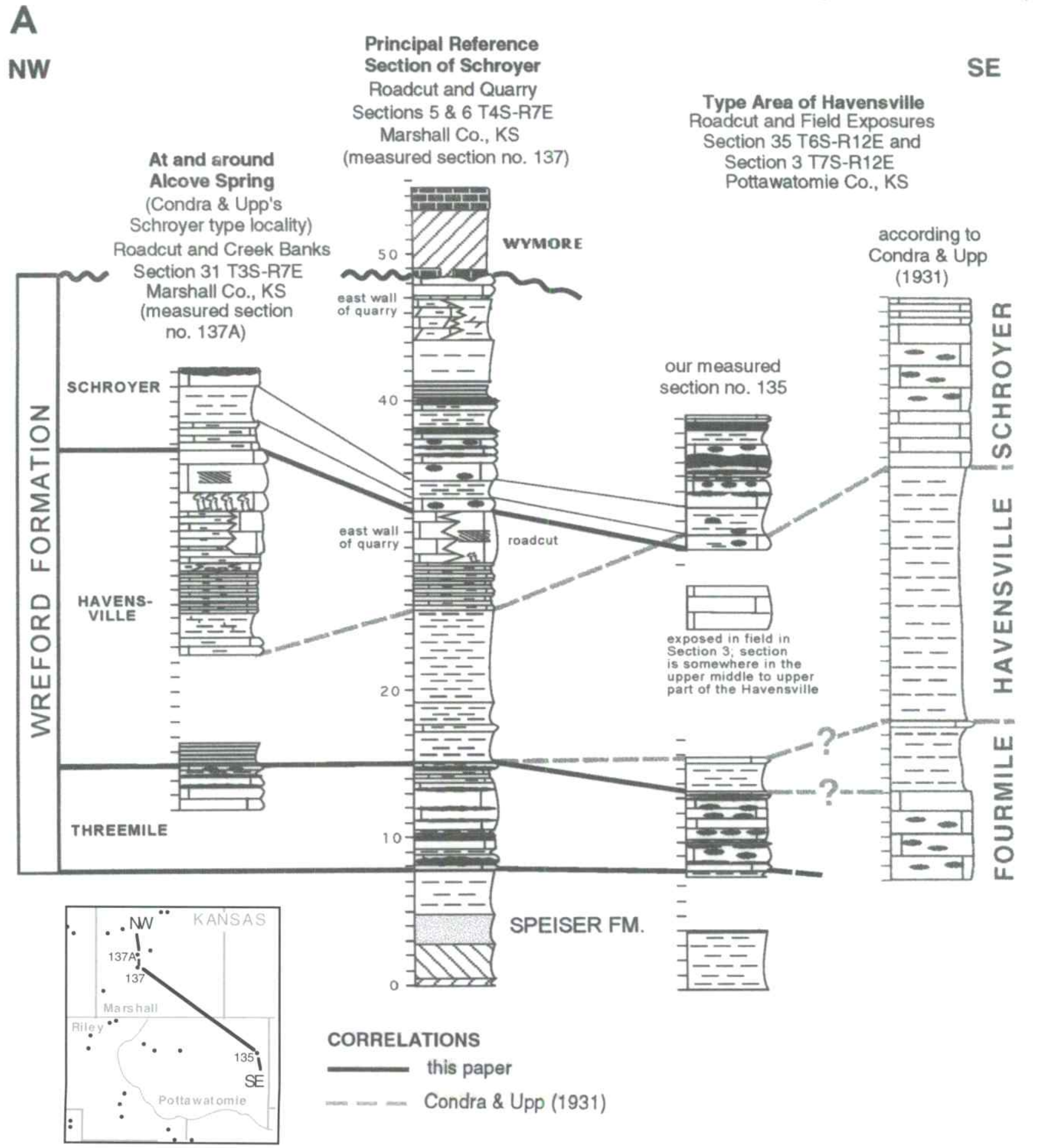


FIGURE 7—A) Lithostratigraphic cross section of Wreford Limestone from type Schroyer area in Marshall County, Kansas, to type Havensville locality in Pottawatomie County, Kansas. This section compares our revised formation and member boundaries and correlations (black lines) and those of Condra and Upp (1931), shown in gray. Inset shows locations of other measured sections of the Wreford in the area.

of the Havensville here was unfossiliferous shale; this section is no longer well exposed. They noted that the Havensville was overlain by nearly 4 ft (1.2 m) of non-cherty limestone which, in turn, supposedly was directly overlain by 8 ft (2.4 m) of exposed cherty limestone. They included all of these carbonate beds within the Schroyer (shown in their section, right side of fig. 7A). We were unable to verify this stratigraphy in that we did not see a section of non-cherty limestone directly beneath the cherty Schroyer along the road, which includes some thin beds of shale (middle section in fig. 7A). We did find, however, approximately 3 ft (0.9 m) of relatively coarse-grained, porous limestone (biopackstone to grainstone) in the fields in sec. 3, T. 7 S., R. 12 S. that appear to be within the upper middle to upper part of the Havensville (fig. 7A). These beds may be the non-cherty limestones referred to by Condra and Upp (1931). Because of poor exposures here and along the road in sec. 35, T. 6 S., R. 12 E., we were unable to ascertain their exact stratigraphic position in the section. These beds, and their presumed stratigraphic equivalents, are discussed in more detail below. Condra and Upp (1931) were uncertain as to the stratigraphic position of what they measured to be 5 ft (1.5 m) of shale capped by a thin bed of fossiliferous limestone at the base of the 17–18-ft (5.2–5.5-m)-thick Havensville at the outcrops in sec. 35 (fig. 7A). By our regional correlations and study of these same outcrops and nearby outcrops, we include this section (instead only about 2.5 ft thick; 0.7 m) within the basal Havensville (fig. 7A).

The Schroyer Member was also formally named and described by Condra and Upp (1931) from the exposures along the east side of the Big Blue Valley, at a locality that they stated was 1.25 mi (2 km) south of the now-abandoned town or railroad siding of Schroyer, in Marshall County, Kansas. At the time, they described this outcrop (their measured section number 11, p. 35) as being badly slumped. Now it is very poorly exposed in the abandoned quarry that is the gravel parking area of Alcove Spring Park; this location is along East River Road in the E/2 sec. 31, T. 3 S., R. 7 E. (fig. 8A). Nevertheless, they described the Havensville here as 8 ft (2.4 m) of shale (no longer exposed) and defined the overlying type Schroyer as including 16 ft 8 inches to 17 ft 8 inches (5.1–5.4 m) of shaly, non-cherty limestones overlain by 5 ft (1.5 m [top contact not exposed]) of cherty limestone (fig. 7A). A composite upper Threemile-to-basal cherty Schroyer section can be compiled in the area around the parking lot/quarry by examination of exposures at: (1) Alcove Spring proper, which is a no-hammer stop because of its historical significance, and (2) the outcrops along East River Road where the creek crosses the road, and the high cutbanks along the creek due east and west of here (fig. 8). These outcrops comprise our measured section number 137A (fig.7A).

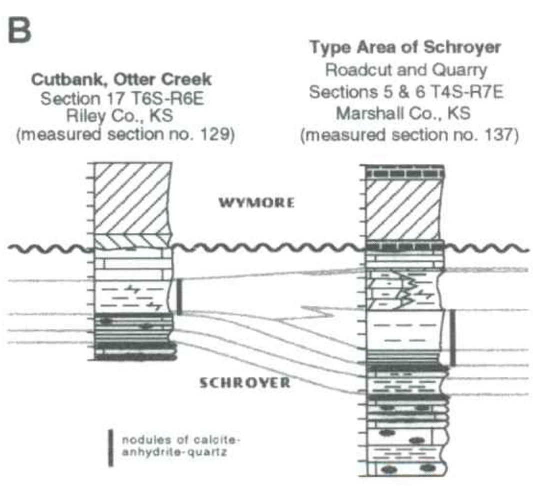


FIGURE 7—B) Correlation of equivalent strata in the upper Schroyer between outcrops at measured section number 137 in Marshall County, and those at measured section number 129 in Riley County, Kansas. Although it has thinned, the section beneath the non-cherty limestone at the top of the Schroyer, of dark shale overlain by dolomitic shale, is present in both areas.

Exposures at the type localities of both the Havensville and Schroyer are incomplete, and hence, they no longer serve as reference sections for these units. The Speiser (and underlying Funston) to the lower Matfield Shale, however, is very well exposed in roadcuts along East River Road in sec. 6, T. 4 S., R. 7 E. and in an adjoining quarry in sec. 5, T. 4 S., R. 7 E. Both locations, which compose our measured section number 137, are about 1 mi (1.6 km) due south of the type locality of the Schroyer (fig. 8A). At these exposures (fig. 8B,C) the Threemile is overlain by 4 ft (1.2 m) of sparsely fossiliferous, yellow, silty shale with a 5-inch (12.7-cm)-thick bed of pelecypod-rich limestone just above the middle (in contrast, the basal 1 ft 7 inches [0.7 m] of the Havensville is fissile black shale in the exposures around Alcove Spring). This section is correlated to what we consider to be the basal Havensville at its type locality in Pottawatomie County (fig. 7A). The overlying 6 ft 5 inches (2 m) of our section 137 consist of yellow, sparsely fossiliferous, silty and calcitic shale to mudrock. This section weathers either as a massive (but laminated) unit that could easily be confused for limestone, or as a very thin bedded unit that, based on amount of insoluble residue, we consider to be a calcitic shale/mudrock. These beds are overlain by 3 ft 2 inches (0.9 m) of thin-bedded, light-yellow, lime mudstone and some fine-grained biowackestone. In turn, this section is overlain, in the roadcuts, by a prominent 3 ft 8 inches (1.1-m)-thick bed of light-gray, locally cross stratified, porous biopackstone to grainstone that underlies cherty limestone (fig. 7A). The equivalent section in the quarry however is medium-bedded biowackestones, packstones, and grainstones that are not cross stratified (fig. 8C). This entire 6 ft 10 inches (2.1 m) section of non-cherty limestones at these localities instead is about 14 ft (4.3 m) thick around Alcove Spring (fig. 7A). These non-cherty beds are overlain, in the quarry, by cherty limestones in the Schroyer (fig. 7A). It is these non-cherty beds that Condra and Upp (1931) included in the basal Schroyer. We were unable to determine whether this limestone section is similarly present in Nemaha County, Kansas, and in Richardson, Pawnee, and Gage counties, Nebraska, because of poor exposures. However, we have traced the beds from Marshall County southeastward into western Pottawatomie County (fig. 9: our measured section 132), an area in which they were also described by Scott et al. (1959). A somewhat similar section of limestones, although not obviously cross stratified at the top, is observed at (unmeasured) roadcut exposures along County Highway 897 in the northeasternmost tip of Riley County (sec. 2, T. 6 S., R. 7 E.). These limestones may be represented by the 3 ft (0.9 m) of porous biopackstone to grainstone in the middle to upper part of the Havensville in the field exposures near Condra and Upp's (1931) Havensville type locality in Pottawatomie County (fig. 7A).

In contrast, throughout most of Kansas south of these areas in Marshall, Pottawatomie, and northernmost Riley counties, the section immediately beneath cherty Schroyer limestones characteristically consists of, with few exceptions, shale and mudrock, generally with only relatively thin beds of limestone. This unit clearly is the Havensville Member of the Wreford Limestone as recognized throughout most of the state. A section of shale/mudrocks rather than limestones occurs directly beneath the cherty Schroyer even close to Condra and Upp's (1931) Havensville type locality, at a roadcut just a few miles south of the town of Blaine along K–99 (our measured section number 134). The point is that non-cherty limestones rather than typical Havensville siliciclastics are present directly beneath cherty limestones of the Schroyer only in Marshall and parts of Riley and Pottawatomie counties in northernmost Kansas. Not surprisingly, then, the stratigraphic terminology in Kansas and Nebraska has

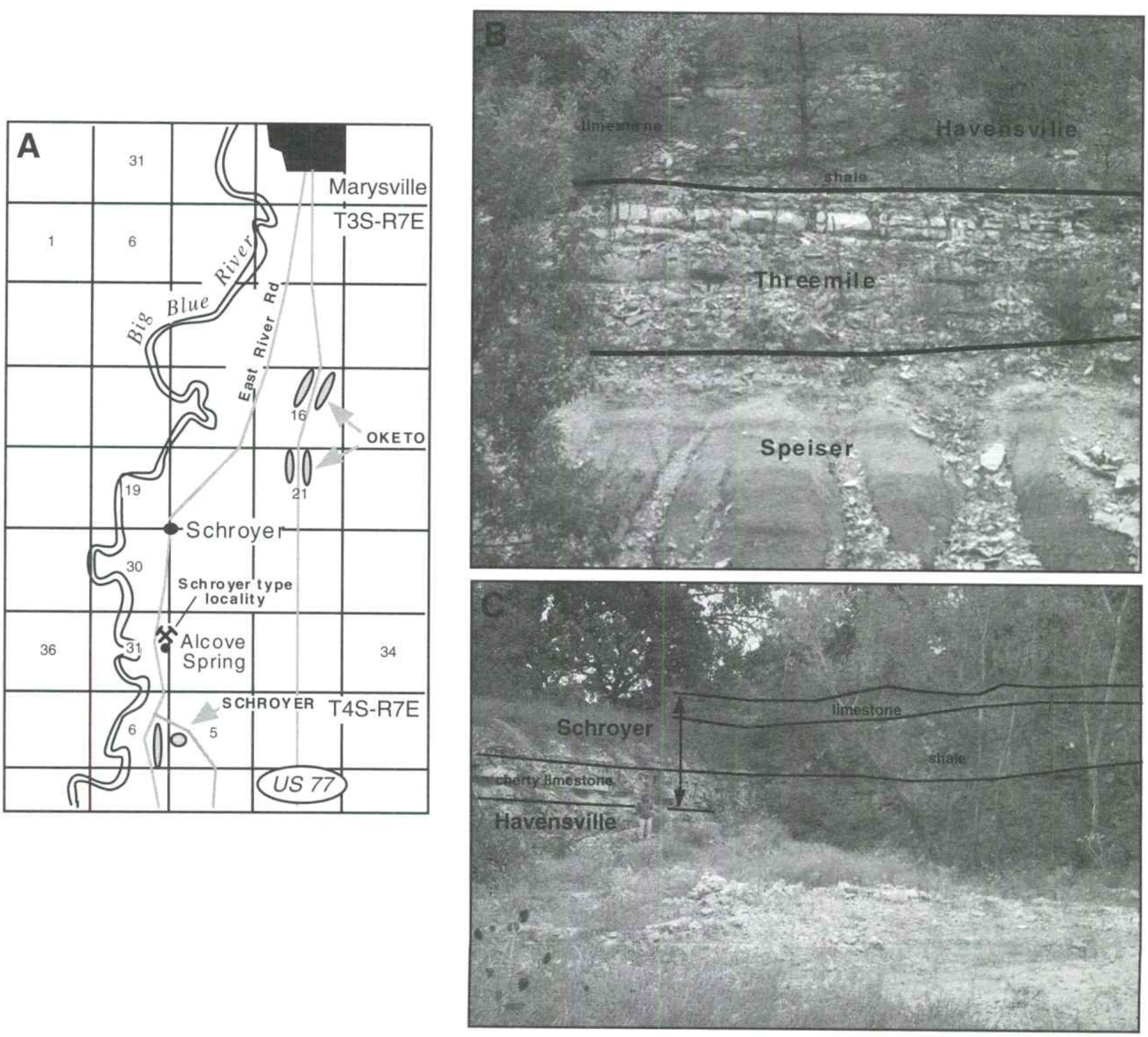


FIGURE 8—A) Location of principal reference sections of the Schroyer Member of the Wreford Limestone (measured section number 137) and also of the Oketo Member of the Florence Formation (measured section number 139), both in Marshall County. B and C) Photographs of the Speiser to Schroyer section along the road (B) and in the quarry (C) at measured section number 137.

and Nebraska has evolved to reflect the useful practice of placing the base of the Schroyer (and the top of the Havensville) at the base of the cherty limestones rather than, where they are present, at the base of underlying non-cherty limestones (fig. 7A)(e.g., Bass, 1929; Hattin, 1957; Bayne, 1962; Zeller, 1968; Burchett, 1988). In fact, the base of the cherty limestones is the only regionally persistent marker in this section, even in that area where non-cherty limestones occur (e.g., Hattin, 1957; Scott et al., 1959).

Despite this accepted practice, a proposal to formally revise Condra and Upp's (1931) initial description of the Schroyer, and in doing so to clarify the stratigraphic assignment of the non-cherty limestones beneath the cherty Schroyer, has not previously been made. We now propose to formally revise the lower boundary of the Schroyer so that it is placed at the base of the section of cherty limestone, thus also concurrently raising the upper boundary of the Havensville. In doing so, we recognize that the subjacent section of non-cherty limestone, where it is present, is a facies of the Havensville. Regional aspects of the occurrence and depositional significance of these limestones are discussed in the second part of this paper.

The choice of principal reference sections that illustrate this proposed boundary stratotype revision is not easy because, logically, they should be located as near as possible to either the original Havensville or Schroyer type localities. Unfortunately, only the top few feet of the Havensville and the basal few feet of the Schroyer are exposed at the type locality of the Havensville Member (fig. 7A), and no other complete sections of these strata exist in this area. As discussed above, the Havensville at the Schroyer type locality is, because of its thick limestones (figs. 7A, 8B), not typical of Havensville facies throughout most of Kansas. We therefore propose to designate a principal reference section for the Havensville as the locality on I–70 in Geary County that is also the reference section of the Wreford Limestone and of the Threemile Member of the Wreford (measured section number 113 [fig. 5A]). The Havensville here (fig. 6) is 18 ft (5.5 m) thick, and its lithologic sequence is representative of that throughout much of Kansas. The basal 6 ft 7 inches (2 m) are mostly very dark gray, sparsely fossiliferous shale (with crinoids, *Derbyia* spp.) that grades upward to unfossiliferous shale, and this section is overlain by 1 ft 7 inches (0.5 m) of sparsely fossiliferous (*Myalina* spp., pectinid molds), yellow-brown, calcitic mudrock. The overlying 2 ft 4 inches (0.7 m) of platy-bedded, yellow-brown limestone includes layers of lime mudstone, some of which are extensively vertically rooted, fossiliferous yellow mudrock, and at the top, a few inches of fine-grained biopackstone to grainstone. Fossils in this section include foraminifers, *Derbyia* spp., *Myalina* spp., and casts of pectinids. Limestones occur at this approximate stratigraphic level throughout most of the study area. Next is 1 ft 10 inches (0.6 m) of unfossiliferous, yellow-brown mudrock which is overlain by a 1 ft 2 inches (0.3 m) thick bed of platy-weathering, light-brown lime mudstone with finely comminuted skeletal debris and *Derbyia* spp. The upper 4 ft 4 inches (1.3 m) consist of sparsely fossiliferous (at the top, with brachiopod fragments), yellow-brown shale to mudrock, with abundant white nodules of anhydrite below the top. The upper contact with the Schroyer is sharp and conformable.

FIGURE 9—Herringbone cross stratification in the limestones in the upper part of the Havensville Member directly beneath cherty Schroyer limestones at measured section number 132, Pottawatomie County, Kansas. Rod divided into 20-cm segments.

We propose to designate those roadcuts and quarry exposures 1 mi (1.6 km) south of the Schroyer type locality, in secs. 6 and 5, T. 4 S., R. 7 E., respectively, in Marshall County (fig. 8) as the principal reference section for the revised Schroyer Member. The revised Schroyer here (our measured section number 137) conformably overlies the Havensville, and is 16 ft (4.9 m) thick (fig. 7A). The basal 10-inch (25.4-cm)-thick bed of yellow-gray, cherty, coarse-grained biopackstone (with crinoids, brachiopod fragments, and gastropods) is overlain by 1 ft 3 inches (0.4 m) of yellow, fossiliferous, calcitic mudrock with *Reticulatia*, crinoids, and bryozoans. Notwithstanding regional thickness changes, these two beds are readily recognized and correlative throughout Kansas (Mazzullo and Teal, 1994; Mazzullo et al., 1995). The overlying 5 ft 11 inches (1.8 m) exposed along the east wall of the quarry consist of medium- to thin-bedded, very light yellow to white, cherty lime mudstone and biowackestone with brachiopod fragments, crinoids, and bryozoans. A 1 ft 3 inches (0.4-m)-thick bed of dark-gray to yellow, calcitic shale to mudrock with *Reticulatia* spp., *Composita* spp., and *Chonetes* spp. occurs just below the top of this section (fig. 7A). The succeeding 4 ft (1.2 m) of unfossiliferous shale present along the east wall of the quarry grade upward from black to greenish-yellow and include relatively abundant, white nodules, which are composed of mixtures of anyhdrite, quartz, and calcite. This section is overlain by 3 ft (0.9 m) of very light gray, shaly dolomudstone to dolomitic mudrock with sparse fossils (crinoids, brachiopod fragments, pelecypod molds), the top

2 inches (5.1 cm) of which is unfossiliferous, green shale. The top 1 ft 5 inches (0.4 m) of the Schroyer along the east wall of the quarry is a medium-bedded section of yellow-orange, intraclastic biopackstone that coarsens upward to biograinstone dominated by foraminifers, and includes accessory crinoids, brachiopod fragments, and high-spired gastropods. Green shale fills interparticle pores and small vugs in the upper half of this unit, the top of which is an unconformity (Mazzullo and Teal, 1994). A poorly developed paleocaliche occurs sporadically at the top of this unit where it is present in the quarry. That the upper 8 ft 5 inches (2.6 m) of section here (fig. 7A) are correctly included within the Schroyer, rather than being part of the Wymore, is supported by correlation to exposures of the same interval at, for example, measured section number 129 in Riley County (fig. 7B). In fact, the non-cherty limestone at the top of the Schroyer, the unconformity at its top, and the underlying shales are, notwithstanding thickness changes, regionally correlative throughout much of Kansas (Mazzullo and Teal, 1994; Mazzullo et al., 1995). The immediately overlying 5 ft 10 inches (1.7 m) of the lower Wymore consist of a basal paleocaliche or paleosol overlain by unfossiliferous, silty, red shale (fig. 7A); similar facies are present throughout central and southern Kansas (e.g., at "Lookout Point" in Butler County, our measured section number 39).

Matfield Shale

History of Terminology

The Matfield Shale was named by Prosser (1902) from unspecified exposures in Matfield Township in Chase County, Kansas; a stratotype description was not given. Prosser (1905) and Prosser and Beede (1904) referred to this formation in their later studies, as have other workers, and the name subsequently has become widely accepted in the literature. Although there are some outcrops of the Matfield in Prosser's type area, the best of which are in parts of secs. 22, 23, 26, and 27 in T. 22 S., R. 8 E., they are poor and do not expose the entire unit. In fact, we have not found complete outcrops of the Matfield, with bounding contacts, anywhere in Chase County. We therefore propose to designate as the principal reference section for this formation the roadcuts along US–54 (north and south sides), and adjoining field exposures to the south, in the SE sec. 5, the NE sec. 8, and the NW sec. 9, T. 26 S., R. 8 E. ("Lookout Point," our measured section number 39) in Butler County, Kansas (fig. 10). This locality is the closest one to the original type area at which the entire formation and bounding strata are exposed.

The Matfield here (fig. 11) is about 48 ft (14.6 m) thick, and continuously exposes the Wymore, Kinney, and Blue Springs members, as well as the underlying Wreford Limestone and the basal few feet of the overlying Florence. The Wymore Shale Member is about 20 ft (4.6 m) thick and consists, in ascending order, of unfossiliferous, generally silty, green, red, and greenish-yellow to yellow mudrocks and shales. The basal part is a tan paleocaliche developed on the erosional upper surface of the Schroyer (Mazzullo and Teal, 1994; Mazzullo et al., 1995) that defines the regionally unconformable base of the member (fig. 10B). The Kinney Member is 17.5 ft (5.3 m) thick and includes a basal fossiliferous limestone (wackestone, with conspicuous *Derbyia* and also crinoids, gastropods, and *Septimyalina*), a middle section of dark-colored, fossiliferous shale and shaly lime mudstone to sparse biowackestone (with *Derbyia*, *Allorisma*, and some ammonites), and an upper lime grainstone dominated by foraminifers. Mazzullo and Teal (1994) incorrectly reported the thickness of this upper limestone to be 11 ft (3.4 m) at this locality. The Blue Springs Shale Member is about 10 ft (3.1 m) thick and consists, in ascending order, of silty, green shales/mudrocks, red shales/mudrocks, and greenish-yellow, calcitic shales and mudrocks, the latter fossiliferous at the top. A conspicuous light-tan paleocaliche (Mazzullo and Teal, 1994; Mazzullo et al., 1995) occurs a few feet above the base (fig. 11). Placement of the contact between the Blue Springs and Florence, and details of the stratigraphy of the three members of the Matfield Shale, are discussed below.

Wymore Member

The Wymore Member was formally named and described by Condra and Upp (1931) from ravine and creek bed exposures in the E/2 sec. 27, T. 2 N., R. 7 E. (now on the Marple Farm, due east of the Big Blue River), immediately southeast of the town of Wymore, in Gage County, Nebraska. At this locality (their section number 13, p. 38–39) Condra and Upp measured 22 ft (6.7 m) of exposed gray, olive, and red unfossiliferous shale and mudrock beneath the Kinney. The contact with the Wreford was not exposed here, although they did report upper Wreford beds to be present in the creek bed. Exposures at this locality are now mostly concealed, and therefore, we propose to designate a principal reference section for this member (our measured section number 148) that is close to the type locality. It is a readily accessible, high cutbank along Plum Creek in the NW sec. 15, T. 1 N., R. 8 E., in Gage County, Nebraska (fig. 12). This is the same location shown in fig. 3 in Condra and Upp (1931, p. 36).

The basal contact with the Wreford unfortunately also is not exposed at this locality, but by our estimates it must be less than a few feet into the subsurface. The exposed Wymore section is 24.5 ft (7.5 m) thick, and consists entirely of unfossiliferous, silty shale and mudrock (figs. 12B and 13). The basal 2 ft (0.6 m), exposed at creek level when we measured the section, are pale-green, conspicuously blocky mudrocks with conchoidal fracture; this unit likely is a paleosol. The overlying 11 ft 8 inches (3.6 m) are interbedded red and green shales and mudrocks, including paleosols (fig. 13). Next is 6 ft 9 inches (2.1 m) of dominantly red shale and some mudrock with some streaks of green shale (this entire section includes paleosols), overlain by 4 ft (1.2 m) of green shale, the upper few inches laminated. The contact with the basal limestone of the overlying Kinney member is sharp and conformable (figs. 12B and 13).

Kinney Member

The Kinney Member was named by Condra and Upp (1931) from exposures along a railroad cut in the center W/2 sec. 32, T. 2 N., R. 8 E., just east of the now-abandoned Kinney railroad siding, in Gage County, Nebraska. Instead of specifying a stratotype description here, however, they described it from exposures on the Marple Farm in sec. 27, T. 2 N., R. 7 E. in Gage County, Nebraska (their measured section number 13), which is their type locality of the Wymore. Condra and Upp also summarily described facies changes within the member as it was traced into southern Kansas, but based these rather sketchy descriptions on only three widely separated localities in the state.

The stratigraphic architecture of the Kinney is highly variable and is perhaps the most complex of all the units within the Chase Group. Regional correlation of lithic units in the Kinney has proved difficult, especially in northern Kansas (e.g., Jewett, 1941), because of pronounced facies changes and Condra and Upp's (1931) sketchy descriptions of the member in Kansas. It was therefore imperative that we traced the Kinney from its type locality in Nebraska southward through Kansas in an attempt to understand its regional stratigraphic development. Unfortunately, outcrops at the type locality, as well as on the Marple Farm where Condra and Upp (1931) described the section, are now extremely poorly exposed—in fact, they are virtually nonexistent. Nearby cutbank outcrops along Plum Creek in sec. 15, T. 1 N., R. 8 E. in Gage County (our proposed principal reference section for the Wymore [measured section number 148]), however, expose the section (figs. 12B, 13) that Condra

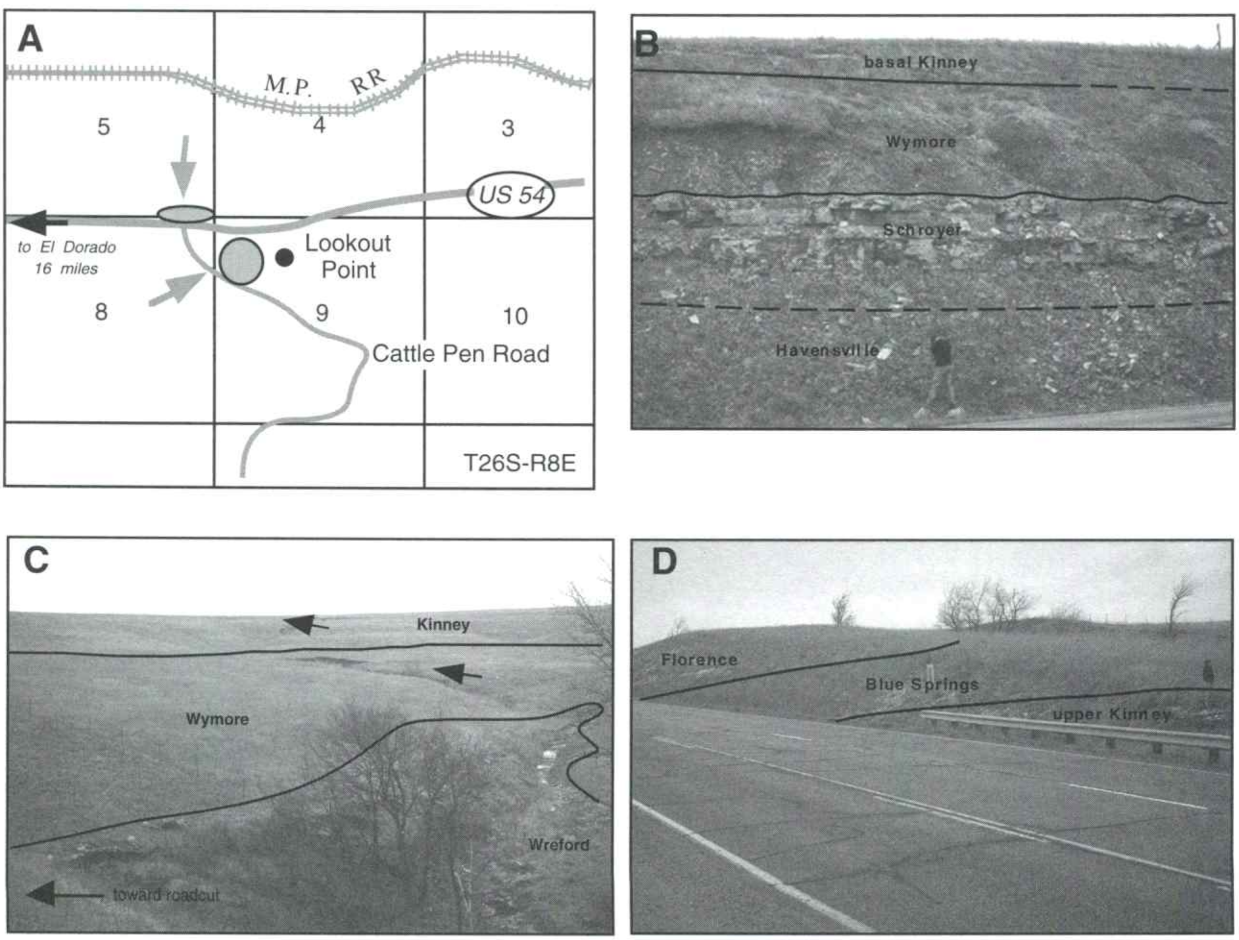


FIGURE 10—A) Location of principal reference section of the Matfield Shale at "Lookout Point" in Butler County. B) Havensville to basal Kinney section on south side of the road; the Speiser and Threemile are exposed to the immediate left (east). C) View looking south from the road (US-54). The Wreford is exposed in the gully (foreground); the Wymore to the middle Kinney are exposed in the gullies (arrows) in the center background; the upper Kinney is exposed along the ridge to the right (west), and along the road to the west (out of the field of view). D) Exposures of the upper Kinney to basal Florence along the north side of the road.

and Upp (1931) regarded as the Kinney. The section of carbonates here is similar lithologically to the section they described on the Marple Farm. We therefore propose to designate these outcrops along Plum Creek as the principal reference section for the Kinney. However, we believe that at this and other localities in northern Kansas, the top of the Kinney should be placed at the top of the section of dark shales immediately above the carbonates rather than at the top of the upper limestone (figs. 12B, 13). We will discuss and fully document this revision in the second part of the paper.

Condra and Upp (1931, p. 37) stated that the Kinney, as they recognized it, was 12 ft (3.7 m) thick in Nebraska. However, they illustrated the outcrop on Plum Creek (fig. 12B) in their fig. 3 (p. 36), where their Kinney (carbonate) section is only 7 ft 8 inches (2.3 m) thick. They did not address this obvious discrepancy in their estimate of thickness of the member. The lower 2.5 ft (0.8 m) of the Kinney section here consist of progressively thinner-bedded, yellow, shaly, dolomitic limestone (fig. 13). Microfacies in this unit fine upward from porous, oncolitic biowackestone to packstone in the basal 7 inches (17.8 cm), to layered and bioturbated lime mudstone above.

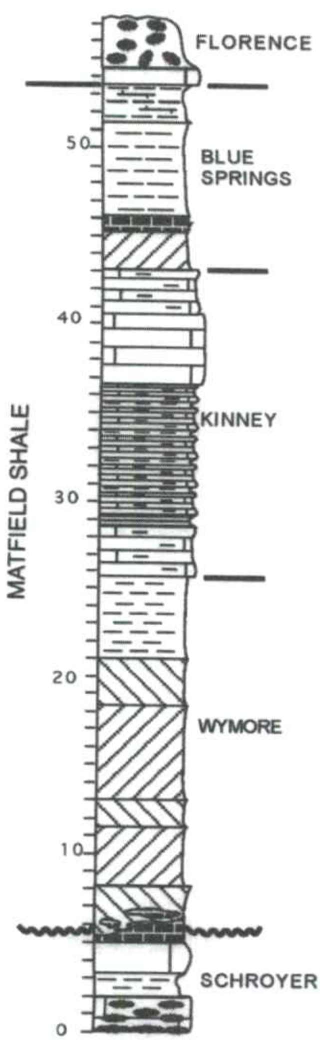


FIGURE 11—Lithostratigraphy of the Matfield Shale at the principal reference section (measured section number 39, secs. 5, 8, and 9, T. 26 S., R. 8 E., Butler County, Kansas).

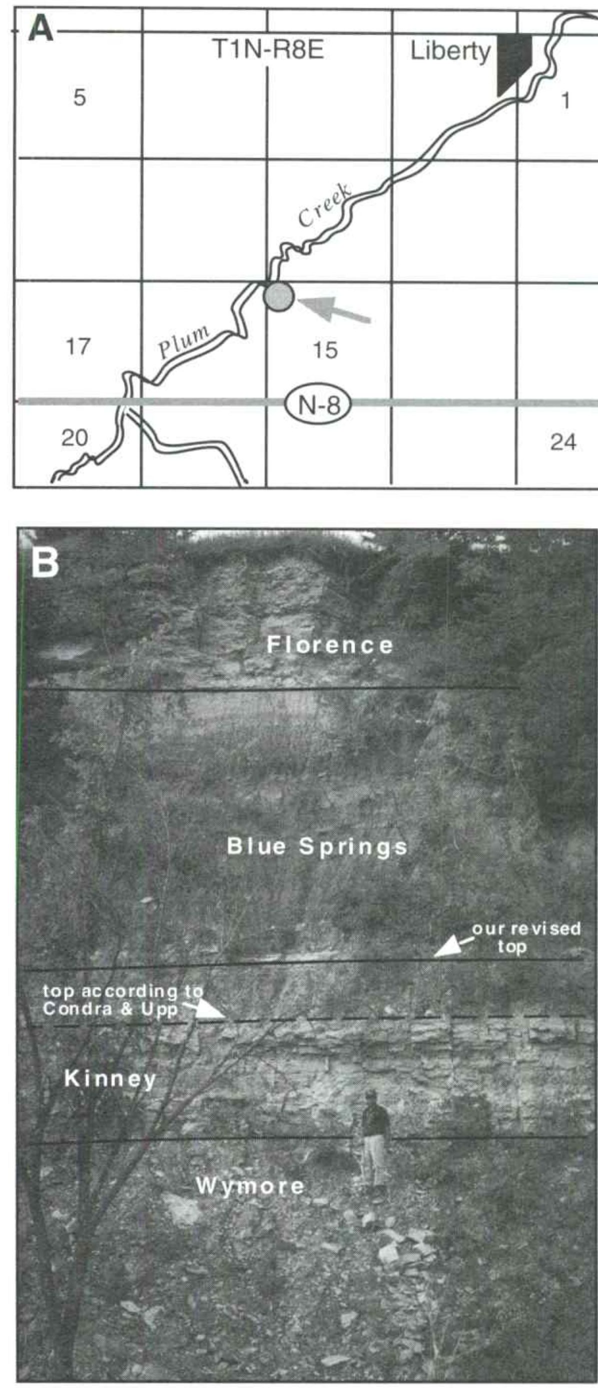


FIGURE 12—A) Location of principal reference section of the Wymore, Kinney, and Blue Springs Members of the Matfield Shale in Gage County, Nebraska. B) The upper Wymore to Florence section at this locality. More of the Wymore is exposed down to river level than is shown in this photo. This is the same outcrop shown in fig. 3 in Condra and Upp (1931). Our revised placement of the top of the Kinney, and that of Condra and Upp (1931), are both shown.

Fossils include crinoids, brachiopod fragments, foraminifers, *Aviculopecten* spp., *Myalina* spp., and *Septimyalina* spp. The basal contact with the Wymore is sharp and conformable. The overlying unit is 2 ft 8 inches (0.8 m) of splotchy medium-gray and yellow, calcitic, bioturbated mudrock with bryozoans, *Derbyia* spp., *Reticulatia* spp., and *Allorisma* spp. The upper unit is 2.5 ft (0.8 m) of thin-bedded, similarly colored, shaly lime mudstone with crinoids, brachiopod fragments, *Aviculopecten* spp., *Myalina* spp., and *Septimyalina* spp. As discussed above and documented later, we include the overlying 3 ft 8 inches (1.1 m) of fissile black shale within the Kinney at this locality (fig. 13).

Blue Springs Member

This member also was formally named and described by Condra and Upp (1931) from exposures on the Marple Farm, in sec. 27, T. 2 N., R. 7 E. in Gage County, Nebraska. They noted that the section here comprised 29 ft (8.8 m) of unfossiliferous olive, red, and gray, partly sandy shale and minor sandstone. However, Blue Springs strata also are now very poorly exposed at this locality. Accordingly, we propose to designate the cutbank exposures along Plum Creek (sec. 15, T. 1 N., R. 8 E., Gage County, Nebraska: figs. 12, 13) as the principal reference section for the Blue Springs Member. In fact, Condra and Upp (1931, p. 38) mentioned that the outcrops of the Blue Springs here expose the same zones as at their Marple Farm type locality. This locality (measured section number 148) can also serve as a supplemental reference section for the entire Matfield Shale. A nearby supplemental reference section of the Blue Springs, at which the basal contact with the Kinney is not exposed, is another cutbank along Plum Creek in the NE NE sec. 30, T. 1 N., R. 8 E. in Gage County (our measured section number 147).

Condra and Upp (1931) defined the top of the Blue Springs in Nebraska as the top of unfossiliferous shales beneath the Florence (see their measured sections 13–16), and they illustrated this contact in their fig. 3 (p. 36)(refer to our figs. 12B and 13). The basal few feet of the Florence as so defined at Plum Creek, as well as at other exposures in Nebraska, are non-cherty carbonates overlain by mudrock, both fossiliferous, above which are cherty carbonates (figs. 12B, 13). Although Prosser (1895) originally named the Florence from an exposure in Marion County, Kansas, the basal contact with the Blue Springs was not exposed at this locality, and hence, he did not specify contact relationships between these two units here. Although he regionally placed the contact at the base of the cherty limestones in the Florence in that area, he noted that the basal 10 ft (3.1 m) of the Florence locally included beds of mostly non-cherty limestone above Blue Springs shales (Prosser, 1895). Hence, his definition of the top of the Blue Springs/base of the Florence at least locally agreed with Condra and Upp's (1931) placement of the contact between these units. Subsequent workers, however, either placed the contact at the base of the chert in the Florence where non-cherty limestones are present (e.g., Moore, 1920; Bass, 1929; Moore et al., 1944, 1951a,b; Bayne, 1962), or like Prosser (1895) and Condra and Upp (1931), placed it at the base of the section of these non-cherty limestones beneath the cherty carbonates (e.g., Beede and Sellards, 1905; Condra and Reed, 1959; Twiss and Underwood, 1988; Twiss, 1991; Archer et al., 1995). Still other workers inconsistently picked the contact at either horizon at different outcrops (Beede and Sellards, 1905; Bass, 1929; Bayne, 1962), thus illustrating the confusion that exists with regard to stratigraphic boundaries in this part of the Chase Group.

We agree with Condra and Upp (1931) in placing the Blue Springs–Florence contact at the base of the section of

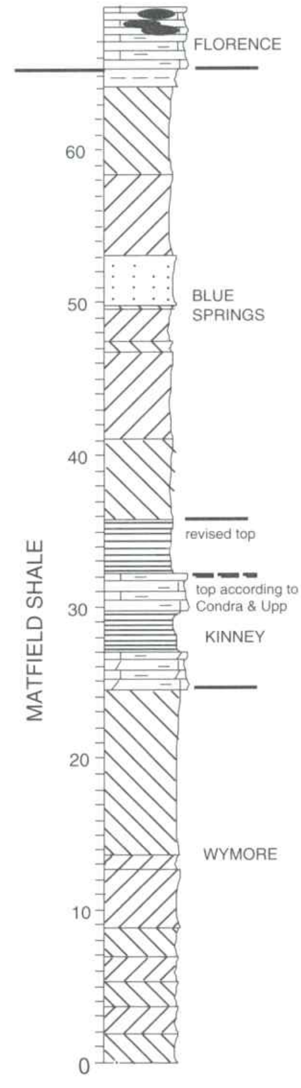


FIGURE 13—Lithostratigraphy of the Wymore, Kinney, and Blue Springs Members of the Matfield Shale at the principal reference section of these units in Nebraska (measured section number 148, sec. 15, T. 1 N., R. 8 E., Gage County, Nebraska). Note the difference between our assignment of the top of the Kinney and that of Condra and Upp (1931).

mostly non-cherty limestones (figs. 12B and 13) because such a stratigraphy (i.e., non-cherty carbonates overlain by cherty carbonates) is readily traceable across the entire study area (e.g., Mazzullo et al., 1995). Furthermore, inclusion of the section of non-cherty limestone and some fossiliferous mudrock within the carbonate-dominated (albeit cherty) Florence, rather than in the Blue Springs (e.g., fig. 13), seems reasonable from a lithologic as well as from a paleontologic viewpoint.

As so recognized, the unfossiliferous Blue Springs at the principal reference section on Plum Creek (fig. 13) is 28 ft 5 inches (8.7 m) thick. This thickness agrees with that given by Condra and Upp (1931) at the type locality on the Marple Farm. The basal 4 ft (1.2 m) consist of green, silty shale and mudrock. The succeeding 4 ft (1.2 m) are dominantly red shale, overlain by a prominent ledge-forming unit (8 ft 2 inches [2.5 m] thick) of red, silty mudrock with thin layers of green shale that grades upward to red, shaly siltstone with prominent green-shale-filled rootlets at the top (fig. 13). These siltstones likely are what Condra and Upp (1931) had referred to as sandstones in the Blue Springs at their type locality. The overlying 12 ft 4 inches (3.8 m) pass upward from red to light-green to yellow shale and mudrock. As discussed in the second part of this paper, the upper few feet of the Blue Springs are fossiliferous shales in south-central Kansas. The contact with non-cherty limestones of the lower Florence is sharp and conformable at this locality.

Bruno limestone bed—Condra and Upp (1931, p. 40) introduced the name Bruno limestone in reference to a thin bed of limestone that occurs about 8 ft (2.4 m) above the base of the Blue Springs Member where they examined it. Although named from exposures on Bruno Creek a few miles northeast of Florence in Marion County, Kansas, they instead described it from exposures near Burden in Cowley County, Kansas (their measured section number 16, p. 40; our measured section number 22). Condra and Upp stated (p. 38) that it could be traced from Burden, "...northward beyond Florence and southward to Oklahoma." Later, however, this unit was not recognized by Condra and Reed (1959), and has not been discussed formally by either Kansas or Nebraska geologists since that time (e.g., Zeller, 1968; Burchett, 1988).

We have not identified any carbonate beds in the Blue Springs Member in Nebraska (e.g., fig. 13) or in Kansas north of Geary County. However, the northernmost occurrence of a distinct bed of carbonate that we consider to be the Bruno, by virtue of its stratigraphic position, lithology, and regional correlation, is present at the exposures on the Wayne White Farm in the NE SW sec. 28, T. 12 S., R. 5 E. in Geary County, a few miles west-southwest of Junction City (fig. 14 [measured section number 111]). This bed is about 7 ft (2.1 m) above the base of the red-shale-dominated, lower Blue Springs at this locality. It consists of 8 inches (20 cm) of light-yellow, very silty dolomudstone, with rootcasts and large dolomite glaebules, and is interpreted as a paleocaliche. A lens of this bed, developed within red siltstones, appears to be present in the spillway of Milford Reservoir, which is a few miles north of the Wayne White Farm. This lens is likely the bed described by Archer et al. (1995) as "calcareous shale or mudstone" that is about 9 ft (2.8 m) below the Florence at this locality. Farther north and east from here, in Kansas and Nebraska, beds within the Blue Springs at, above, and below the approximate horizon of the Bruno are prominent ledges of red, shaly siltstones, typically with abundant rootcasts and associated with inferred paleosols.

We have traced the sporadic occurrence within the Blue Springs of a typically thin (generally less than 2 ft [0.6 m]) marine carbonate and/or paleocaliche that we consider to be the Bruno, south and southeast from the Wayne White Farm through parts of Morris, Marion, Butler, and Cowley counties in Kansas (fig. 14). The thickness of the Blue Springs varies considerably in these areas, and accordingly, the Bruno may occur anywhere from 3 to 10 ft (0.9–3.1 m) above its base (fig. 14). The southernmost occurrence we have found of such a carbonate unit considered to be the Bruno is in the roadcuts along Cowley County Highway 1 in secs. 8 and 17, T. 35 S., R. 5 E. (our measured section number 1), less than 1 mi (1.6 km) north of the Kansas–Oklahoma border. Although Chaplin (1988) noted the occurrence of lenses of (sandy) limestone in the Blue Springs in Kay County, Oklahoma, he apparently did not then regard them to be the Bruno; we suspect they are Bruno-equivalent strata. Where present, typical Bruno lithofacies variously include: (a) fossiliferous, marine lime mudstone to biowackestone and, at exposures along the railroad tracks just east of Burden in Cowley County (the locality at which Condra and Upp [1931] described it), fine-grained, foraminiferal grainstone; and (b) light-colored, shaly lime mudstone or dolomudstone with rootcasts, calcite glaebules, and incipient pisoliths and occasional rhizoconcretions, interpreted as paleocaliche (Mazzullo et al., 1995).

We recommend that the name Bruno limestone bed be retained in reference to this carbonate rock horizon within the Blue Springs Member for two reasons. First, although it is thin we have been able to identify and trace it across much of central and southern Kansas (fig. 14), and as discussed above, it may even be present in Oklahoma. Second, and most importantly, regional aspects of its occurrence and thickness, which are illustrated and discussed in the second part of this paper, suggest that it is a stratigraphic unit of considerable significance in the inferred sequence-stratigraphic development of the Matfield Shale. The Bruno limestone bed is not well exposed in the type area in Marion County defined by Condra and Upp (1931), and a stratotype was not specified by them in this area. We therefore propose to designate the nearby roadcut exposures in the SW NW sec. 8. T. 21 S., R. 6 E. in Chase County, Kansas, southeast of the town of Cedar Point, as the principal reference section of the Bruno (fig. 15).

At this locality (shown graphically in fig. 17 as measured section number 83) the Bruno is 10 inches (25.4 cm) thick and includes lithologies of both marine and nonmarine aspect that are regionally typical of this unit. The basal 3 inches (7.6 cm) consist of shaly, orange-yellow lime mudstone, with glaebules, circumgranular cracks and blocky texture, interpreted as paleocaliche. The overlying 2 inches (5.1 cm) are laminated, medium-brown shale with comminuted skeletal debris, overlain by 5 inches (12.7 cm) of green-gray, shaly, intraclastic lime mudstone, with foraminifers and fragmented pelecypod and brachiopod shells, and small vugs filled with green shale. Upper and lower contacts with unfossiliferous, gray-green to brownish-green mudrocks of the enclosing Blue Springs are sharp. The top of the Bruno, as well as the paleocaliche in the lower part of this unit, appear to be unconformities at this locality.

Barneston Limestone

History of Terminology and Proposed Revision

The Barneston Limestone was defined by Condra and Upp (1931) to include the Florence and overlying Fort Riley limestones as members; the Oketo Shale Member was not recognized as a formal stratigraphic unit at that time. The type area of the formation was designated to be

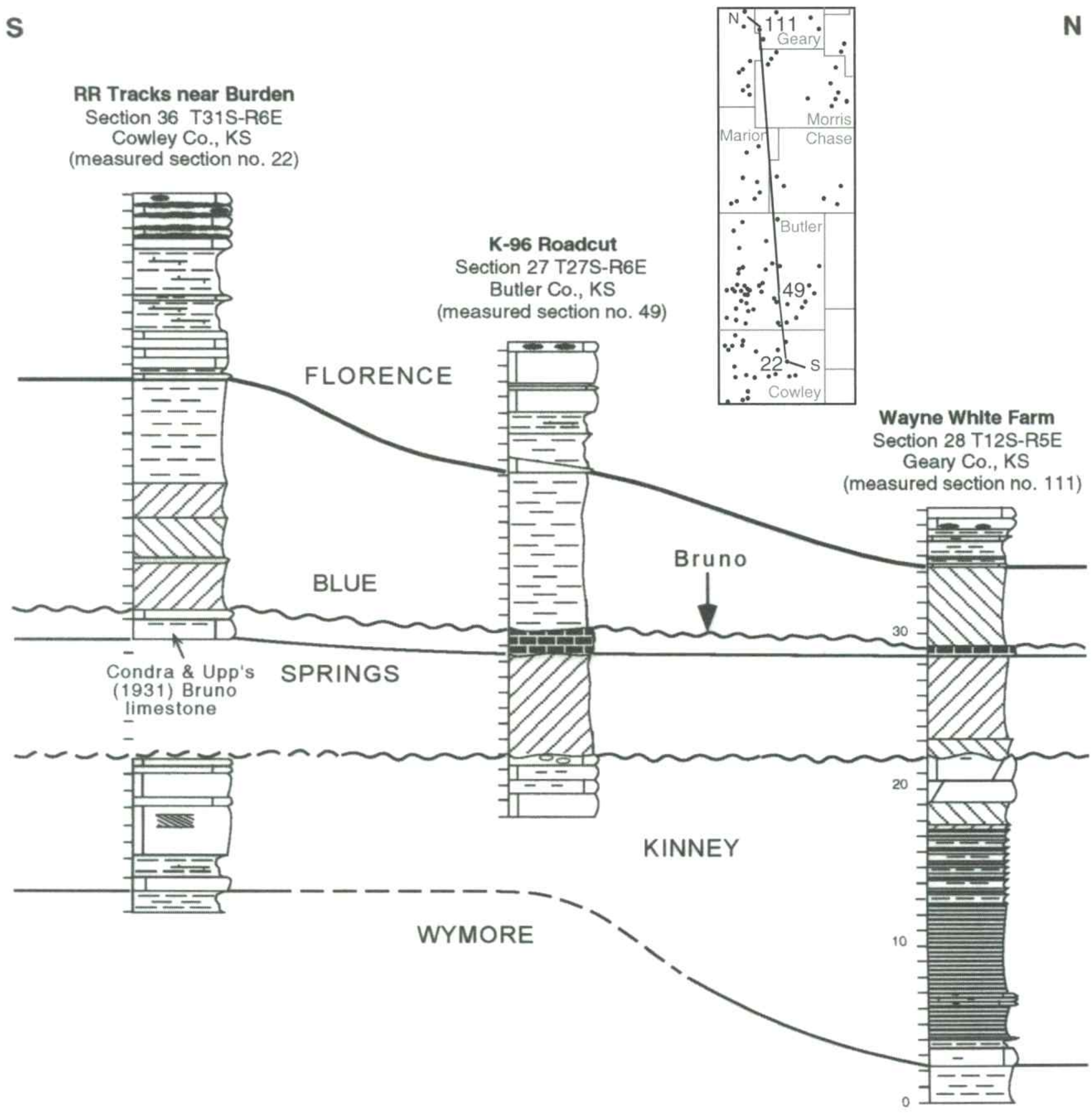


FIGURE 14—Cross section showing regional stratigraphic relationships of the Bruno limestone bed and correlative strata in north-central to south-central Kansas.

the bluffs along the Big Blue River, west and southwest of the town of Barneston in Gage County, Nebraska (in T. 1 N., R. 7 E.), where the formation is now very poorly exposed. Condra and Upp (1931) did not specify a stratotype description of the Barneston. Apparently in defense of erecting this formation, they stated (p. 41): "The Florence or lower member is distinguished from the Fort Riley by its abundant chert content. Otherwise there is no essential distinction between the two horizons."

Such a statement is, for several obvious reasons, completely erroneous and misrepresentative of actual lithostratigraphic and biotic relationships within and between the Florence and the Fort Riley. First, as Condra and Upp (1931) themselves pointed out, the chert content of the Florence clearly distinguishes it and the Fort Riley. Second, although these units commonly are conveniently grouped together for mapping purposes in Kansas and Nebraska, both are sufficiently thick and lithologically distinct so that they easily can be mapped separately (Mazzullo and Teal, 1994; Mazzullo et al., 1995). As discussed and illustrated in the second part of this paper, both the Florence and the Fort Riley can readily be subdivided into recognizable lithic units that are mappable and correlated across large areas of Kansas and Nebraska. Even early workers such as Bass (1929), Moore et al. (1944), and particularly, Fath (1921) recognized these natural subdivisions in the Fort Riley, as did Prosser (1895) in the Florence. Third, the biota of the Florence is dominated by bryozoans with accessory brachiopods, fusulinids, and locally, rugose corals. In distinct contrast, the biota of the Fort Riley is dominated largely by brachiopods and foraminfers, and oncolites are abundant in the lower part of the Fort Riley throughout most of south-central Kansas (Mazzullo and Teal, 1994; Mazzullo et al., 1995).

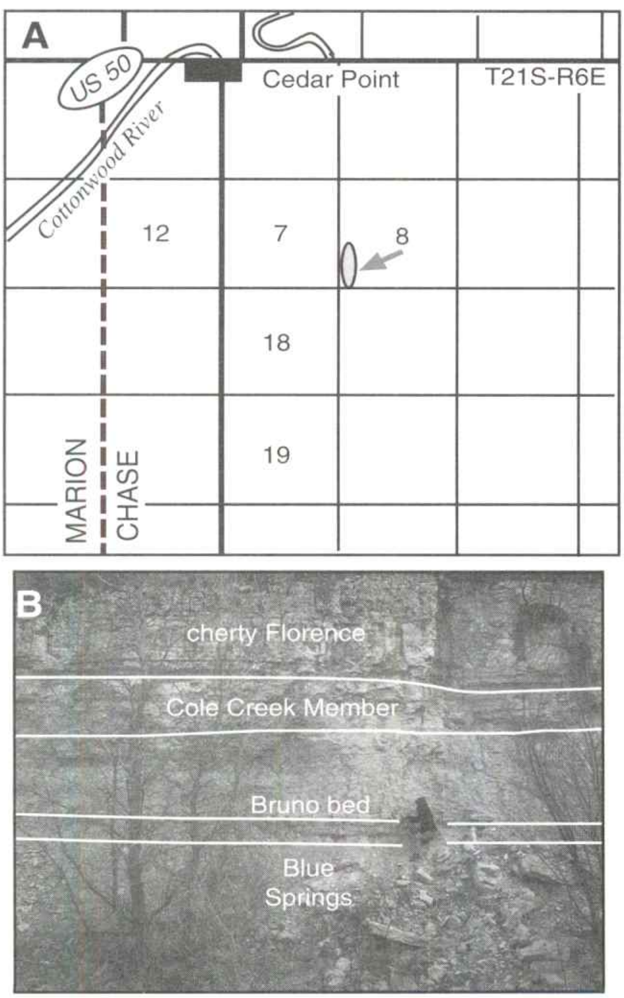


FIGURE 15—A) Location of principal reference section of the Bruno limestone bed, and supplemental reference section of the lower, non-cherty Florence, in Chase County, Kansas. B) The Blue Springs, Bruno bed, and basal Florence at this locality.

We contend that inclusion of the Florence and the Fort Riley within a formation (i.e., the Barneston Limestone) is a purely artificial and stratigraphically meaningless construction that underscores the stratigraphic significance of these units. We further contend that these aforementioned lithologic and biotic characteristics warrant elevation of the Florence and Fort Riley to formation status, and accordingly, we propose that the name Barneston Limestone be abandoned. Documentation for such proposed revisions, and consideration of the assignment of the intervening Oketo Shale Member, are provided below.

Florence Formation (revised)

The "Florence flint and limestone" was originally named by Prosser (1895, p. 772) for exposures ". . . along the McPherson Branch of the A.,T. & S.F. R.R., and in the Jones' quarries from one to two miles northeast of Florence," in Marion County, Kansas. These localities are in the E/2 sec. 6, T. 21 S., R. 5 E. (fig. 16A). The Jones quarries and exposures along the railroad referred to by Prosser (1895) now encompass the large Martin Marietta Sunflower quarry in sec. 6. This quarry and the Florence Rock Company quarry in adjoining sec. 5 both expose the upper Florence and the Fort Riley (fig. 16B) and are readily accessible with prior permission of the operators. The unit was later referred to as the Florence flint by Prosser (1902), Prosser and Beede (1904), Beede (1908, 1909), and Condra and Upp (1931).

Although he designated the type locality, Prosser (1895, p. 773) instead described a composite of several outcrops in Marion and Riley counties as the stratotype for the Florence. The basal contact with the Matfield Shale is not exposed at the type locality. However, Prosser (1895, p. 772) noted that, in some unspecified exposures near Marion, the main body of cherty limestone (his "Florence flint") was immediately underlain by, as discussed above, a 10-ft (3.1-m)-thick section of cherty to locally noncherty limestone and some shale. Inspection of Prosser's composite measured section (p. 773) shows that he included these cherty to non-cherty limestones within the "Florence flint" at these particular outcrops, but he inconsistently did not do so at all outcrops (i.e., he included the non-cherty limestones beneath the "Florence flint" within the upper Blue Springs at some other localities). As so alluded, the basal contact of the Florence concurs, at least locally, with the upper contact of the underlying Blue Springs Member as defined later by Condra and Upp (1931). Accordingly, Prosser (1895) reported the Florence flint to be 22 ft (6.7 m) thick and indicated that it was overlain by a then-unnamed, 15-ft (4.6-m)-thick section of shaly limestone, and then, a 5-ft (1.5-m)-thick bed of massive limestone which he (Prosser, 1895, 1897a,b) referred to as the "Florence limestone" (fig. 4). Hence, the total thickness of the entire "Florence flint and [sic, Florence] limestone" section was about 42 ft (12.8 m) according to Prosser (1895, 1897a,b). The upper 5-ft (1.5-m)-thick limestone bed, however, had earlier been referred to as the "Fort Riley main ledge," or "Fort Riley limestone," by Swallow (1866), Hay (1893), and others. Accordingly, Prosser (1902) and Prosser and Beede (1904) later included this 5-ft (1.5-m)-thick bed and some overlying strata, together with some beds beneath it, within the Fort Riley Formation, an assignment that was consistent with that of previous workers (Swallow, 1866; Hay, 1893), and which

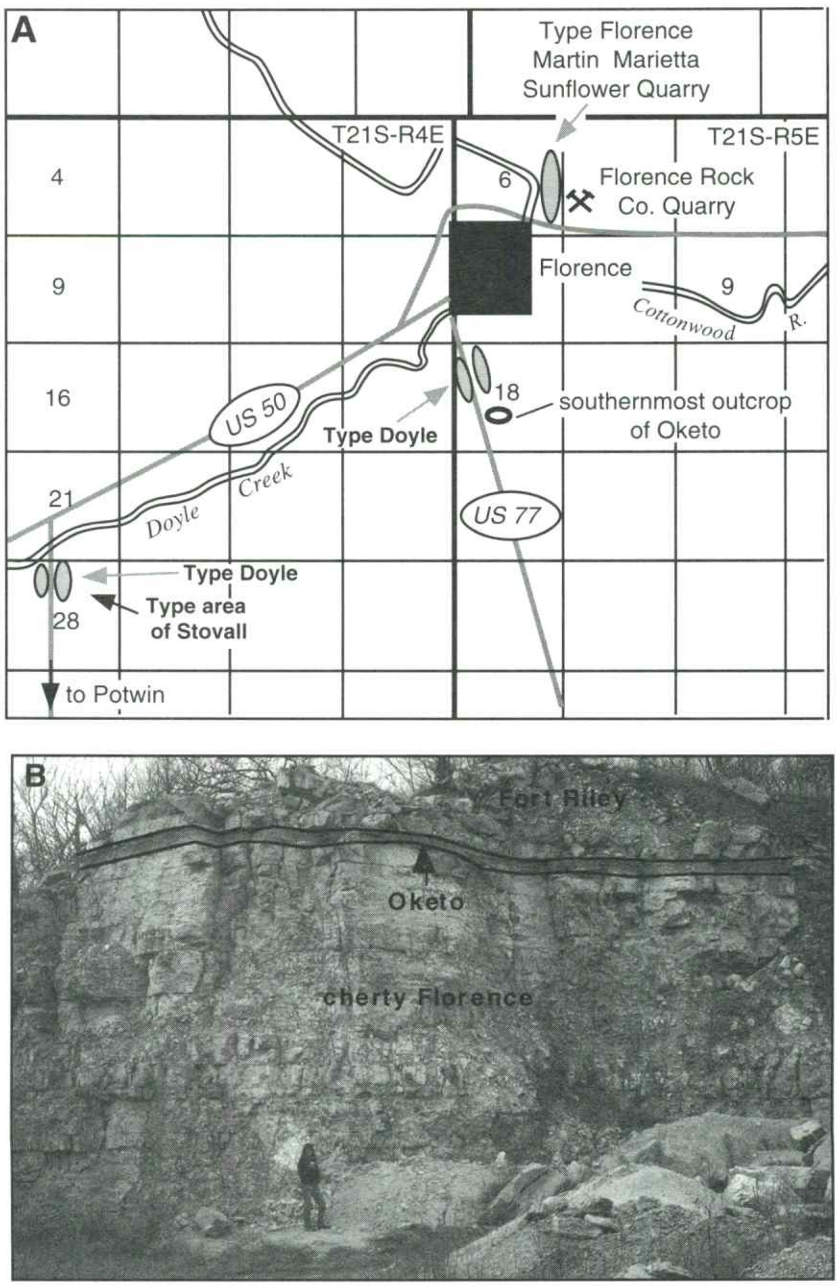


FIGURE 16—A) Type locality of the Florence Formation (Martin Marietta's Sunflower quarry), and also, the type areas of the Doyle Shale and the Stovall Member of the Winfield Limestone in Marion County, Kansas. B) Photograph of the Florence, thin Oketo Shale Member, and basal Fort Riley at the Sunflower quarry.

was followed subsequently by most later workers (fig. 4). Hence, the amended thickness of the Florence here was slightly less than 37 ft (11.3 m).

In proposing to elevate the Florence to formation rank, we see no reason why the original type locality of this unit (at the Sunflower quarry, fig. 16) should not be maintained as a unit stratotype because exposures are excellent and readily accessible (our measured section number 89 [fig. 17]). The basal contact with the Blue Springs is not exposed here, although a few feet of strata across this contact are exposed in a nearby gully on private land just north of US–50, in the SE SE sec. 5, T. 21 S., R. 5 E. However, a much thicker, better-exposed, and more readily accessible section of upper Blue Springs-to-Florence strata is well exposed in the roadside outcrops southeast of the town of Cedar Point, in the SW SW sec. 8, T. 21 S., R. 6 E., in Chase County (figs. 15, 17). This locality (measured section number 83 [the principal reference section for the Bruno limestone]) is therefore designated as a supplemental reference section at which to examine the lower, noncherty Florence.

The exposed Florence section beneath the Oketo Shale at the Sunflower quarry is 31 ft (9.5 m) thick, and the basal 2 ft 5 inches (0.7 m) of section here consist of cherty biowackestone and medium- to dark-gray, cherty, fossiliferous mudrock. At the roadcut in sec. 8, T. 21 S., R. 6 E. in Chase County, the basal 3 ft (0.9 m) of the Florence beneath the main body of cherty limestones consist of

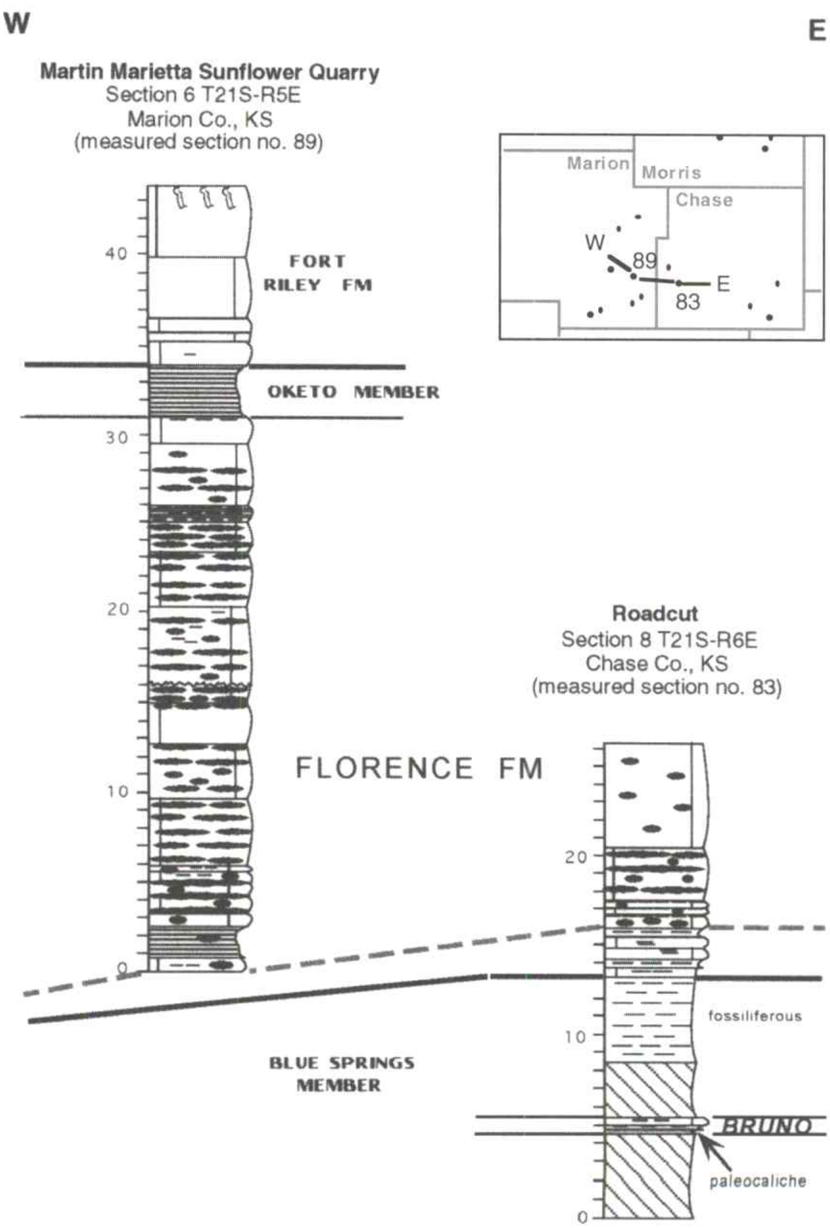


FIGURE 17—Lithostratigraphy of the Florence Limestone at the Sunflower quarry type locality in Marion County (measured section number 89), and correlation to nearby outcrop in Chase County (measured section number 83, the principal reference section of the Bruno limestone bed) where the basal non-cherty unit and the lower contact of the Florence are exposed.

interbeds of non-cherty limestone (mudstone and biowackestone) and fossiliferous, yellow mudrock. Lithologic correlation of the basal Florence sections between these two locations (fig. 17) suggests a Florence thickness of about 34 ft (10.4 m) in the type area. As discussed below, however, addition of the Oketo as a member of the Florence results in a total thickness of 37 ft (11.3 m) here, which concurs with the amended thickness of the Florence following Prosser (1902) and Prosser and Beede (1904). Fossils in the lower non-cherty beds at this location include bryozoans, crinoids, echinoid fragments, *Bellerophon* spp., various pelecypods (including *Permophorus* spp.), and the brachiopods *Derbyia* spp., *Reticulatia* spp., *Composita* spp., and *Meekella* spp.

The main body of cherty limestone beneath the Oketo at the Sunflower quarry is 29.5 ft (9.0 m) thick and consists of mostly light-yellow limestone, including fine-grained biowackestones and some biopackstones. About 5 ft (1.5 m) below the top is a 1-ft (0.3-m)-thick zone of interbedded fossiliferous mudrock and shaly lime mudstone to biowackestone (fig. 17). Chert occurs as nodules and layers and generally is lighter in color than in the Wreford. The chert is typically medium- to light-gray when fresh and light-gray, yellow, and orange when weathered. Fossils in the limestones and in many of the chert layers and nodules in this section mainly include bryozoans, crinoids, *Reticulatia* spp., and accessory *Derbyia* spp., *Composita* spp., echinoid fragments, and coiled gastropods. Fusulinids are common beginning a few feet above the base of the cherty limestone section here, as well as throughout nearly all of Kansas. According to Thompson (1954) and Sanderson and Verville (1988), *Pseudoschwagerina texana* and *Pseudofusulina moranensis* are the common fusulinids in the Florence. Possible new fusulinid genera collected from the Florence by us presently are being studied by Charles A. Ross. The top 1.5 ft (0.5 m) of the Florence directly beneath the Oketo are non-cherty, light-yellow, oncolitic biowackestone to packstone with bryozoans, crinoids, echinoid fragments, *Derbyia* spp., *Composita* spp., and *Amphiscapha* spp. The contact with the overlying Oketo is conformable and mostly sharp as it is at most other localities in the study area. At the Florence Rock Company quarry in adjoining sec. 5, and along some quarry walls at the Sunflower quarry, however, the upper contact with the Oketo appears to be gradational over a few inches.

Cole Creek Member (new name)—The tripartite division of the Florence into non-cherty limestone and shale at the base, cherty limestone in the middle, and generally non-cherty limestone, and locally, shale at the top is traceable across much of Kansas (fig. 18). The basal non-cherty unit of the Florence, in particular, persists through nearly all of Kansas (fig. 18) and into Nebraska (see figs. 12B and 13). The regional persistence, thickness, and numerous exposures of this section warrant its recognition as a formally designated member, particularly considering the confusion that has existed in the past with regard to the Blue Springs–Florence contact. This non-cherty unit is also recognized on electric logs in the subsurface (see cross section by Tyler Sanders in Mazzullo and Teal, 1994). At this time we do not advocate naming new members for the overlying cherty and succeeding non-cherty limestones and shales in the Florence.

The basal noncherty unit of the Florence is herein named the Cole Creek Member (new name) for well-exposed roadside outcrops along Cole Creek Road, immediately south of Hickory Creek, along the north-south boundaries between secs. 15 and 16, T. 28 S., R. 6 E. in Butler County, Kansas (fig. 19). The section here, our measured section number 46 (figs. 18 and 19B) is 8 ft 2 inches (2.5 m) thick. The basal 1 ft 7 inches (0.5 m) are thin- to medium-bedded, light-gray, bioturbated limestones that fine upward from biopackstone-grainstone to biowackestone. This section is overlain by 5 inches (12.7 cm) of fossiliferous, laminated, black shale, which in turn, are overlain by 1 ft 3 inches (0.4 m) of fossiliferous and bioturbated, gray, calcitic mudrock to shaly lime mudstone. Next is 1 ft 7 inches (0.5 m) of medium-bedded, yellow-gray, very coarse grained biowackestone with conspicuous large, horizontal burrows along bedding planes. This bioturbated horizon is present at many outcrops in Butler and northern Cowley counties, and it is a readily recognizable marker bed useful in mapping. The succeeding 2 ft 4 inches (0.7 m) consist of thin-bedded, yellow-gray, fossiliferous, calcitic mudrock to shaly biowackestone. The top of the member is a 1-ft (0.3-m)-thick bed of yellow-gray, biowackestone. Fossils in this member at this location include crinoids, foraminifers, bryozoans, small coiled gastropods, pectinid casts, *Aviculopecten* spp., *Myalina* spp., *Permophorus* spp., *Derbyia* spp., and *Composita* spp. The basal contact with the underlying Blue Springs Shale here is sharp and conformable, although it is gradational at some localities in Butler County (e.g., at measured section number 49 [see Appendix]). The upper contact with the cherty beds of the Florence also is sharp and conformable (fig. 18).

The member is 4 ft to 8 ft 2 inches (1.2–2.5 m) thick in Cowley and Butler counties; 2–3 ft (0.6–0.9 m) thick in Marion, Morris, Geary, and Riley counties; about 4 ft (1.2 m) thick in Marshall County; and about 2 ft 10 inches (0.9 m) thick in Gage County, Nebraska. Regional aspects of lithofacies and inferred depositional environments of this member are discussed later in this paper. The member is not recognized in the extreme southern part of Cowley County, for example, at roadside outcrops along Cowley County Highway 1 in secs. 8 and 17, T. 35 S., R. 5 E. (measured section number 1) or in the quarry in sec. 3, T. 35 S., R. 5 E. (measured section number 2).

Oketo Shale—The name Oketo Shale apparently first appeared in Moore et al. (1934) in reference to exposures in the bluffs along the Big Blue River at a railroad depot near the town of Oketo in Marshall County, Kansas, just south of the Kansas–Nebraska state line. This outcrop appears to be in the SE sec. 14, T. 1 S., R. 7 E. The Oketo was later included in stratigraphic sections, and exposures of it were mentioned as field stops in a field trip guidebook (Moore, 1936). The name subsequently gained acceptance as a member of the Barneston Limestone (e.g., Condra and Reed, 1959; Zeller, 1968). The Oketo Shale is present in all counties in Kansas and Nebraska where Florence–Fort Riley boundary strata are exposed except in Butler and Cowley counties in Kansas. The southernmost exposure of the Oketo that we have found is in unmeasured streambank exposures in the E/2 SW sec. 18, T. 21 S., R. 5 E., in Marion County, Kansas. This locality is due east of US–77, 1.25 mi (2 km) south of the intersection of US–77 and the A.,T. & S.F. railroad tracks in the southwest corner of the town of Florence and is on private land (fig. 16A).

Outcrops at the type locality of the Oketo defined by Moore et al. (1934) are poorly exposed. Furthermore, they did not specify a stratotype for the Oketo here, where bounding contacts are obscure. Because of facies changes from carbonate to shales in the upper Florence (discussed later), recognition, correlation, and reported thickness of the Oketo have in the past been somewhat unclear in many areas. According to Moore (1920), for example, fossiliferous and calcareous shales then included within the basal Fort Riley around Oketo, Marysville, and Junction City are 6–9 ft (1.8–2.7 m) thick; by Moore's descriptions, this unit *is* the Oketo as currently recognized (e.g., Zeller, 1968). Later, Jewett (1941) tentatively assigned 17 ft (5.2 m) of strata to the Oketo at some outcrops in northeastern Riley

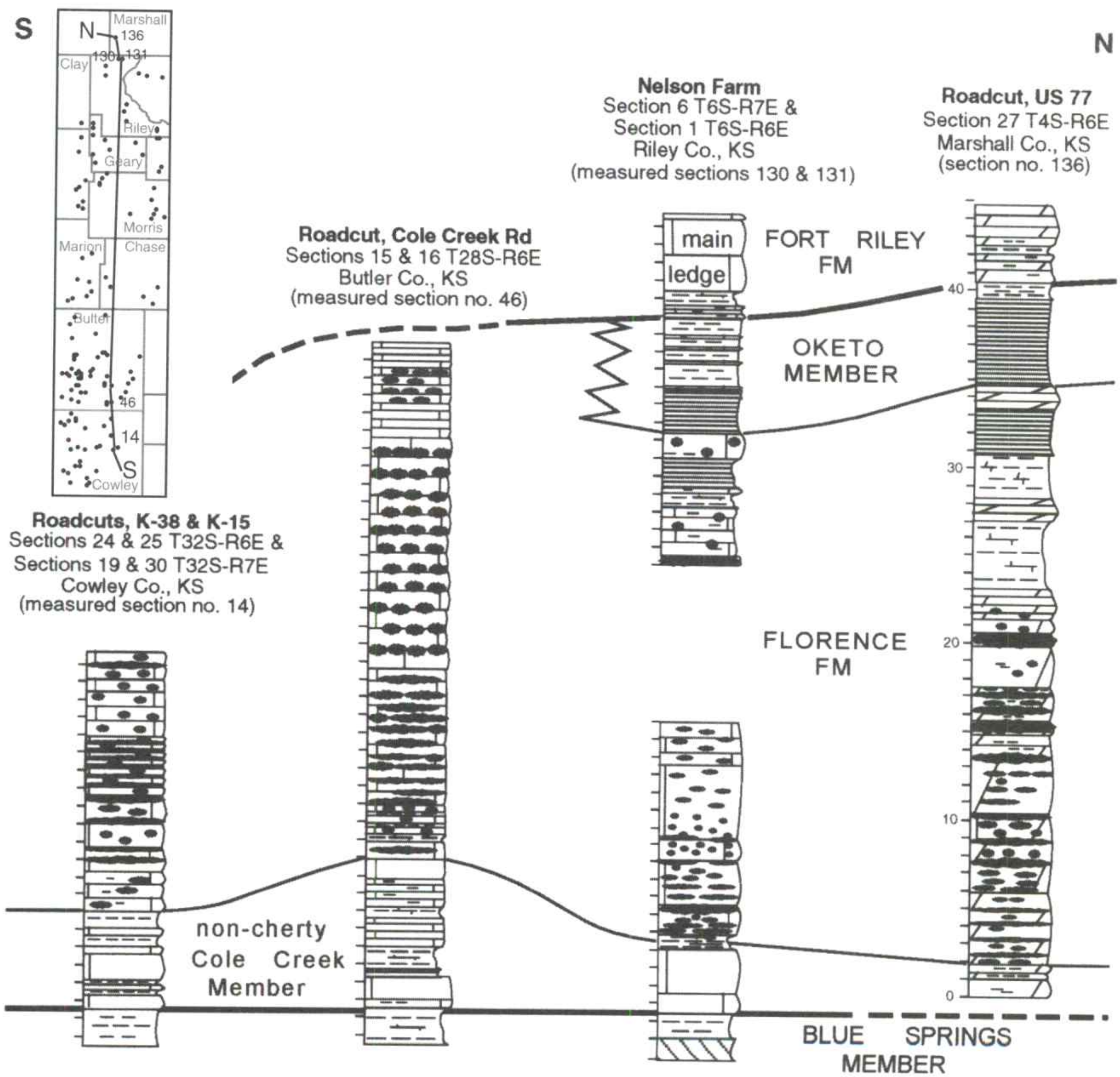


FIGURE 18—Lithostratigraphic cross section showing tripartite division of the Florence: lower non-cherty beds, middle cherty strata, and in central and southern Kansas, upper non-cherty limestone and/or shale or mudrock. Also shown is the basal Cole Creek Member (new name) of the Florence.

County, and Moore et al. (1944) likewise reported this maximum thickness of the member. Even later, the thickness of the Oketo was revised by Moore et al. (1951a) to be 5–8 ft (1.5–2.4 m) thick. Whereas Condra and Reed (1959) recognized as much as 3 ft (0.9 m) of Oketo in southern Gage County, Nebraska, Burchett (1988, his fig. 7, p. 58) believed that the Oketo was not present in Nebraska.

In an attempt to clarify these problematic relations, we first propose to designate a principal reference section for the Oketo to be the two closely spaced roadcuts on US–77 in the NE sec. 16 and in the N/2 sec. 21, T. 3 S., R. 7 E. in Marshall County, Kansas, just south of Marysville (fig. 8A). These outcrops, composite measured section number 139 (fig. 20), are the closest exposures to the type locality at which clearly defined Oketo strata and underlying and overlying units are exposed. The Oketo here is about 8 ft (2.4 m) thick, and seemingly conformably overlies the Florence; and in turn, it is conformably overlain by the Fort Riley. As such, its thickness is the same as that reported in more recent times by several workers (e.g., Moore et al., 1951a). The basal 2 ft 8 inches (0.8 m) consist of yellow, calcitic and silty mudrock with crinoids, bryozoans, and brachiopod fragments. This section is overlain by 4 ft (1.2 m) of light-yellow, bioturbated, silty, dolomitic mudrock, with thin lenses of shaly dolomudstone, with crinoids, echinoid fragments, bryozoans, *Derbyia* spp., *Composita* spp., *Reticulatia* spp., *Crurithyris* spp., *Meekella* spp., *Allorisma* spp., and *Amphiscapha* spp. The upper 1 ft 8 inches (0.5 m) of the Oketo consist of light-yellow, silty mudrock with similar fossils.

The top of the Oketo here is placed at the base of a 3 ft 3 inches (1-m)-thick section of porous, silty and shaly, dolobiowackestone in the basal Fort Riley (fig. 20). These rocks contain crinoids, bryozoans, echinoid fragments, *Aviculopecten* spp., *Meekella* spp., *Reticulatia* spp., and *Edmondia* spp.. To the south, this basal Fort Riley section changes facies to coarse-grained, shaly limestone with conspicuously abundant echinoid debris and similar fossils, and in turn, is overlain by fossiliferous, silty mudrock and shaly biowackestone immediately beneath the so-called Fort Riley "main ledge" or "rimrock" (fig. 18). We have been able to trace this stratigraphy, including the prominent echinoid-rich beds immediately above the Oketo, as far south as Marion County (fig. 17). The top of the Oketo as we define it is regionally correlative and consistent with that of other workers (e.g., Jewett, 1941; Moore et al., 1944, 1951a).

One of the outcrops in Riley County at which Jewett (1941) suggested that the Oketo may be as much as 17 ft (5.2 m) thick was found to be very poorly exposed, with contact relationships completely obscure. We located the other of his two outcrops of presumably thick Oketo (his measured section number 9), which is a cutbank along Swede Creek on the Nelson Farm (our measured section number 131, shown graphically in fig. 18) in the center N/2 S/2 sec. 1, T. 6 S., R. 6 E. in northeastern Riley County. At this outcrop (fig. 21A) the Oketo is, by regional correlation, only 6.5 ft (2 m) thick rather than 17 ft (5.2 m) thick. Its base is defined by the highest occurrence of regionally correlative (cherty) limestone in the Florence (fig. 18). Jewett (1941) had even indicated in his measured section here that this cherty limestone may actually be in the Florence, which would have reduced his estimate of Oketo thickness so that it corresponded to ours. His uncertainty in this regard apparently is what led Moore et al. (1951a) and subsequent workers (e.g., Zeller, 1968) to lower their thickness estimates of the Oketo. The mudrocks beneath this cherty limestone that Jewett (1941) had tentatively included within the Oketo are, by our regional correlations, indeed within the upper Florence (figs. 18 and 20A).

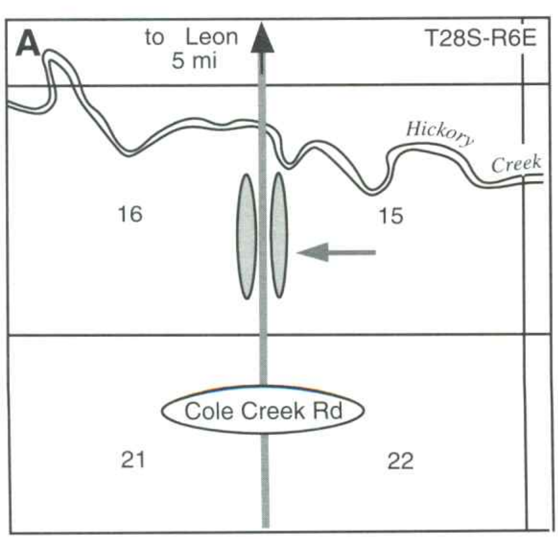


FIGURE 19—A) TYPE LOCALITY OF THE COLE CREEK MEMBER (NEW NAME) OF THE FLORENCE FORMATION IN BUTLER COUNTY, KANSAS. B) Roadcut at this locality (east side of the road) showing the Cole Creek Member and adjoining strata.

Top of Florence and assignment of Oketo Shale—According to currently accepted terminology (e.g., Condra and Reed, 1959; Zeller, 1968) and some older assignments (e.g., Jewett, 1941; Moore et al., 1944, 1951a), the Oketo is considered to be a member of the Barneston Limestone, and its base has traditionally been regarded as the top of the Florence Member. With our proposed abandonment of the Barneston Limestone and consequent elevation of both the Florence and Fort Riley to formation rank, the top of the Florence Formation and stratigraphic assignment of the Oketo must be clarified.

Where the Oketo is absent (in Butler and Cowley counties), most previous workers have picked the Florence–Fort Riley contact at the highest bed of cherty limestone in the section (e.g., Moore, 1920; Fath, 1921; Bass, 1929; Moore et al., 1944, 1951a; Bayne, 1962). Although this is an easy pick, it poses difficulty on a regional basis for two reasons. First, where the Oketo *is* present, it is variously underlain across large areas of Kansas by either cherty limestone or non-cherty limestones and mudrocks (e.g., figs. 17, 18, 20, and 22). In such areas, picking the top of the Florence at the top of the cherty limestone obviously would be inconsistent from place to place. This inconsistency is compounded by the fact that, in northernmost Kansas and in Nebraska, cherts occur in the upper Florence immediately beneath the Oketo, but are separated from the main body of underlying cherty limestone by mudrocks (figs. 18, 20). Second, in southernmost Cowley County and in Kay County, Oklahoma, where the Oketo is absent, nearly the entire upper half of the Florence, which is clearly identified by its lithology and biotic content (Toomey, 1992; Mazzullo et al., 1995), is not cherty. Picking the top of the Florence at the top of the chert would therefore result in an anomalously thin Florence section (e.g., Chaplin, 1994). Our studies (Mazzullo et al., 1995), as well as that of Toomey (1992), have shown that the Florence–Fort Riley contact in this area is lithologically and biotically gradational and is not defined by chert content. That is, the section grades upward from: (a) cherty, bryozoan-rich limestones with occasional fusulinids (Florence sensu stricto), through (b) the upper non-cherty limestone beds of the Florence which contain some oncolites and bryozoans (transitional beds), to (c) densely packed, oncolitic limestones (biowackestone and packstone) with small oncolites and some bryozoans (identified as Fort Riley).

Within the limitation of available outcrops, we have traced what we believe to be the pinchout of the Oketo from Marion into northernmost Butler County (fig. 22). In Marion County, the Oketo overlies about 2 ft (0.6 m) of non-cherty limestone in the Florence that contains relatively abundant bryozoans and large oncolites, and the Oketo also contains small as well as conspicuous large oncolites (fig. 21B). A similar stratigraphy is present in the nearby unmeasured streambank outcrops in sec. 18, T. 21 S., R. 5 E. in Marion County (fig. 16A). At streambed exposures at the head of the Walnut River in the SE SW sec. 20, T. 23 S., R. 6 E. in northernmost Butler County (our measured section number 79 [shown in fig. 22]), non-cherty upper Florence beds, similarly with oncolites and

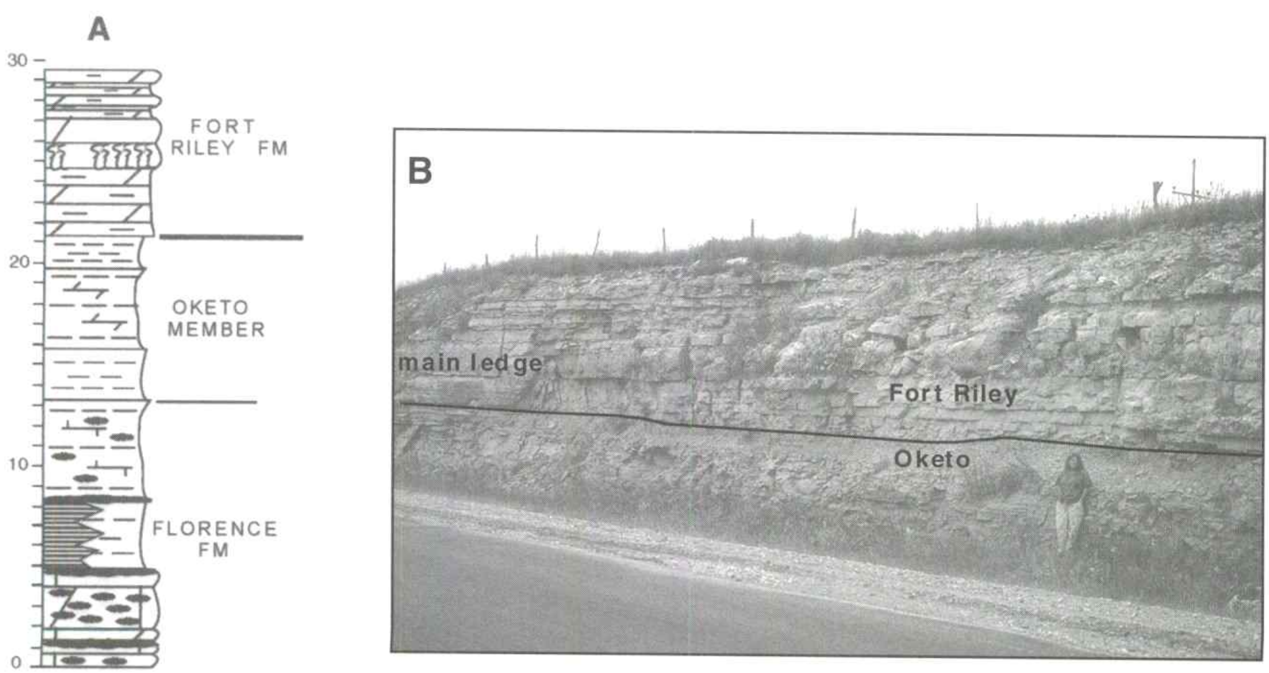


FIGURE 20—A) Lithostratigraphy of the Oketo and adjoining strata at the principal reference section in Marshall County, Kansas (measured section number 139, secs. 16 and 21, T. 3 S., R. 7 E.). B) The Oketo to lower Fort Riley section at this locality.

relatively abundant bryozoans, are overlain by a few inches of dark-gray, shaly biopackstone that contains large oncolites like those in the Oketo in Marion County. We interpret these dark-colored, shaly, oncolitic carbonates to be the featheredge equivalent of the Oketo, and they are overlain here by a section of platy- to medium-bedded, oncolitic biowackestone and packstone with small oncolites and only few bryozoans (fig. 22). The same gradational lithofacies and biofacies pattern that occurs across the Florence–Oketo–Fort Riley contact in Marion County also occurs across what we consider to be the Florence–Fort Riley contact in areas to the south where the Oketo is not present. That is, platy- to medium-bedded oncolitic limestones in the lower Fort Riley commonly are separated from the underlying section of bryozoan-rich, generally sparsely oncolitic limestones in the upper Florence by a zone of stylolites (figs. 21C, 22).

Based on the aforementioned regional correlations and lithofacies-biofacies relationships, where the Oketo is absent we pick the Florence–Fort Riley contact at the base of a section of vertically continuous beds of densely packed, oncolite wackestone to packstone, and local grainstone, with small oncolites (fig. 22). Toomey (1992) and Mazzullo and Teal (1994) similarly placed the contact at this level in Oklahoma based on lithologic and biotic attributes of the section. This is a datum that usually is defined by prominent stylolites (fig. 21C), and which seems to correlate to the top of the Oketo where it is present (fig. 22).

Regional correlations, however, are inconclusive in regards to assigning the Oketo as a member of either the Florence or the Fort Riley. On the one hand, the occurrence of the Oketo in northern Kansas and Nebraska is coincident with the appearance of two to three beds of mudrock in the upper Florence, which thicken to the north (fig. 18). Accordingly, the Oketo could be considered a member of the Florence in the sense that it represents a continuation of episodic siliciclastic influx during deposition of the middle and upper Florence. In fact, prior to its recognition as a separate member of the Barneston Limestone, the Oketo was once included in the Florence (e.g., Prosser, 1902; Prosser and Beede, 1904). On the other hand, some workers included beds now regarded as Oketo within the Fort Riley (e.g., Beede, 1908, 1909; Moore, 1920; and apparently, also Condra and Upp, 1931)(fig. 4). We consider the Oketo to be a member of the

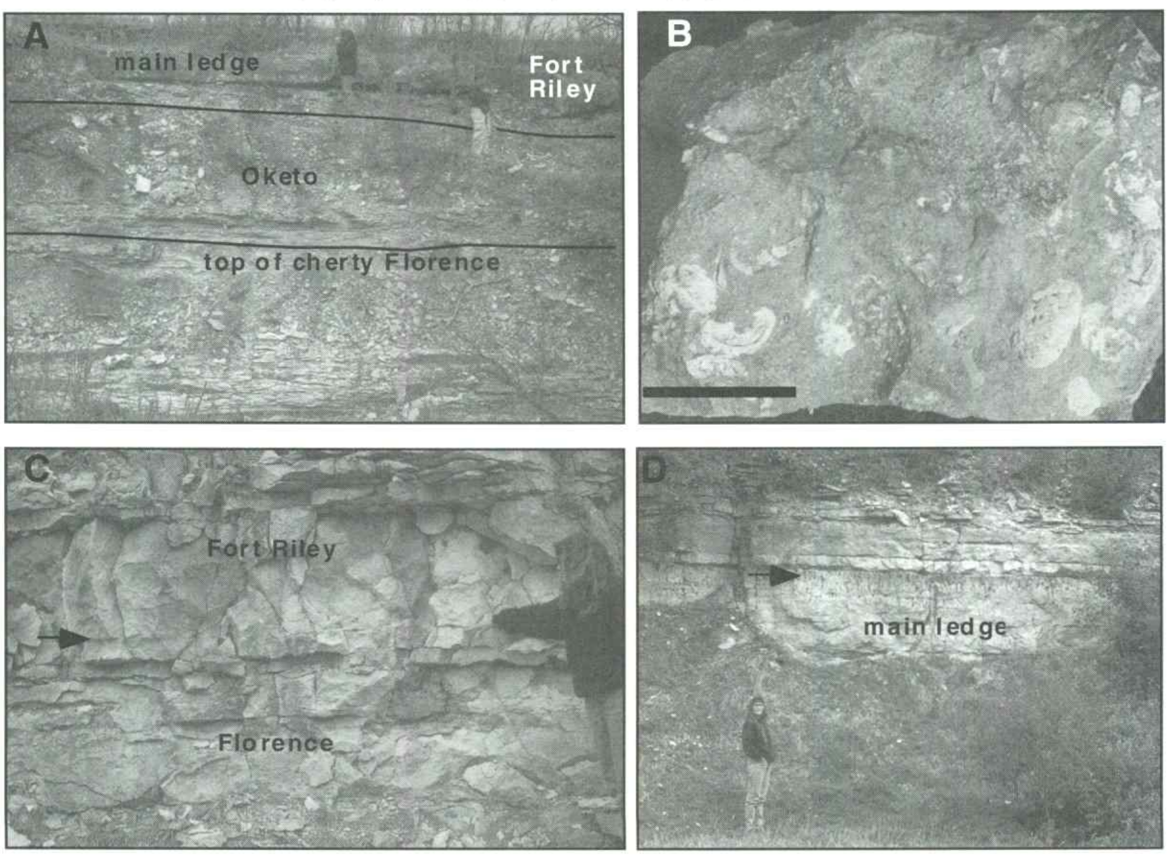


FIGURE 21—A) Photograph of the Oketo Shale Member and bounding strata at the location along Swede Creek where Jewett (1941) erroneously considered it to be 17 ft (5.2 m) thick; Nelson Farm, measured section number 131, Riley County, Kansas. B) Rock slab with large oncolites in the Oketo Shale Member, Sunflower quarry (measured section number 89, Marion County, Kansas); length of scale 1.5 inches (3.8 cm). C) Stylolitic contact (pointed out by the arrow on the left and person's hand on the right) between the bryozoan-dominated Florence and oncolitic division I of the basal Fort Riley; roadcut, measured section number 25, Cowley County, Kansas. D) Vertical burrows in the Fort Riley main ledge (arrow); roadcut along K–16, west of the bridge over Tuttle Creek Reservoir, in NW sec. 23, T. 7 S., R. 6 E., Riley County, Kansas.

Florence Formation because it seems logical to group together the typically dark-colored mudrocks in this part of the section. Such an assignment renders placement of the contact between the Florence and Fort Riley Formations straightforward in northernmost Kansas and Nebraska, where thick sections of mudrock occur in these boundary sections (fig. 18).

Fort Riley Formation (revised)

The names "Fort Riley limestone" and "Fort Riley main ledge" were originally used by Swallow (1866) in reference to his bed number 52—the 8–10-ft (2.4–3.1-m)-thick limestone ledge that conspicuously crops out high on the slopes in the valleys of the Republican, Smoky Hill, and Kansas rivers, particularly around the Fort Riley Military Reservation, in Geary and Riley counties, Kansas (e.g., fig. 21D). Hay (1896) likewise recognized the Fort Riley main ledge, although Prosser (1895) earlier had considered it to be the 5-ft (1.5-m)-thick "Florence limestone" within his "Florence flint and limestone" section (fig. 4). According to these workers, the main ledge was overlain by 30–40 ft (9.2–12.2 m) of limestone and shale that Prosser (1895), for example, included within a then un-named section of strata beneath his "Marion flint" (now the Stovall Member of the Winfield Limestone)(fig. 4). As a unit, the Fort Riley was amended and defined as a formation by Prosser (1902; and later reiterated by Prosser and Beede, 1904), to include the main ledge, the overlying 30–40 ft (9–12 m) of section, and some limestones and shales between the main ledge and what is now regarded as the Oketo Shale (fig. 4).

In describing his bed number 52, Swallow (1866) merely designated a type area only for the Fort Riley main ledge. Prosser (1902) and Prosser and Beede (1904) specified neither a type locality nor a stratotype description for their amended Fort Riley Formation, but instead, referred to the type area of the main ledge described by Swallow (1866). Likewise, Condra and Upp (1931) did not specify a stratotype for the Fort Riley when they included it within their then newly named Barneston Limestone. In fact, they may have erroneously included uppermost Florence strata in their Fort Riley at some places in Nebraska (compare their fig. 4, p. 41, to our measured section number 151 in fig. 18). Despite its subsequent widespread acceptance as a stratigraphic unit, the Fort Riley has never been formally described because a type area for only part of the unit (the main ledge) was ever designated (Swallow, 1866).

We propose to elevate the Fort Riley to formation rank from its present status as a member of the Barneston Limestone. Even earlier workers such as Prosser (1902)

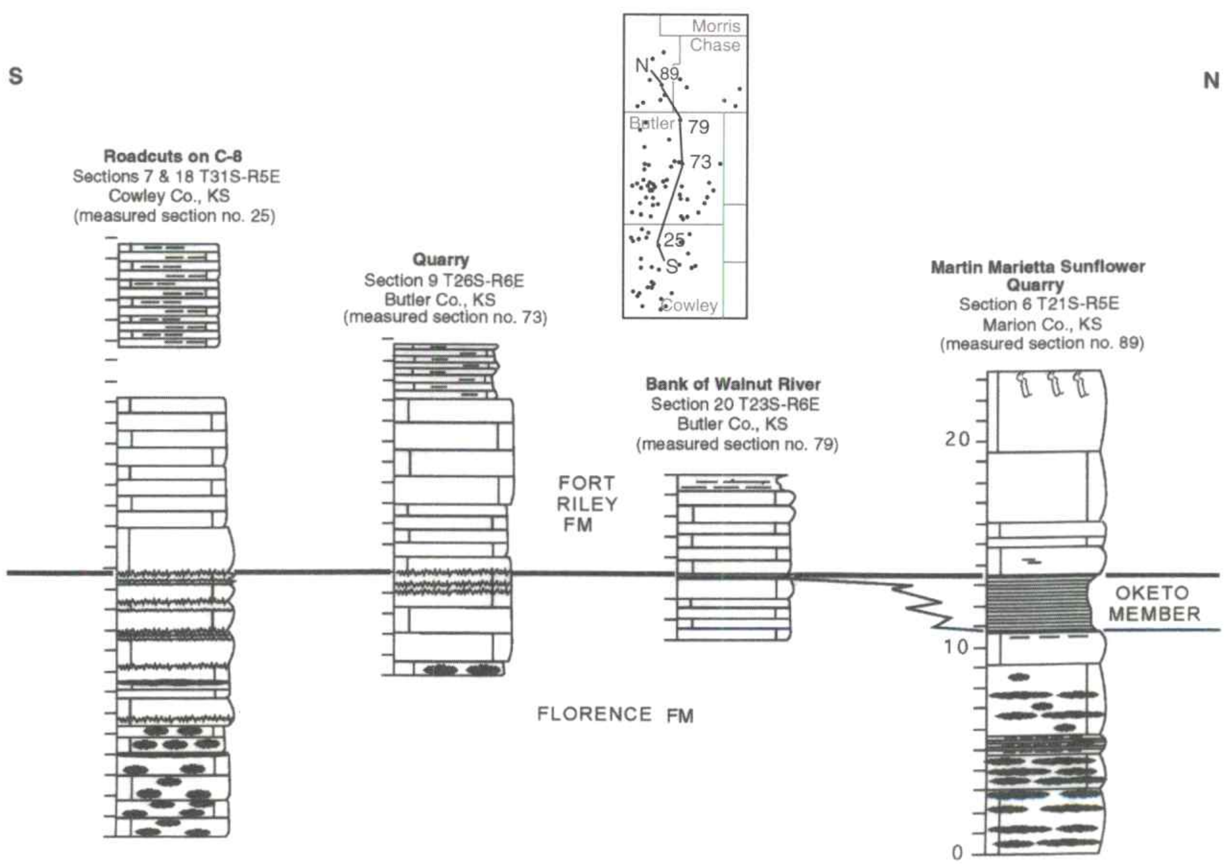


FIGURE 22—Lithostratigraphic cross section showing pinchout of Oketo Shale Member, and correlation of the Florence–Fort Riley contact in south-central Kansas.

and Prosser and Beede (1904) initially recognized the Fort Riley as a formation because of its obvious, clear distinction from the Florence (fig. 4). Although natural lithologic subdivisions within the formation are readily apparent (illustrated in the second part of this paper), we do not now propose to subdivide the Fort Riley into formally recognized members. The Fort Riley is well exposed in many areas of Kansas, although it differs drastically in terms of lithology in south-central Kansas versus northern Kansas and southeastern Nebraska. Hence, a single reference locality would not suffice for descriptions of this unit on a regional basis. Nevertheless, insofar as a principal reference section should be defined, we so designate it to be the roadcut exposures along US–77 in the NW sec. 22, T. 11 S., R. 5 E., immediately north-northwest of Junction City and due north of the Republican River, in Geary County, Kansas (fig. 23). This location (our measured section number 110A) is within the original type area of Swallow's (1866) Fort Riley main ledge, and the entire formation, including its upper and lower contacts, is well exposed. A nearby roadcut along US–77, south of this principal reference section, also exposes the Fort Riley to the lower Holmesville (our measured section number 110B). Roadcuts along Tuttle Creek Boulevard (US–24) just north of Manhattan, Kansas, in Riley County (our measured section number 127), expose the same section as at these localities. Other localities in south-central Kansas at which different lithofacies occur in the Fort Riley are described in the second part of this paper.

The Fort Riley Formation is about 32.5 ft (9.9 m) thick at the principal reference section (fig. 24). The basal 2.5 ft (0.8 m) consist of medium- to thin-bedded, light-yellow, coarse-grained, silty, oncolitic biowackestone to packstone that becomes shaly upsection. Common fossils include echinoids, crinoids, gastropods, *Reticulatia* spp., *Composita* spp., and bryozoans. The succeeding 5 ft 5 inches (1.7 m) are the massive "main ledge" of prior usage, or the "rimrock" of current terminology (fig. 24). The characteristic stratigraphy of upper Florence to lower Fort Riley bounding strata, that is: (a) Oketo Shale, (b) coarse-grained, echinoid fragment-rich limestone, and (c) the "main ledge," is recognized from southern Marion County northward to Marshall County, Kansas, but loses this characteristic identity northward and southward from these areas (e.g., compare figs. 18 and 22). The main ledge fines upward from biowackestone and packstone to biowackestone, and at many localities, has conspicuous vertical burrows extending downward from the middle of the unit (fig. 21D). Readily identifiable fossils include crinoids, gastropods, and *Aviculopecten* spp. The fusulinid genera *Nankinella* spp. and *Oketaella fryei* have been reported from the lower and basal middle units of the Fort Riley in Kansas and northern Oklahoma, and locally from the Oketo, by Thompson (1954), Sanderson and Verville (1988), and Toomey (1992).

The overlying 3 ft 7 inches (1.1 m) of thick-bedded, yellow biowackestone to packstone is in turn overlain by 6 ft 2 inches (1.9 m) of yellow to medium-gray (weathers dark), laminated, sparsely fossiliferous, shaly lime mudstone with some lenses of biowackestone. Foraminifers, crinoids, *Derbyia* spp., *Permophorus* spp., and casts of pectinids locally are common in these beds. This unit locally changes facies to dark calcitic shale at, for example, the outcrops along Tuttle Creek Boulevard near

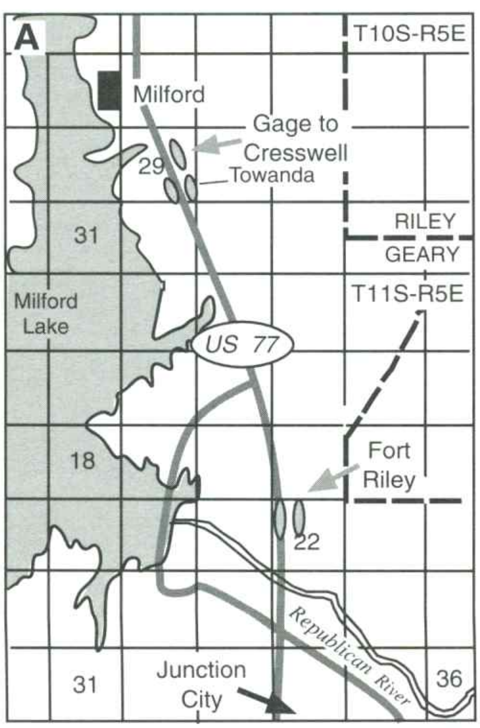


FIGURE 23—A) Location of principal reference sections of the Fort Riley Formation, and also, of the Gage Member of the Doyle Shale, both in Geary County, Kansas. B) The Oketo Shale Member to basal Towanda Limestone Member section at the principal reference section of the Fort Riley Formation in Geary County (measured section number 110A). Scoriaceous-weathering beds compose nearly the upper third of the Fort Riley here.

Manhattan (measured section number 127). The succeeding 12 ft 8 inches (3.9 m) are generally medium-bedded, light-yellow, shaly and silty, calcitic dolomudstone with abundant golf-ball-size, calcite-lined vugs (inferred dissolved evaporite nodules). The upper 10.5 ft (3.2 m) locally weather to a characteristic porous, scoriaceous appearance (fig. 23B) that can be traced northward into Riley County. Foraminifers, crinoids, and gastropods occur rarely in this section. The upper contact with the Holmesville Member of the Doyle Shale is picked at the top of the succeeding 2-ft (0.6-m)-thick, recessive unit of unfossiliferous, laminated, silty and shaly dolomudstone, also with calcite-lined vugs; a discontinuous but thick paleocaliche occurs locally in the lower Holmesville directly above this unit (fig. 24). The immediately overlying Holmesville section is unfossiliferous, gray, yellow, and red shale and mudrock. Further discussion of the Fort Riley–Doyle contact appears below.

Doyle Shale

History of Terminology

The Doyle Shale was named by Prosser (1902) from outcrops in ". . . various places . . ." along the valley of Doyle Creek, southwest of Florence, in Marion County, Kansas. He did not specify a stratotype description, or define a particular type locality for this unit. Prosser and Beede (1904) later referred to this formation, which subsequently has become widely accepted in the stratigraphic literature on the Chase Group. We have not been able to locate an outcrop in Prosser's specific type area at which the entire Doyle Shale is exposed. However, the lower and middle Doyle (Holmesville and Towanda of present usage) are well exposed in a roadcut along US–77 in the NW sec. 18, T. 21 S., R. 5 E. in Marion County (figs. 16A, 25), which is at the confluence of the valleys of the Cottonwood River and Doyle Creek due south of Florence, Kansas. The middle to upper Doyle, including the Towanda and Gage Members, and the overlying Stovall Member and lower part of the Grant Member of the Winfield Limestone, are fairly well exposed a few miles to the west-southwest, in exposures along the bluffs of Doyle Creek in the NW NE sec. 28, and in an adjoining roadcut in the NE NW sec. 28, in T. 21 S., R. 4 E. (fig. 16A). These outcrops, and those roadcuts along US–77, are our measured section numbers 85 and 87, respectively, which are within the Doyle type area as originally designated; together they compose our principal reference section of this formation (fig. 26). Although the uppermost Gage to Grant section is fairly well exposed at measured section number 87, the lower and middle Gage are only sporadically exposed here, and examination of this section requires some digging, which the owner of the land might not appreciate. The reader is therefore referred to the following outcrops as supplemental reference localities for the upper Doyle: (a) the high roadcut along 210th Street in the NW sec. 23, T. 29 S., R. 4 E., in Butler County (measured section number 42); and (b) the roadcuts along US–77 north of the town of Rock, in the E/2 sec. 8, T. 30 S., R. 4 E., in northern Cowley County (measured section number 30).

The lower to middle Doyle and underlying Fort Riley are well exposed along both sides of the road at the US–77 locality (figs. 25, 26). According to some workers (e.g., Fath, 1921; Bass, 1929; Condra and Upp, 1931; Bayne, 1962; Chaplin, 1988), the contact between these two formations is gradational. Fath (1921) and Bayne (1962), for example, recognized a tripartite division of the Fort Riley in south-central Kansas (i.e., massive beds at the base, shaly limestone in the middle, massive "oolitic" limestone at the top), and included the commonly poorly exposed section of thin-bedded, shaly limestones above the "oolitic" beds within the Holmesville. Based on our regional studies (Mazzullo et al., 1995), we disagree with this assignment, and instead, suggest that the Fort Riley–Doyle contact is best placed at the top of the section of shaly carbonate that overlies the "oolitic" limestone or its

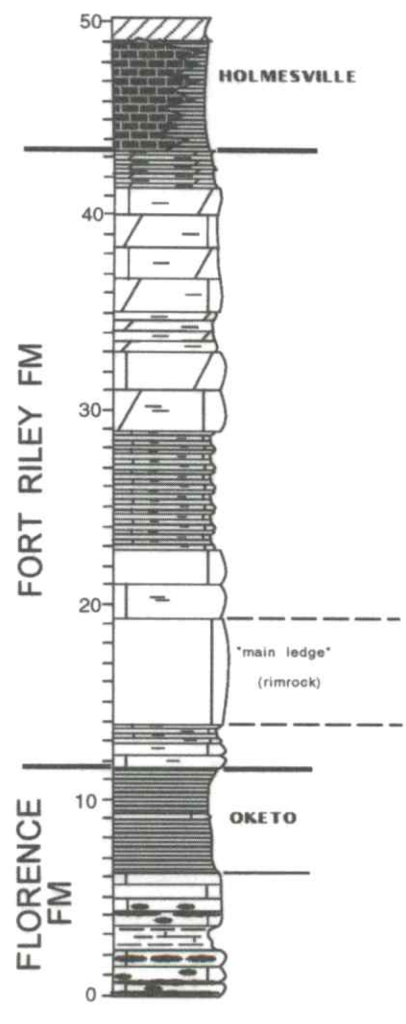


FIGURE 24—Lithostratigraphy of the Fort Riley at the principal reference section in Geary County, Kansas (measured section number 110A in sec. 22, T. 11 S., R. 5 E.).

facies equivalent (fig. 26) because (1) we can correlate this actual four-fold division of the Fort Riley across much of central and southern Kansas (illustrated in the second part of this paper); (2) such a contact is lithologically and paleontologically distinct, and therefore, is regionally correlative. Whereas it is true that these shaly beds are lithologically transitional between Fort Riley carbonates below and Doyle shales above, they nevertheless are carbonate rocks that carry a Fort Riley-type biota. Such a contact therefore marks a natural boundary between dominantly carbonate versus dominantly siliciclastic deposition; and (3) the Doyle as a whole (excluding the Towanda Limestone Member), and the basal Holmesville Member in particular, were originally described by Prosser (1902) and Condra and Upp (1931) as being dominantly shale rather than limestone; Fath (1921) and Bayne (1962) incorrectly included these upper shaly beds in the Holmesville because they did not trace this unit regionally. We therefore take the position that the Fort Riley–Doyle contact, whether it be sharp or somewhat more gradational, should be placed at the base of a relatively thick section of shale and/or mudrock overlying a thick section of dominantly marine or peritidal carbonate rocks.

Accordingly, the base of the Doyle at the roadcuts on US–77 (fig. 25) is picked at the top of the 10 ft 10 inches (3.3-m)-thick section of thin-bedded, shaly lime mudstone in the Fort Riley, the upper part of which is shown in figs. 25 and 26. This contact correlates with that at the proposed Fort Riley reference section in Geary County (fig. 24). As so defined, the basal 14 ft 4 inches (4.4 m) of the Doyle (the Holmesville Member) here consist mainly of unfossiliferous, yellow-brown and green-gray shales and mudrocks, locally silty, with calcite geodes. A thin layer (few inches) of intraclastic biowackestone (with pelecypod fragments and crinoids) occurs about 4 ft (1.2 m) above the base, and a 1 ft 8 inches (0.5-m)-thick bed of porous, shaly, coarse-recrystallized limestone with secondary calcite veins and boxwork structure (likely, a replaced evaporite layer) occurs just below the top of this basal 14 ft 4 inches unit (fig. 26). The overlying 10 ft (3.1 m) of limestone (the Towanda Member) consist of medium to mostly thin interbeds of lime mudstone, biowackestone to packstone, and fine-grained, foraminiferal biograinstone.

At the exposures in sec. 28, T. 21 S., R. 4 E. (figs. 16A, 26), the Towanda is overlain by about 31 ft (9.5 m) of strata of the Gage Member. The basal 19 ft (5.8 m) of the Gage are incompletely exposed, unfossiliferous shales and mudrocks which are silty and red in the middle, and green at the top and base. The overlying 3 ft (0.9 m) consist of two thin beds of fossiliferous, shaly limestone (with crinoids, foraminifers, and *Composita* spp.) separated by unfossiliferous, yellow mudrock. The upper 9 ft (2.7 m) similarly are unfossiliferous, yellow to yellow-brown mudrock in the lower part, commonly rooted; and sparsely fossiliferous (pectinid casts), greenish-yellow mudrock in the upper part. The Doyle in the field exposures is overlain by 2.5 ft (0.8 m) of cherty limestone (Stovall Member), which likewise is present in the roadcut where it is overlain by a few feet of the basal Grant Shale Member of the Winfield Limestone.

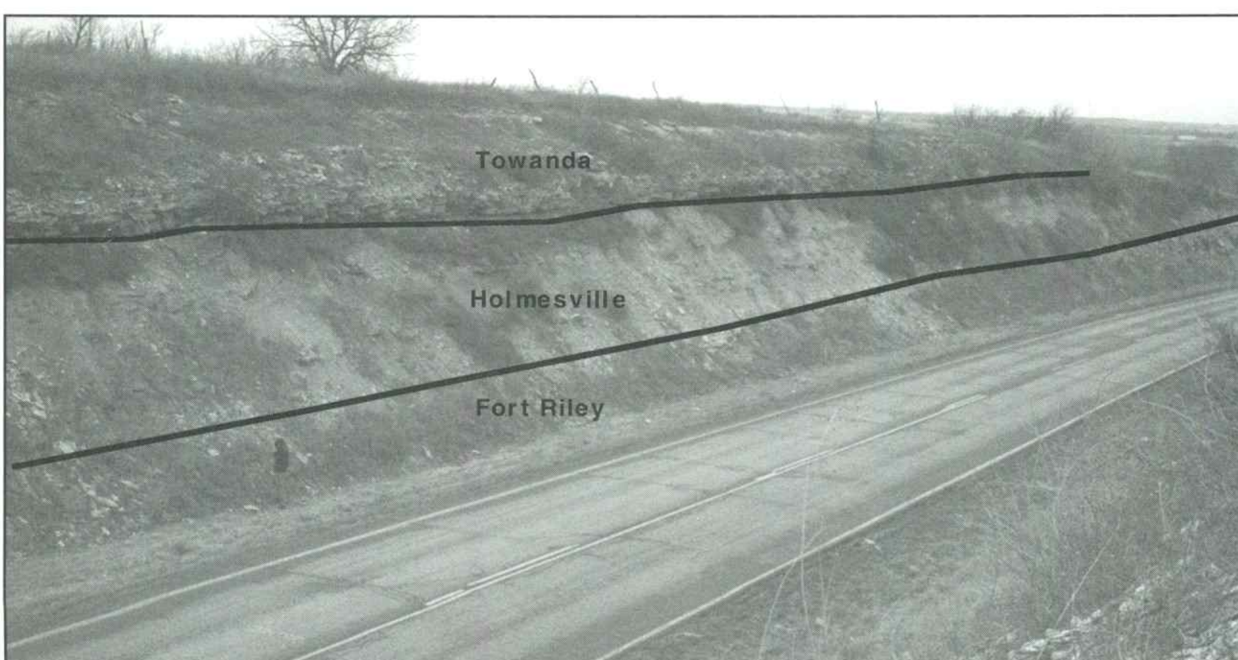


FIGURE 25—Photograph of roadcut of the upper Fort Riley to Towanda section along the west side of US–77 south of Florence at measured section number 87, sec. 18, T. 21 S., R. 5 E., Marion County, Kansas. A similar section is exposed along the east side of the road here.

Holmesville Member

This member was named by Condra and Upp (1931) from exposures described as being 1.5 mi (2.4 km) west and 0.5 mi (0.8 km) north of the town of Holmesville, in Gage County, Nebraska. They described the unit here as consisting of, in ascending order, 7 ft (2.1 m) of gray shale, 1 ft (0.3 m) of blocky limestone, and 10–11 ft (3.1–3.4 m) of gray and red shale. We found no outcrops at the specific location given by Condra and Upp (1931), although we do not know the exact point in town from which their coordinate location originated. However, upper beds of the Fort Riley and overlying Holmesville are exposed in this area in a cutbank of a tributary to the Big Blue River, and in an adjoining roadcut, in the SW sec. 13, T. 3 N., R. 6 E. in Gage County, Nebraska (fig. 27). This location (our measured section number 154) may actually be the type locality of the Holmesville because there are no other outcrops around it that expose the same units. Accordingly, a principal reference section for this member is not totally warranted. The upper 6 ft 2 inches (1.9 m) of what we consider to be the Fort Riley here (fig. 28) are thin-bedded, medium-gray to light-yellow, very shaly dolomudstone with calcite-lined vugs (inferred dissolved evaporite nodules). These beds are quite similar lithologically to uppermost Fort Riley strata at the Doyle principal reference section described above, and to equivalent strata at the principal reference section of the Fort Riley in Geary County. The overlying 2 ft (0.6 m) of basal Holmesville consist of light-yellow, laminated, unfossiliferous, dolo-

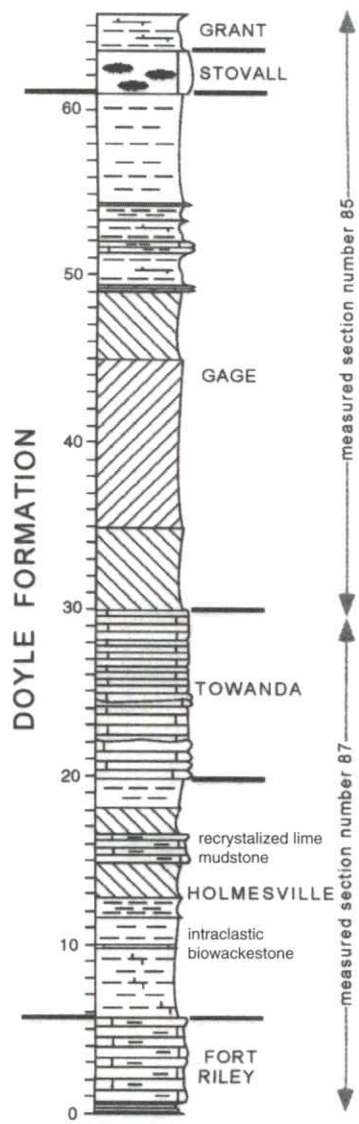
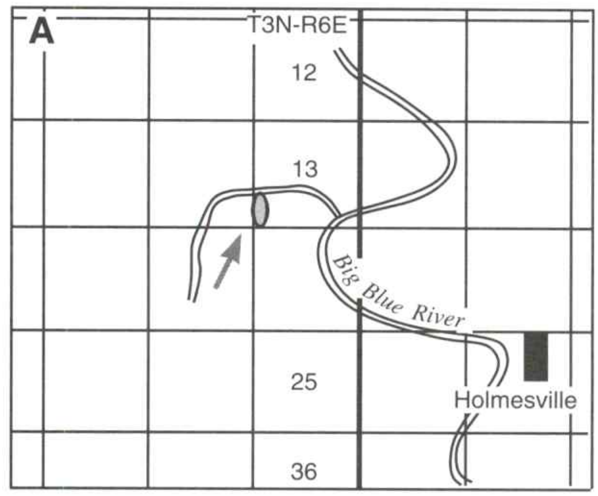


FIGURE 26—LITHOSTRATIGRAPHY OF THE DOYLE SHALE AT THE PRINCIPAL REFERENCE SECTION IN MARION COUNTY (composite of measured sections 85 and 87).



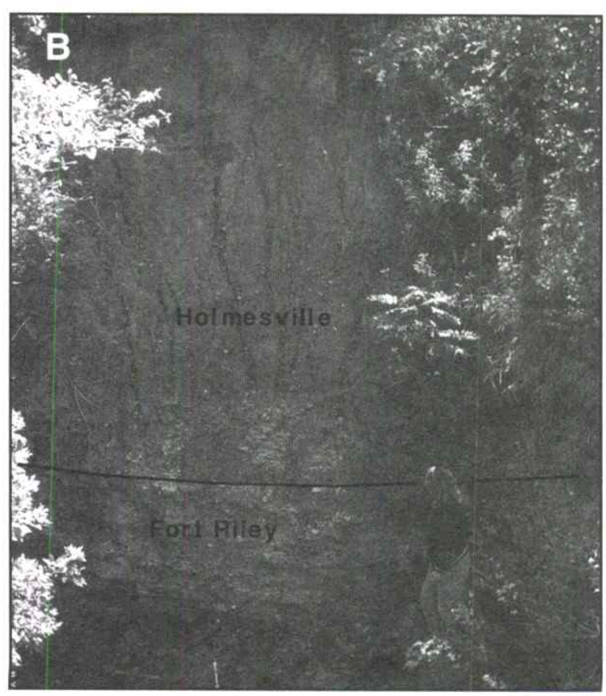


FIGURE 27—A) THE PRESUMED LOCATION OF CONDRA AND UPP'S (1931) TYPE LOCALITY OF THE HOLMESVILLE MEMBER IN GAGE COUNTY, NEBRASKA (MEASURED SECTION NUMBER 154). B) The upper Fort Riley and lower Holmesville at this locality.

mitic mudrock with streaks of red shale. Condra and Upp (1931) could easily have mistaken this combined 8 ft 2 inches (2.5-m)-thick section for what they referred to as "gray shale and blocky limestone" in their basal Holmesville, because of their very shaly character, especially years ago when the outcrops were fresher. The overlying 10 ft (3.1 m) are unfossiliferous, mostly red, silty shale and mudrock, with thin layers of green shale at the base and in the upper 6 ft (1.8 m) of the section. The upper contact with the Towanda is not exposed at this locality.

The Holmesville mostly is poorly exposed throughout the study area because of its recessive weathering characteristic. In Kansas, the entire section is exposed at the following locations, any one of which can be regarded as a supplemental reference section: (1) roadcuts in the E/2 sec. 4, T. 1 S., R. 8 E. in Marshall County (measured section number 142); (2) roadcuts along US–77 in the NW sec. 22, T. 11 S., R. 5 E. in Geary County (measured section number 110A); (3) roadcuts along US–77 south of Florence, which were described above (measured section number 85); and (4) along the north wall of the Martin Marietta Sunflower quarry in sec. 6, T. 21 S., R. 5 E. in Marion County (measured section number 89).

Towanda Limestone Member

The Towanda Limestone Member was named by Fath (1921) for exposures along the bluffs north-northwest of the town of Towanda in Butler County, Kansas (fig. 29). He described the member in the county as 5–9.5 ft (1.5–2.9 m) of flaggy-bedded limestones, but did not specify a stratotype. Outcrops of the Towanda and bounding strata in this area are found in a roadcut and adjoining small quarry on River Valley Road in the SW and NW sec. 9, T. 26 S., R. 4 E. (fig. 29B,C). This locality is our measured section number 69, where the Towanda is about 6 ft 4 inches (1.9 m) thick (fig. 30A). A nearby, poorly exposed

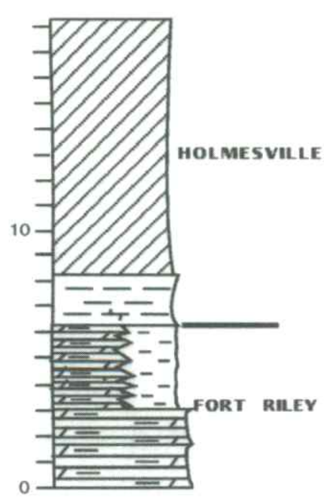


FIGURE 28—Lithostratigraphy of the Holmesville at the presumed type locality in Gage County, Nebraska (measured section number 154, sec. 13, T. 3 N., R. 6 E.).

outcrop along 3rd Street in town, in the NE SW sec. 9 (fig. 29A), is included in fig. 30A for reference.

The upper 7 ft (2.1 m) of the Holmesville at the roadcut and quarry along River Valley Road are unfossiliferous, dark-green-gray shale/mudrock that pass upward to orange-yellow mudrock. The basal 1 ft 4 inches (0.4 m) of the Towanda lie conformably on the Holmesville and consist of two beds of light-yellow, recrystallized lime mudstone separated by unfossiliferous, yellow mudrock. The basal contact of the Towanda is a reasonably persistent datum throughout most of the study area. The overlying 1.5 ft (0.5 m) of unfossiliferous, yellow-orange mudrock are in turn overlain by 1 ft 2 inches (0.3 m) of light-yellow, thin-bedded to laminated, brecciated lime mudstone. This section is succeeded by 2 ft 4 inches (0.7 m) of medium- up to thin-bedded, yellow-orange, porous, recrystallized lime mudstone. The contact with the overlying Gage is sharp. The Gage is 2 ft 8 inches (0.8 m) of unfossiliferous, red shale seemingly capped by a 4-inch (10-cm)-thick bed of yellow-orange lime mudstone with small bivalve fragments (fig. 29C). At the roadcut on 3rd Street in town, the Towanda appears to be about 10.5 ft (3.2 m) of light-yellow, hard, fine-grained biowackestone to packstone with foraminifers and molds of pelecypods and gastropods (fig. 30A).

As shown in fig. 30A, we can not definitively correlate strata, nor can we resolve the apparent differences in lithology and thickness of the Towanda between the roadcut and quarry exposures and the outcrop on 3rd Street in town. Unfortunately, there are no complete exposures of the Towanda, with bounding contacts, anywhere in Butler County that could serve as a principal reference section for this member. We therefore propose to designate the exposures in the Martin Marietta Sunflower quarry in Marion County (fig. 16A) as the principal reference section of the Towanda Member. At this locality the Towanda is about 10 ft (3.2 m) thick (fig. 30B, C). The basal 2.5 ft (0.8 m) are thin-bedded, light-yellow calcitic mudrock and lime mudstone to foraminiferal biopackstone. The overlying 5 ft (1.5 m) are generally thin-bedded, yellow, lime mudstone to foraminiferal biograinstone. The upper 2.5 ft (0.8 m) are thin interbeds of yellow mudrock and foraminiferal biowackestone to packstone. Although the upper contact with the Gage is not exposed here, regional mapping suggests that the Towanda likely is only 10 ft (3.1 m) thick in this area. The Towanda–Gage contact is rarely exposed, but where it is, it either is sharp, or as at measured section number 107 in Dickinson County, it is gradational.

Gage Member

The Gage was formally described by Condra and Upp (1931, their measured section number 18) from exposures between 1 to 2 mi (1.6–3.2 km) south of the west side of the town of Wymore, in Gage County, Nebraska. This location encompasses rather poor gully and low roadcut exposures in the E/2 sec. 31 and the W/2 sec. 32 in T. 2 N., R. 7 E. They described the unit as greenish-gray, olive, and red shales and mudstones, locally sandy, that are unfossiliferous except for the top 5 ft (1.5 m); they noted that the contact with the Towanda was concealed here. There are inconsistencies, however, in their reported thickness of the member at this locality. For example, Condra and Upp explicitly stated (p. 45) that the thickness of the member increases from Nebraska into Kansas, from "... about 28 to 50 feet." Yet, in their measured section (p. 45) they appear to have indicated that the Gage was 35 ft (10.7 m) thick rather than 28 ft (8.5 m) thick, and in fact they described this much section (35 ft [10.7 m]) of exposed strata. However, they then noted that there was an additional 12 ft (3.7 m) of concealed strata at the base of the section within which the Towanda–Gage contact presumably occurred. These figures instead add up to give a maximum thickness of about 47 ft (14.3 m) of Gage section in Nebraska, and not 28 ft or 35 ft. Because of the incomplete nature of the exposures here, and slumping of strata, we were unable to correlate zones within the member or to measure the section, and therefore, we were also unable to verify any of the several thicknesses reported by Condra and Upp (1931). We found no other outcrops of this member in Gage County that could supplement this exposure, and only incomplete exposures were found in nearby Marshall and Riley counties in Kansas.

The entire Gage and bounding strata are fairly well exposed, however, at two closely spaced roadcuts 0.25 mi (0.4 km) apart along US–77, in the E/2 sec. 29, T. 10 S., R. 5 E., about 1 mi (1.6 km) southeast of the town of Milford in Geary County, Kansas (fig. 23A). This locality, our measured section number 116 (fig. 31), is proposed to serve as the principal reference section of this member. The Gage overlies the Towanda (which is exposed along the road 0.25 mi [0.4 km] to the south), and is 24 ft (7.3 m) thick. The basal 6 ft (1.8 m) of light-gray-green mudrock and shale are overlain by 9.5 ft (2.9 m) of mostly red, silty mudrock and siltstone with some thin layers of green shale. A 4-inch (10-cm)-thick, discontinuous bed of light-greenish-gray, shaly lime mudstone caps this unit. The upper 8 ft (2.4 m) are light-gray mudrock, poorly exposed in the upper half of the section. We found no fossils in the exposed siliciclastics here, although the upper Gage is fossiliferous at other outcrops in northern Kansas. The Gage is overlain here by Stovall, Grant, and lowermost Cresswell strata (fig. 31).

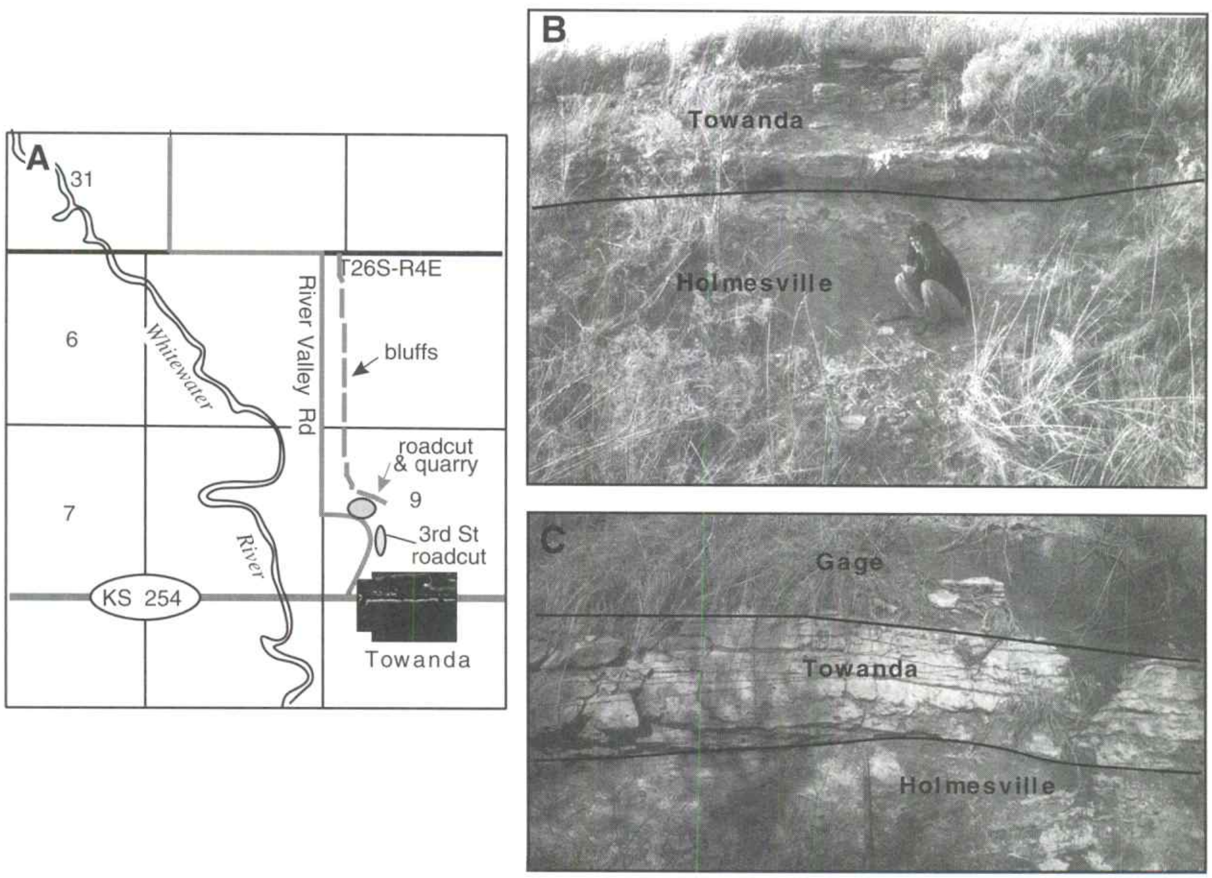


FIGURE 29—A) Fath's (1921) type area of the Towanda along the bluffs north of the town of Towanda in Butler County, Kansas. B and C) Photographs of the outcrops of the Holmesville, Towanda, and Gage along the bluff (B) and in the quarry (C) at this locality; the rod is divided into 20-cm segments. In photo C, float blocks of lime mudstone to the right of and below the word "Gage" are from a discontinuous (in situ?) layer 2 ft 8 inches (0.8 m) above the Towanda–Gage contact.

Winfield Limestone

History of Terminology

The history of stratigraphic terminology of this unit is most complex. Prosser (1895) initially recognized the "Marion chert and concretionary limestone" (fig. 4), named from exposures near Marion but described from (now poor) outcrops near Marion and Burns (p. 773) in Marion County, Kansas. This unit included, in ascending order, about 4 ft (1.2 m) of flinty limestone, 13 ft (4 m) of yellow shale, and 10 ft (3.1 m) of limestone with "large, brown, irregular concretions" (Prosser's "sand bricks"). It is clear that Prosser's "Marion chert" referred to the lower flinty limestones, whereas the thick, upper limestone was his "concretionary limestone." He regarded the top of the latter as the top of the Chase Formation and proposed the name Marion Formation to include the then-undivided section of overlying shales and limestones (fig. 4).

Later, Prosser (1897b) referred to the 9–11 ft (2.7–3.4 m) thick, massive limestones exposed around the towns of Augusta and Douglass, in Butler County, as the Winfield

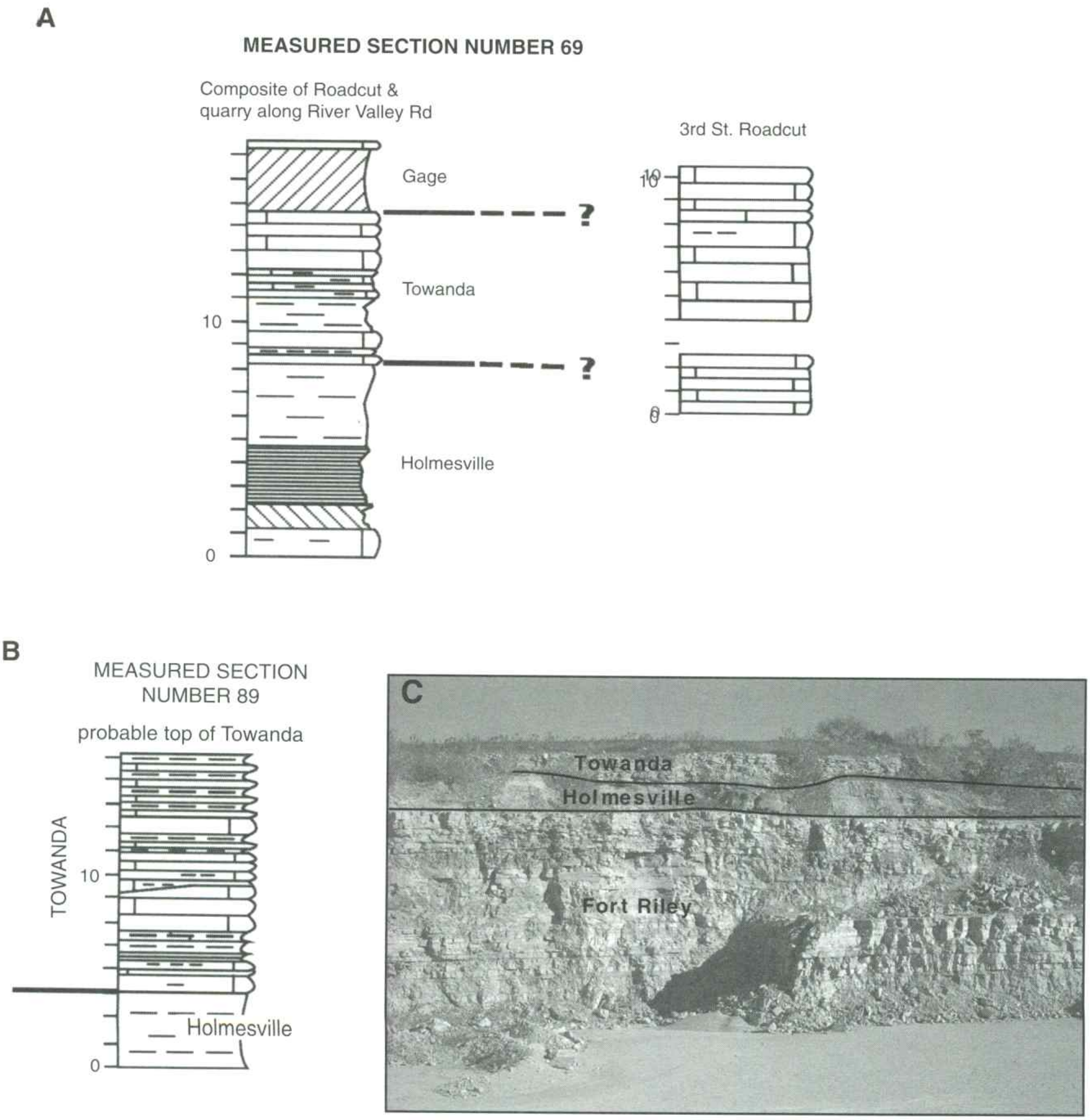


FIGURE 30—A) Lithostratigraphy of the Towanda in the type area (measured section number 69, sec. 9, T. 26 S., R. 4 E., Butler County, Kansas). B) Towanda at the principal reference section in the Martin Marietta Sunflower quarry in Marion County (measured section number 89, sec. 6, T. 21 S., R. 5 E.). C) The Fort Riley to Towanda section in the Sunflower quarry, north end. For reference to scale, the Towanda here is 10 ft (3.1 m) thick. The seemingly irregular Towanda–Holmesville contact is a result of the irregularity of the exposure.

Limestone. He had earlier referred to these beds as the upper "concretionary limestone." Prosser (1897c) then correlated these strata exposed around the town of Winfield in Cowley County to the concretionary limestone exposed around Marion and Burns in Marion County, and stated (p. 64) that the term "Marion concretionary limestone" was never intended to be used in a formal sense. Accordingly, he withdrew this name and formally proposed the name Winfield concretionary limestone for these beds. The type area of this unit was designated to be exposures around the west edge of the town of Winfield, in the bluffs along the Walnut River. In this paper (1897c), Prosser made no mention of the underlying yellow shale and "Marion flint" that he had described in 1895, and it is unclear whether he included them within the Winfield concretionary limestone. In another paper published in 1897b, Prosser recognized these beds to be stratigraphically below the Winfield. Then, in his 1902 paper, he once again redefined the Winfield Limestone to include cherty limestone at the base (his former "Marion flint"), yellow shale in the middle, and massive concretionary limestone at the top (his former "concretionary limestone" [e.g., 1895] and/or Winfield Limestone [e.g., 1897c]). Prosser and Beede (1904) reiterated this stratigraphic terminology and regarded the overlying Marion Formation, which included the Luta at its base, as the basal unit of the Sumner Stage (fig. 4).

Condra and Upp (1931), recognizing Prosser's (1902) Winfield Formation per se, subdivided it into three

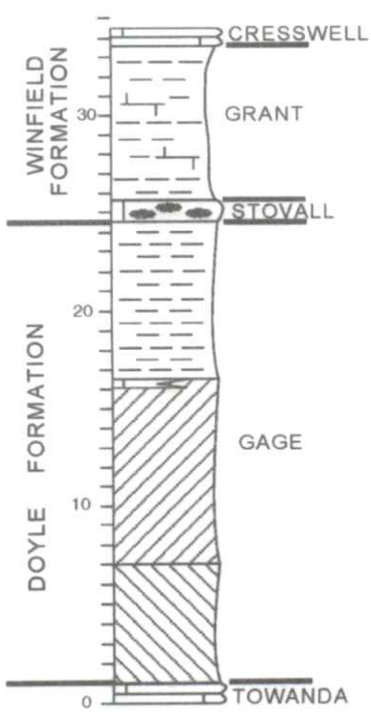


FIGURE 31—Lithostratigraphy of the Gage at the principal reference section in Geary County, Kansas (measured section number 116).

members, in ascending order, the Stovall (= the "Marion flint" of Prosser), the Grant (= yellow shales), and the Cresswell (= the "Marion concretionary limestone" or the "Winfield")(fig. 4). The Luta limestone had earlier been recognized by Beede (1908) as the basal member of the overlying Marion Stage, an assignment that was followed later by Moore (1920). Condra and Upp (1931) included the Luta as the basal unit of the overlying Enterprise Shale of the Marion Formation (fig. 4), but it was ". . . not thought to extend to northern Kansas and Nebraska . . ." (p. 57). Where it was present elsewhere in Kansas, however, they considered that it may be a facies of the Odell Shale. As of 1931 the top of the Chase Group was placed at the top of the Winfield Limestone (fig. 4). Moore et al. (1934) and Moore (1936) later included the Luta, referred to specifically by that name, as the upper member of the Winfield Limestone, but subsequently, Moore et al. (1944, 1951a) included these beds within the Cresswell Member, thus effectively (but not formally) abandoning the name Luta. Their revised stratigraphy for the formation was adopted by the Kansas Geological Survey (e.g., Zeller, 1968 [fig. 3]). Even after this change, however, for some reason Moore periodically continued to refer to the Luta as the upper member of the Winfield Limestone (Moore, 1964 [his fig. 3]). By 1944 the Chase Group had been revised to include strata to the top of the Herington Member of the Nolans Limestone. Condra and Reed (1959) continued to include the Luta, where present in Kansas, in the basal Odell Shale (fig. 4), although more recent descriptions of Chase Group stratigraphy in Nebraska do not mention the Luta because of its apparent absence in the state (Burchett, 1988).

Although the Winfield Limestone as currently recognized (e.g., Condra and Upp, 1931; Zeller, 1968) is different than the Winfield Formation defined by Prosser (1902), it nevertheless has become a widely accepted stratigraphic unit within the Chase Group. Yet, a type area or type locality for the formation as it is recognized today has never been formally designated. The argument is that Prosser (1902) did not, by strict rules, specify a stratotype for the formation because he included in it only what is now recognized as the Stovall and the Grant Members, plus the Cresswell Member exclusive of the Luta. Although Prosser (1897c) earlier had designated a type area for his Winfield concretionary limestone (a representative outcrop of which is in the center W/2 sec. 29, T. 32 S., R. 4 E. in Cowley County [our measured section number 20]), this unit, as he defined it, excluded the Luta that is exposed there. Moore (1936) and Moore et al. (1934, 1944, 1951a) likewise did not formally document their proposed changes in the stratigraphy of the Winfield. To complicate this issue even further, Mazzullo and Teal (1994) and Mazzullo et al. (1995, 1996) recently suggested that the name Luta once again be used in reference to the upper member of the Winfield Limestone because of its stratigraphic significance and clear lithologic distinction from the Cresswell sensu Condra and Upp (1931).

We are somewhat hesitant, however, to formally propose a new type locality for the Winfield Limestone as is currently recognized in Kansas. Doing so might be construed as violating the rules of stratigraphic nomenclature because at least part of the formation has already been defined. Furthermore, it would compound the convoluted history of stratigraphic terminology that already exists. On the other hand, the formation as recognized today has not been formally described, and the suggestion to once again recognize the Luta by name as its upper member must be addressed because it has proven to be a viable stratigraphic unit (Mazzullo and Teal, 1994; Mazzullo et al., 1995, 1996). The issue of the Luta is particularly significant because, as was noted long ago by Condra and Upp (1931) and more recently by Chaplin (1988) and Mazzullo et al. (1995), questions still exist concerning its regional correlation and stratigraphic assignment because it is, in fact, a natural stratigraphic subdivision.

In the attempt to resolve these issues, we will first discuss each of the members of the Winfield Limestone as they are currently recognized. Then, we will consider the status of the Luta in its stratigraphic and regional context. Finally, rather than designating a new type locality for the formation, which does not appear totally warranted, we will designate a principal reference section for the Winfield Limestone as we now recognize it—that is, including the Luta as its upper member. The reader should remember that we are not strictly proposing a revision in the stratigraphic terminology by doing so. Instead, we are merely clarifying the definition of the Winfield Limestone and re-establishing a name that was never formally abandoned.

Stovall Member

The Stovall Limestone Member was named by Condra and Upp (1931) from unspecified exposures in the bluffs along Doyle Creek, about 7 mi (11.3 km) southwest of Florence in Marion County, Kansas. The field and roadside exposures of the Stovall in sec. 28, T. 21 S., R. 4 E. in Marion County (figs. 16A, 26) are in this type area, which is also Prosser's (1902) type area of the Doyle, and our principal reference section of this formation. In fact, this is the only locality within Condra and Upp's (1931) type area where we have found good outcrops of the Stovall. Hence, this locality can serve as the principal reference section of this member. Condra and Upp (1931) did not specify a stratotype description of the Stovall in this area, which we have provided in our measured section number 85 at this locality (fig. 26). The Stovall is 2.5 ft (0.7 m) here, and the basal contact with the underlying Gage Shale is sharp and conformable. The Stovall is light-yellow biowackestone, the top few inches being somewhat shaly, with angular nodules of gray-yellow chert; this is the typical lithology of the cherty Stovall in Kansas (fig. 32A). The upper contact with the Grant Shale is somewhat gradational. Fossils in the Stovall here include crinoids, echinoid fragments, bryozoans, and *Reticulatia* spp.

The Stovall sensu stricto is a cherty limestone that is not recognized in southern Kansas, specifically, in Cowley and most of Butler counties (Bayne, 1962; Zeller, 1968; Mazzullo et al., 1995), nor in northern Oklahoma (Chaplin, 1988, 1994). The southernmost occurrence of the Stovall we have found is in roadcuts along River Valley Road in the NW sec. 28, T. 23 S., R. 4 E. in northern Butler County, Kansas (our measured section number 78 [shown in fig. 33]).

Santa Fe Lake Member (new name)—Generally non-cherty carbonate strata that occur at the same stratigraphic level as the Stovall are present at many localities in south-central Kansas (fig. 33), where they are expressed as subdued ledges on outcrop. We have recognized these beds as far south as Arkansas City in southern Cowley County. These strata are thin-bedded to laminated, variously unfossiliferous and highly recrystallized lime mudstones, to sparsely fossiliferous, shaly lime mudstones to biowackestones (pelecypod casts, crinoids, brachiopods, and locally, oncolites and foraminifers) that overlie the unfossiliferous Gage and underlie the fossiliferous Grant. These limestones, which occur as lenses that locally pass laterally into calcitic shale/mudrock, occur over a large area of south-central Kansas.

According to the Code on Stratigraphic Nomenclature (North American Commission on Stratigraphic Nomenclature, 1983), this section of limestones can be formally named despite the fact that, like the Stovall, it is not developed everywhere in the study area, in this case, because of its lenticular nature. We contend that formal recognition of this unit is important for stratigraphic studies in Kansas in that it serves to clarify regional stratigraphic relationships within the Winfield Limestone. Where the Stovall is absent in south-central Kansas, for example, many workers had indicated that either: (1) the Grant directly overlies the Gage (e.g., Zeller, 1968); or (2) the Grant is not present, and therefore, the Cresswell directly overlies the Gage (e.g., Bass, 1929, and Bayne, 1962, who incorrectly included Grant strata within the Gage in this area). The Grant similarly is not now recognized in northern Oklahoma (Chaplin, 1988, 1994), perhaps because of the earlier opinions of Bass (1929) and Bayne (1962), which were reiterated in Zeller (1968). We believe these assertions are inaccurate because recognition of this non-cherty, Stovall-equivalent section assists in readily identifying and tracing both the Grant and the Gage at least as far south as the Kansas–Oklahoma border (fig. 33). Even where this unit is not present, the Grant is clearly identified by its generally fossiliferous nature, whereas we have found that the Gage is unfossiliferous everywhere we have examined it in south-central Kansas.

We therefore propose to name this section of generally non-cherty limestones the Santa Fe Lake Member and consider it to be a facies of, and correlative with, the cherty Stovall Member of central and northern Kansas (fig. 33). We designate its type locality to be the cutbank exposures of the Gage to Cresswell along Dry Creek in the

NW sec. 18, T. 27 S., R. 4 E., in Butler County, Kansas, to the immediate east of Santa Fe Lake Road (fig. 34). The Cresswell-to-Luta section also is exposed here, along the west side of the road in adjoining sec. 13, T. 27 S., R. 3 E. The creek bed and roadside outcrops compose measured section number 55, which is illustrated graphically in fig. 33. The Santa Fe Lake Member is 3 ft 5 inches (1.1 m) thick here (fig. 34B) and consists of unfossiliferous, thin-bedded to laminated, light-yellow-gray, shaly lime mudstone with calcite-lined vugs (presumed dissolved evaporite nodules). The basal contact with the Gage is sharp and conformable, and the upper contact with the Grant is somewhat gradational. Other localities at which this member is exposed are shown in fig. 33. A particularly good outcrop of it is the field exposure due west of Buffalo Road, in the center of sec. 8, T. 27 S., R. 4 E., Butler County, between Wichita and Augusta, Kansas (our measured section number 59). Ripple-forms are common on bedding planes of the peritidal deposits of the Santa Fe Lake Member at this locality.

Grant Member

The Grant Shale Member was named by Condra and Upp (1931) for exposures 5–6 mi (8–9.7 km) north of Florence, in Grant Township, Marion County; they did not specify a stratotype description in this area. We were unable to locate any decent exposures of the Grant in this heavily grassed area, and therefore, propose to designate a principal reference section for this unit. The nearest outcrop to the type area we have found that exposes the Grant and bounding strata is in a roadcut along Vane Road in the NW sec. 25 and adjoining NE sec. 26, T. 15 S., R. 4 E. in Dickinson County, Kansas, just north of the town of Herington (fig. 35A). This location is our measured section number 104, shown in fig. 35B. The Grant here is 9 ft (2.7 m) thick and sharply and conformably overlies the cherty Stovall. It consists of light-yellow-gray, calcitic mudrock with *Composita* spp., *Derbyia* spp., bryozoans and crinoids, and contains abundant calcite nodules in the upper 2 ft (0.6 m). The contact with the overlying Cresswell is sharp and conformable. Nearby outcrops that

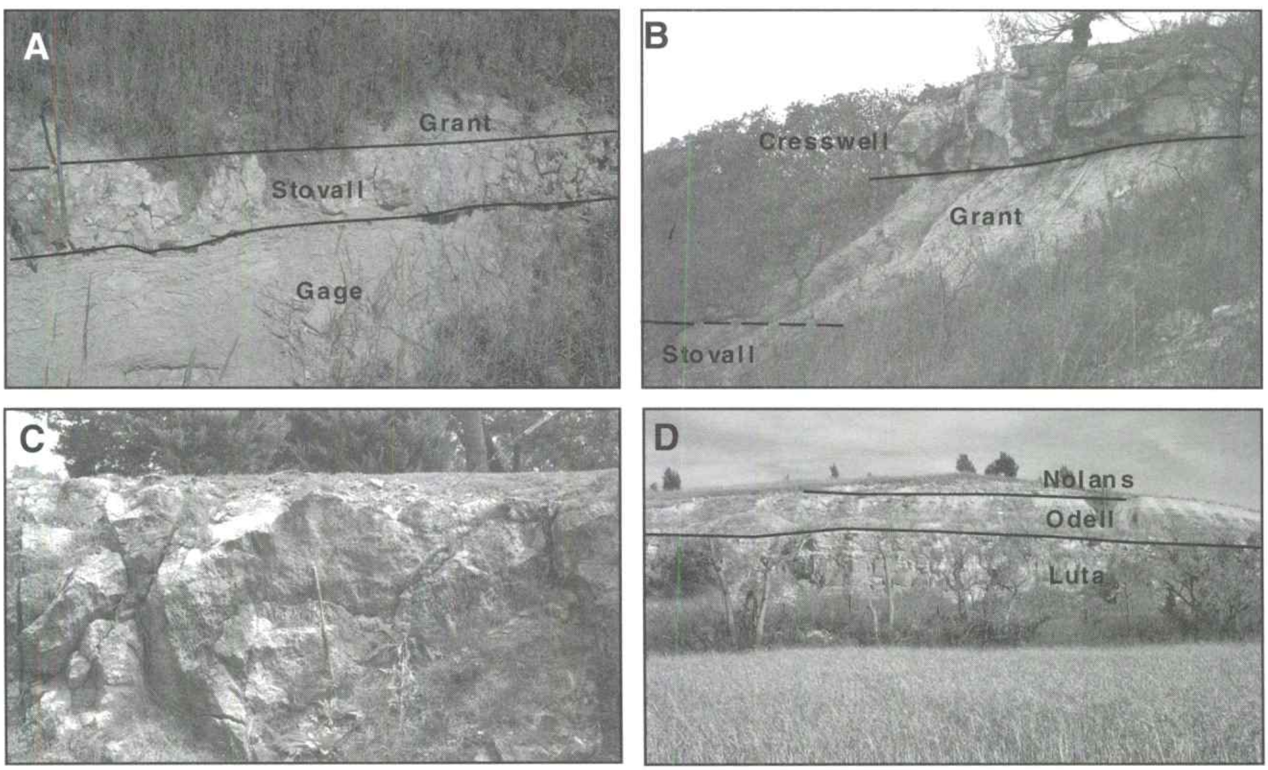


FIGURE 32—A) Typical appearance of the cherty Stovall in the study area: measured section number 100, Morris County, Kansas (the rod is divided into 20-cm segments). The Gage is fossiliferous here. B) The Stovall to Cresswell section at the cutbank along West Branch of Lyon Creek in Dickinson County, Kansas (measured section number 106). A thin section of the Luta is exposed along the crest of the ridge (out of sight in this photograph). For reference to scale, the Grant is 9.5 ft (2.9 m) thick here. C) Roadcut exposure of the Cresswell at measured section number 7 in Cowley County, Kansas (rod is divided into 20-cm segments). The underlying Grant and Stovall, and overlying Luta, were also exposed at the time we measured this section. D) The "crusher quarry," type locality of the Luta in Marion County, Kansas (measured section number 92). For reference to scale, the Odell is 11 ft (3.4 m) thick here.

expose a similar section of Stovall, Grant, and Cresswell strata are the roadcuts along Trail Road in sec. 3, T. 15 S., R. 4 E., and the high cutbank along the West Branch of Lyon Creek in sec. 34, T. 14 S., R. 4 E. (fig. 32B), also in Dickinson County (our measured sections 105 and 106, respectively).

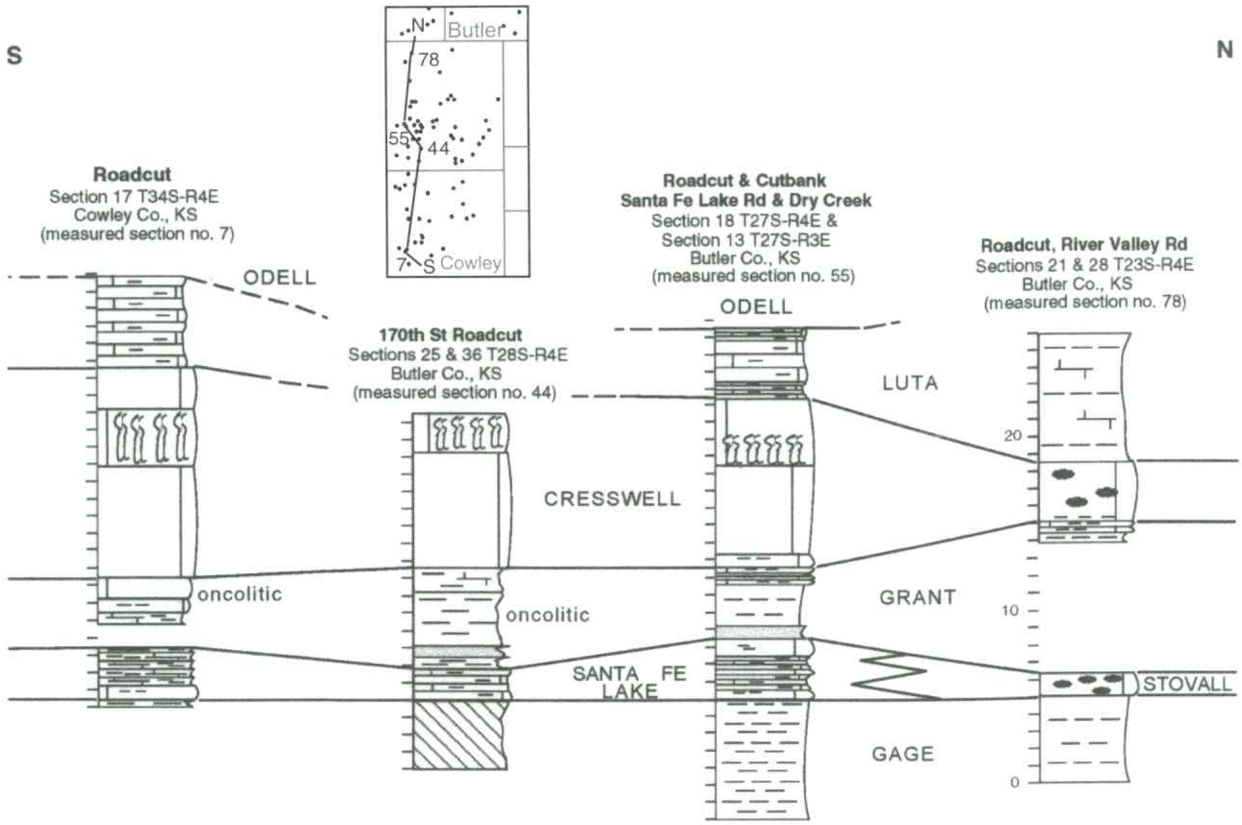


FIGURE 33—Lithostratigraphic cross section showing pinchout in Kansas of the cherty Stovall into correlative, non-cherty limestones of the Santa Fe Lake Member (new name). The exposure along River Valley Road (measured section number 78) is the southernmost occurrence of the cherty Stovall. The measured section at the Santa Fe Lake Road–Dry Creek locality (number 55) is the stratotype of the Santa Fe Lake Member.

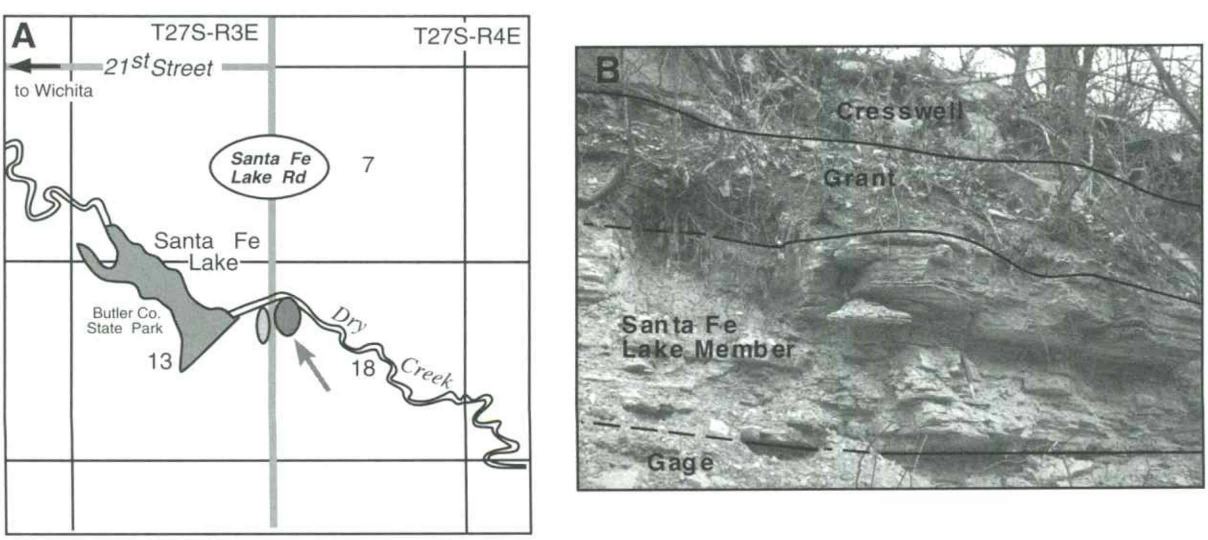


FIGURE 34—A) Type locality of the Santa Fe Lake Member (new name) of the Winfield Limestone in Butler County, Kansas (measured section number 55, which is shown graphically in fig. 33). B) Santa Fe Lake Member and bounding strata along Dry Creek at the type locality of the member; hammer for scale.

Cresswell Member

The Cresswell Member was named by Condra and Upp (1931) for exposures along the east side of the municipal golf course (now the Spring Hill Golf Club), along the railroad tracks, in the SW NE sec. 18, T. 34 S., R. 4 E. in Arkansas City, Cowley County, Kansas; they did not specify a stratotype description for this member here. As so defined, this member did not include beds recognized earlier by Beede (1908) as the Luta. Eleven feet (3.4 m) of Cresswell are well exposed here as massive-bedded, light-yellow, porous, relatively coarse-grained biowackestone to grainstone with silicified fossils (mainly echinoid spines/plates and crinoid fragments). This outcrop can still serve as the type locality for the Cresswell as defined originally by Condra and Upp (1931), and therefore, designation of a principal reference section for this member is not warranted. A description of the Cresswell here appears in our measured section number 8. Basal beds of the overlying Luta are also exposed here, although the basal contact with the Grant is poorly exposed.

A nearby locality at which the Santa Fe Lake and Grant Members, the Cresswell sensu Condra and Upp (1931), and the Luta sensu Beede (1908) are continuously exposed and more readily accessible is the roadcut in the NW sec. 17, T. 34 S., R. 4 E. in Cowley County, which is less than 0.5 mi (0.8 km) to the east of the Cresswell type locality. This locality is our measured section number 7, which is shown in figs. 32C and 33. The mostly thick-bedded Cresswell here is 12 ft 2 inches (3.7 m) thick, and sharply and conformably overlies about 4 ft (1.2 m) of Grant. The exposed 8 inches (20.3 cm) of yellow-orange mudrock with lenses of shaly lime mudstone in the middle of the Grant are overlain by 10 inches (25.4 cm) of shaly biopackstone with conspicuous large oncolites. This bed is overlain by a 1 ft 2 inches·(0.3 m) of very light gray biowackestone, also with large oncolites. Because we have recognized similar beds with conspicuous large oncolites in the upper Grant north of here, in northern Cowley and southern Butler counties, we have included these limestones within the upper Grant (fig. 33). This correlation is further discussed in the second part of this paper.

The basal 6 ft 4 inches (1.9 m) of the Cresswell here compose a single bed of light-yellow, porous limestone that rapidly coarsens upward from biowackestone to oncolitic biopackstone and grainstone. The overlying 3 ft 4 inches (1-m) bed is porous biograinstone, with prominent vertical burrows (figs. 32C, 33) which, in turn, is succeeded by a 2.5-ft (0.8-m)-thick bed of slightly porous, oncolitic biopackstone. Oncolites in the Cresswell are consistently much smaller than in the upper Grant. Fossils in the Cresswell include bryozoans, foraminifers, crinoids, gastropods, *Derbyia* spp., and pelecypod fragments. The Cresswell is conformably and somewhat gradationally overlain by 5 ft 4 inches (1.6 m) of thin-bedded lime

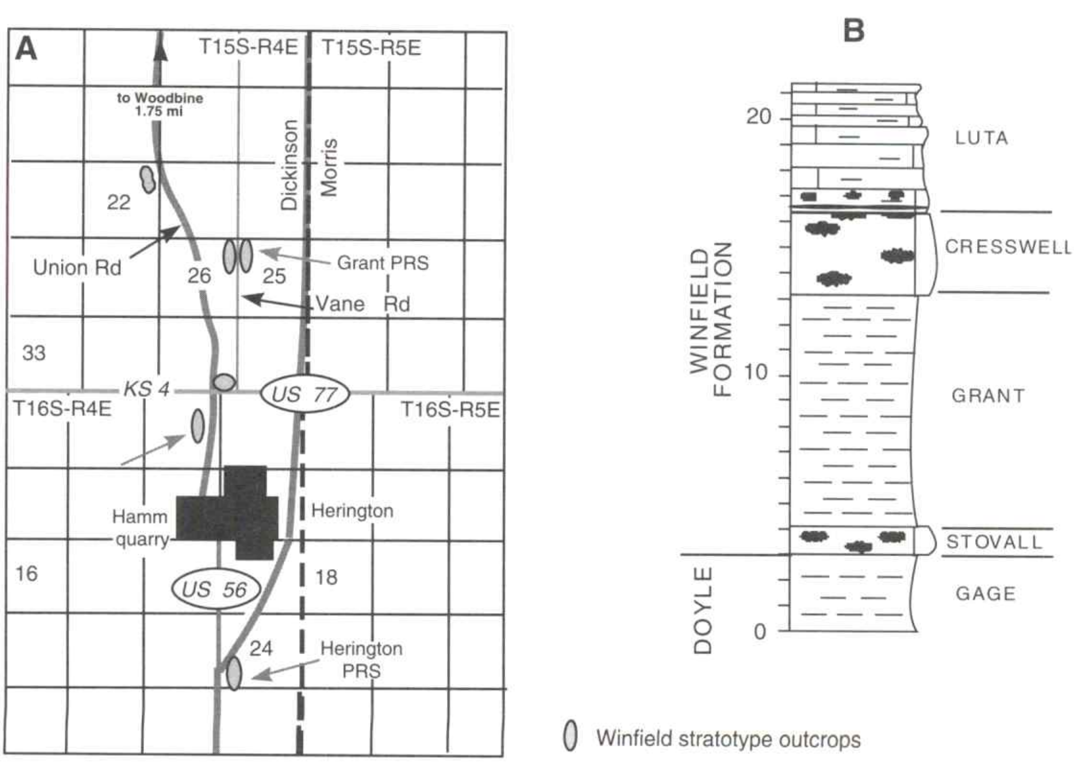


FIGURE 35—A) Locations of principal reference sections of the Grant Member of the Winfield Limestone, of the entire Winfield Limestone, and also, of the Herington Member of the Nolans Limestone, all in Dickinson County, Kansas. B) Lithostratigraphy of the Grant Member at its principal reference section (measured section number 104).

mudstone to biowackestone assigned to the Luta (discussed below).

Luta Member

The Luta Limestone was named by Beede (1908), who formally described it from exposures in the "crusher quarry" about 5 mi (8 km) northeast of the town of Marion, along the Chicago, Rock Island & Pacific Railroad, in Marion County, Kansas. This locality, our measured section number 92, is the now-abandoned quarry due west of US–77, in the NW sec. 15, T. 19 S., R. 4 E. (figs. 32D, 36). Uppermost Cresswell (sensu Condra and Upp, 1931) through lower Herington strata are well exposed in the quarry, which therefore can still serve as the type locality of the Luta without the need of designating a principal reference section. According to Beede (1908), the Luta here is 30 ft (9.2 m) thick, which was considered by Condra and Upp (1931) to be somewhat excessive, although they did not offer an alternative thickness for it. Instead of being limestone, however, as so described by Beede (1908), the Luta here is entirely dolomitic.

At the quarry a few inches of poorly exposed, cherty, light-gray lime mudstone are overlain by a 1-ft (0.3-m)-thick bed of light-yellow, relatively coarse-grained, "rough" biopackstone (with *Derbyia* spp., crinoids, and echinoid fragments) with large, oval, black chert nodules that weather brown (the "sand bricks" of Prosser, 1895). That these strata are within the upper Cresswell is confirmed by lithologic similarity and correlation to other outcrops of the Cresswell in the area (fig. 36). By our measurements, the overlying Luta at this location is 30.5 ft (9.3 m) thick, which confirms Beede's (1908) thickness estimate. The basal 4 ft (1.2 m) of the Luta are medium-bedded, white to yellow-orange dolomudstone with some golf-ball-size nodules composed of mixtures of anhydrite, calcite, and quartz; and then, 1 ft 8 inches (0.5 m) of medium-bedded, white, dolomudstone to dolobiowackestone (crinoidal) with discontinuous layers of small, black chert nodules. A similar Cresswell-to-basal Luta stratigra-

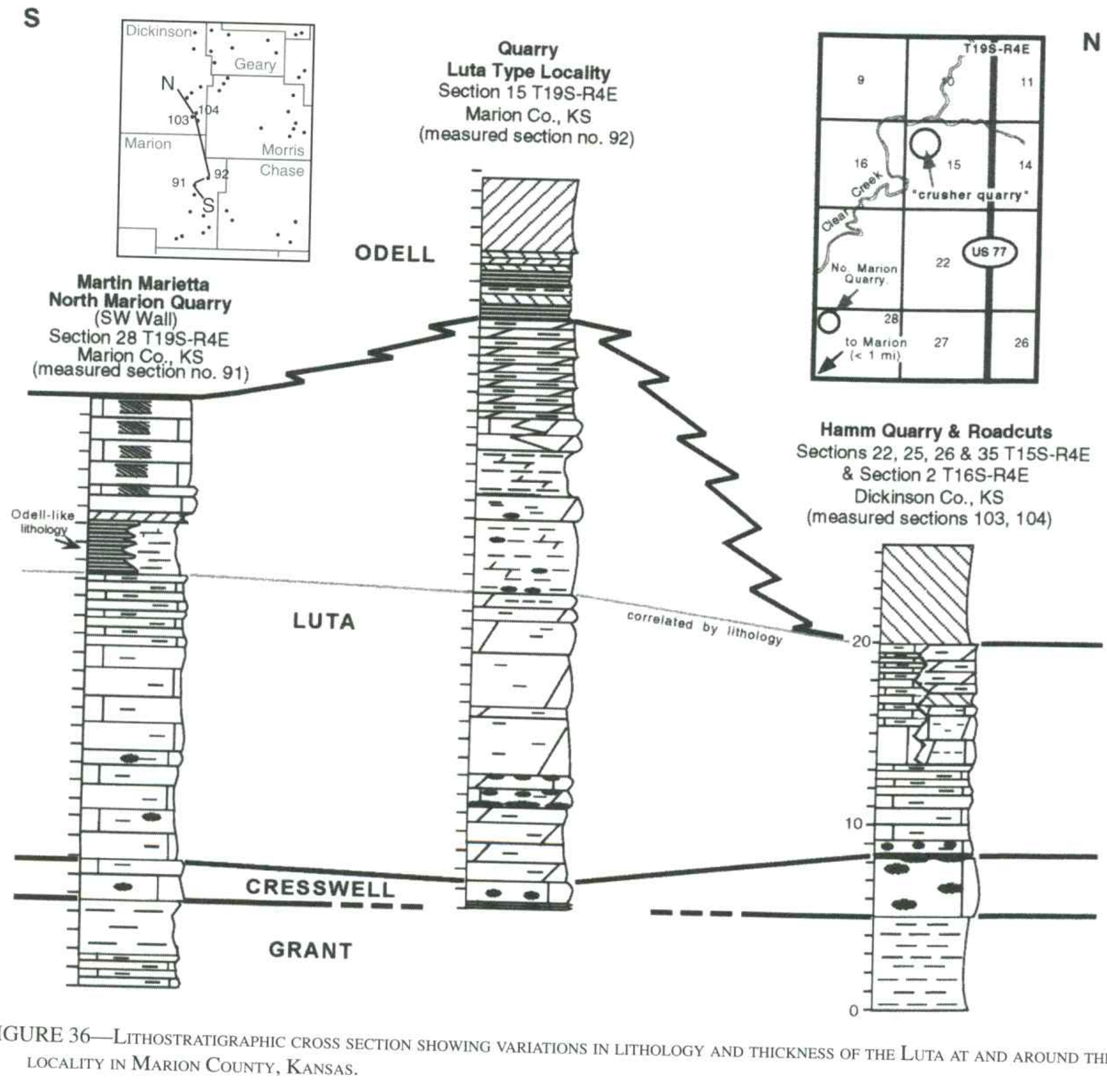


FIGURE 36—Lithostratigraphic cross section showing variations in lithology and thickness of the Luta at and around the type locality in Marion County, Kansas.

phy is exposed in several roadcuts north of the town of Herington in Dickinson County (e.g., at measured sections 104 [shown in fig. 36] and 106), and at a roadcut along US–77 in southwestern Morris County (in sec. 29, T. 14 S., R. 5 E., illustrated in fig. 84). The succeeding section is 9 ft (2.7 m) of mostly thick-bedded, unfossiliferous, white to very light yellow-gray dolomudstone, also with some anhydrite-calcite-quartz nodules, and vugs resulting from their dissolution. The overlying 8 ft 5 inches (2.6 m) consist mostly of white and light-yellow, dolomitic mudrock, and beds of dolomudstone, with some chert nodules and abundant nodules of anhydrite, calcite, and quartz. Although generally unfossiliferous, the top few inches of this unit contain abundant coiled gastropods, ammonites (identified by Darwin Boardman as *Artinskia* spp. and *Properrinites* spp.), gastropods, *Allorisma* spp., and *Aviculopecten* spp. This unit is capped by a 1 ft 10 inches (0.6-m)-thick lense of medium-bedded, white, porous, dolomitic biopackstone, with casts and molds of gastropods and pelecypods, that passes laterally (southward) along the west-facing quarry wall to unfossiliferous dolomudstone. The upper 5.5 ft (1.7 m) of the Luta are unfossiliferous, thin-bedded, locally cherty (small nodules at the base), shaly, white dolomudstone with scattered anhydrite-calcite-quartz nodules and vugs resulting from their dissolution. The Luta is overlain, somewhat gradationally, by green, green-gray, and red shales and mudrocks of the Odell Shale (fig. 36), which is anomalously thin at the expense of the thickened Luta section here (fig. 32D).

Proposed Inclusion of the Luta within the Winfield Limestone

Since 1944 (Moore et al., 1944), strata formerly referred to as the Luta have been included within the Cresswell Member (except for Moore, 1964) by the Kansas Geological Survey (e.g., Zeller, 1968) without the name Luta having been formally abandoned. Prior to then, after it was removed from the Marion Formation, the Luta was recognized to be the upper member of the Winfield Limestone in Kansas, at least for a short period of time (Moore et al., 1934; Moore, 1936). We (Mazzullo and Teal, 1994; Mazzullo et al., 1995, 1996) once again recognized the Luta to be a separate, mappable lithologic unit distinct from the Cresswell in our regional studies in Kansas. We now formally propose that the name Luta, as originally defined by Beede (1908), be retained as the upper member of the Winfield Limestone, in reference to the relatively thick and well-exposed section of thin-bedded carbonates above the Cresswell sensu Condra and Upp (1931) and below the Odell Shale. Both the Cresswell and Luta, as we recognize them in this paper, were previously described formally (Condra and Upp, 1931, and Beede, 1908, respectively) from well-exposed outcrops that are still accessible, and therefore, principal reference sections are not warranted for either unit. Insofar as the Luta is mostly dolomite in central and northern Kansas and in Nebraska, and limestone in south-central Kansas, it should properly be referred to as the Luta Member rather than as the Luta Limestone as suggested by Beede (1908).

We believe that the Luta is a natural stratigraphic unit that warrants member status once again, separate from the Cresswell, for the following reasons. First, not only is it lithologically distinct from the Cresswell, but it also carries a different biota (e.g., Boos, 1929; Condra and Upp, 1931). Throughout most of the study area the Cresswell, disregarding thickness and local facies changes, is a massive-bedded, commonly porous limestone (fig. 32C) with silicified foraminifers, *Derbyia* spp., echinoid fragments, and in south-central Kansas, oncolites (Mazzullo and Teal, 1994; Mazzullo et al., 1995). In contrast, the Luta in south-central Kansas is thin-bedded and shaly limestone (fig. 32D), and where fossiliferous (e.g., in northern Oklahoma and in Cowley, Sumner, Butler, and parts of Marion, Dickinson, and Morris counties), it includes a biota dominated by *Composita* spp. (Mazzullo et al., 1995) and accessory other brachiopods, mollusks, echinoderm spines and plates, crinoids, bryozoans, gastropods, and locally, corals (Boos, 1929). In central to northern Kansas and Nebraska, the Luta is mainly medium-bedded dolomite, with some shales, and evaporite nodules. Second, as was indicated in our earlier studies (Mazzullo and Teal, 1994; Mazzullo et al., 1995, 1996), we can separately trace and map the Luta, with its various changes in thickness, lithology and biota, across Kansas and into Nebraska. These regional relationships, and those discussed in the next paragraph, are fully documented in the second part of this paper.

With regard to its stratigraphic assignment, Condra and Upp (1931) stated (p. 58): "Whether the Luta should be correlated with the Winfield or with the Marion [now, the Odell] has not been determined to the full satisfaction of all geologists concerned, nor is it agreed that the member is not a zone of the Cresswell limestone." However, they then suggested (p. 58–59) that, in Nebraska, the Luta may be unrecognized because it has changed facies to Odell-like lithologic aspect. In many places the Luta–Odell contact in fact is gradational, although in other areas it is sharply defined. In northern Oklahoma, and in southern Cowley County at the Spring Hill Municipal Golf Course in Arkansas City (our measured section number 8), for example, the upper Luta may interfinger with the basal Odell (e.g., Chaplin, 1988; Mazzullo et al., 1995). At the type locality quarry in Marion County, the Luta–Odell contact is sharp (fig. 36). At the Martin Marietta North Marion quarry in Marion, Kansas (fig. 36), however, the upper 6 ft (1.8 m) of the Luta overlie 3 ft 4 inches (1 m) of shale of Odell-like lithology, a relationship that suggests local interfingering of the Odell and Luta. Similar interfingering may occur in Kay County, Oklahoma, where a zone of *Composita*-rich, shaly limestones occurs within the Enterprise–Odell section (e.g., shown in Chaplin, 1994). On the other hand, although the Cresswell–Luta contact typically is sharp, at some localities the basal Luta appears to interfinger with the upper Cresswell (e.g., see our measured section number 128, which is near the town of Walsburg in Riley County). Hence, depending on location, the Luta variously appears to be a facies of both the Cresswell and the Odell. Condra and Upp's (1931) apparent indecision concerning the stratigraphic relationships among the Cresswell, Luta, and Odell are the result of the real stratigraphic complexity of this interval.

We contend, however, that the dominant carbonate mineralogy of the Luta, and its marine to peritidal facies, contrast sharply with the terrestrial red and green shales and mudrocks of the overlying Odell. In fact, despite their earlier comments, which are quoted above, Condra and Upp (1931) went on to state (p. 58): "It seems, however, that it [the Luta] was developed in the cycle which produced the Cresswell, in which the deposition changed from lime to lime and shale, becoming more shaly at the top as a transition to the lower zones of the Odell." We agree with this statement and for this reason, and because of its dominant carbonate mineralogy, we contend that the Luta belongs within the Winfield Limestone rather than in the overlying Odell Shale. We consistently pick the top of the Luta at the highest occurrence of carbonate beds in the section; we have not observed any carbonate strata, fossiliferous or otherwise, in the lower Odell anywhere in the study area. The base of the Luta is readily picked at most outcrops at the top of the massive-bedded, porous and typically oncolitic (in south-central Kansas) or dense and cherty (in central and northern Kansas), light-yellow to yellow-brown limestones of the Cresswell. The only locality at which placement of the Luta–Cresswell contact is complicated because of interbedding of contrasting lithologies is the roadcut north of Walsburg, in sec. 31, T. 7 S., R. 6 E. in Riley County, Kansas (measured section number 128). Regional stratigraphic relationships among the Cresswell, Luta, and Odell are discussed and illustrated later in this paper.

Principal Reference Section of the Winfield Limestone

The choice of a principal reference section for the Winfield Limestone as we recognize it is difficult because of the many facies and thickness changes that occur within it across Kansas and into Nebraska, and the fact that exposures of the entire formation, with bounding contacts, are not very common. We designate the following closely spaced exposures in Dickinson County, Kansas, just north of the town of Herington, as its principal reference section (fig. 35A): (1) roadcuts along Union Road in sec. 22, T. 15 S., R. 4 E. [expose the Cresswell and Luta]; (2) roadcuts along Vane Road in adjoining secs. 25 and 26, T. 15 S., R. 4 E. [expose the upper Gage, Stovall, Grant, and Cresswell]; (3) roadcuts along K–4 in sec. 35, T. 15 S., R. 4 E. [expose the Cresswell and Luta]. These three localities compose our measured section number 104 (shown in fig. 35B), which also includes the previously described principal reference section of the Grant Member of the Winfield Limestone; and (4) the Hamm Sand and Gravel quarry in sec. 2, T. 16 S., R. 4 E. (measured section 103) [exposes the Luta, Odell, and basal Nolans (shown in fig. 36)].

The Stovall along Vane Road is a 1-ft (0.3-m)-thick bed of yellow-gray, cherty lime mudstone to biowackestone with crinoids and brachiopod fragments. It sharply overlies about 3 ft (0.9 m) of fossiliferous, greenish-yellow-brown shale and mudrock in the Gage Member of the Doyle Shale. The Grant along Vane Road is 9 ft (2.7 m) of fossiliferous, yellow-gray shale and mudrock with *Composita*, *Derbyia*, fenestrate bryozoans, and crinoids; it contains abundant calcite nodules in the upper 2 ft (0.6 m). The Cresswell at all three roadcuts is a 3 ft 2 inches (0.9-m)-thick bed of light-yellow, crudely layered and bioturbated, lime mudstone and biowackestone with scattered dark-gray chert nodules. Fossils include crinoids, ramose bryozoans, *Derbyia*, *Composita*, echinoid fragments, and high-spired gastropods; many of these fossils are silicified. The total thickness of the Luta in this area is about 11.6 ft (3.5 m) as compiled from the roadcuts along K–4 and exposures in the nearby Hamm quarry (fig. 36). The basal 5 ft (1.5 m) are medium- up to thin-bedded, light-gray, shaly lime mudstones and some thin lenses of biowackestone, with scattered small chert nodules and upward-decreasing amounts of *Derbyia*, *Composita*, *Permophorus*, crinoids, and echinoid fragments. The overlying section is thin- to medium-bedded, shaly lime mudstone that grades up to shaly dolomudstone, both with presumed cyanobacterial laminations, nodules of anhydrite-calcite-quartz, and toward the top, desiccation cracks. The upper contact with the Odell Shale is sharp. Total thickness of the Winfield Limestone in this area is about 25 ft (7.6 m).

Odell Shale

History of Terminology

Marion Formation—The Marion Formation was named by Prosser (1895) to include what is now recognized as the Odell and Nolans formations (figs. 3, 4). Beede (1908) elevated the Marion Formation to stage status and included in it, in ascending order, the Luta Limestone, Enterprise Shale, and Herington Limestone (fig. 4). Condra and Upp (1931) later redefined the Marion Formation to include the Enterprise Shale (which was subdivided into the Odell Shale, Krider Limestone, and Paddock Shale) and overlying Herington Limestone. Where present in Kansas, they assigned the Luta as the basal unit of the Odell (fig. 4). The names Marion Formation and Enterprise Shale were abandoned in Kansas (Moore et al., 1934; Moore, 1936) in favor of current terminology (fig. 3). In northern Oklahoma, however, the Odell of Kansas usage is referred to as the Enterprise–Odell Shale (e.g., Chaplin, 1988, 1994). Revision of the stratigraphic assignment of the Luta was discussed above.

Odell Shale—The Odell Formation was named by Condra and Upp (1931) from exposures in ravines and roadcuts along highway N–8, southeast of the town of Odell in Gage County, Nebraska, the specific locations of which are the S/2 sec. 16 and W/2 sec. 21, T. 1 N., R. 6 E. (fig. 37A). Roadcuts along N–8 that expose the Odell are no longer present here, and ravine exposures are relatively poor, with bounding contacts covered. Instead of describing the Odell from these exposures, however, Condra and Upp (1931) described it from the roadcut exposures immediately south of the nearby railroad siding at Krider, Nebraska (fig. 37A). This location is our measured section number 152, which is along N–112, 0.3–0.45 mi (0.5–0.7 km) south of Krider in the E/2 sec. 9 and the W/2 sec. 10, T. 1 N., R. 6 E. (figs. 37, 38A). They indicated that, at the time, the Odell here was in contact with both the Winfield and Krider, and stated that the Odell is about 30 ft (9.2 m) of unfossiliferous gray, green, and red shales. We measured only about 20 ft (6.1 m) of exposed Odell beneath the Nolans here (fig. 37B), and could not find outcrop of the basal Odell and its contact with the Winfield.

We were unable to locate outcrops of the entire Odell anywhere in southeastern Nebraska where it was in contact with both overlying and underlying units. The outcrop nearest to the type locality where the Odell is in contact with both the Nolans and Winfield is the roadcut and adjoining field exposure north of the town of Hanover, in the NW SE sec. 5, T. 2 S., R. 5 E., in Washington County, Kansas (our measured section number 144). The Odell here is about 21 ft (6.4 m) thick, but it is very poorly exposed. Furthermore, the basal contact with the Winfield, which is exposed only as a low cut along the shoulder of the road, most likely will eventually be obscured by weathering or road work. Several other outcrops of the Odell occur in the area around Hanover, but generally, they expose only the lower or the upper beds of the formation, and we have not been able to correlate these exposures with certainty so as to define a composite reference section for this unit here. About 20 ft of the Odell are exposed at an unmeasured roadcut in the E/2 sec. 9, T. 5 S., R. 5 E. in Washington County, Kansas, about 6 mi (9.7 km) south of the town of Barnes. However, basal beds of the Odell and the contact with the Winfield are poorly exposed and complicated by faulting here. Several incomplete outcrops expose the Odell farther to the south, the nearest one to the type locality being the roadcut in the S/2 sec. 17 and the N/2 sec. 20, T. 12 S., R. 4 E. in northern Dickinson County, Kansas (our measured section number 109). The outcrops on the bluffs beneath the Spring Hill Golf Course in Arkansas City, Cowley County, Kansas (measured section number 8) expose the entire Odell section, where it is 30 ft 4 inches (9.2 m) thick. This locality is far to the south of the original type locality, and facies changes have occurred in the upper part of the formation that are not represented farther to the north in Kansas and Nebraska.

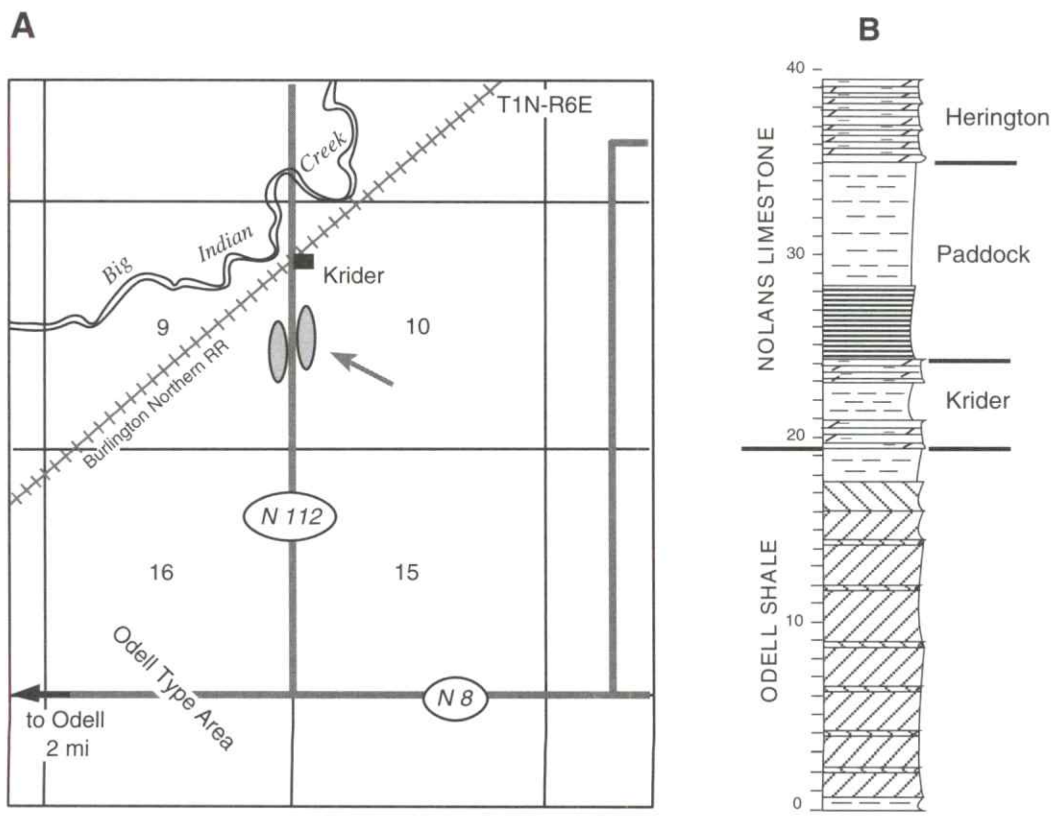


FIGURE 37—A) Condra and Upp's (1931) type localities of the Odell Shale and of the Krider and Paddock Members (of the then-Enterprise Shale) in Gage County, Nebraska. B) Lithostratigraphy of the Odell through lower Herington at this locality (our measured section number 152).

Because of the paucity of good outcrops, then, the roadcuts in secs. 9 and 10, south of Krider, in Gage County (fig. 37), will serve as the principal reference section for the Odell because they are close to the type area, they expose at least the upper two-thirds of representative lithologies in the formation, and the upper contact with the Nolans is clearly defined (figs. 37B, 38A). Except for the top few feet of section, which are light-colored (unfossiliferous) shale, the exposed Odell here is interbedded, unfossiliferous, red and green mudrocks and shales.

Nolans Limestone

History of Terminology

The Nolans Limestone was named by Moore et al. (1934), and subsequently recognized by Moore (1936), Moore et al. (1944), and in later studies in Kansas (e.g., Zeller, 1968). Moore and Elias (no date, open-file report, p. 146) stated that the formation was named after the town of Nolans, in Washington County, Kansas, and that the type locality was the ". . . exposures about 1 mile northwest of Hanover, Washington County, which is 2.5 miles east of Nolans." As far as we are aware, other than the sketchy descriptions in Moore and Elias (no date, open-file report), the formation has not been formally described.

Several closely spaced roadcuts in sec. 31, T. 1 S., R. 5 E. in Washington County, north of the town of Hanover (fig. 39A), appear to be the type locality, or at least within the type area of the Nolans, as indicated by Moore and Elias. Two of these outcrops, which are the best exposures of the Nolans in this area, compose our measured section numbers 145 and 146 (figs. 38B,C, and 39B). Although the sharp and conformable basal contact of the Nolans with the Odell is exposed in this general area (fig. 38B), the upper contact between the Herington Member and the overlying Wellington Formation is not exposed. The total thickness of the Nolans in this general area, however, based on our mapping and discussion below, is about 25 ft (7.6 m)(fig. 39B).

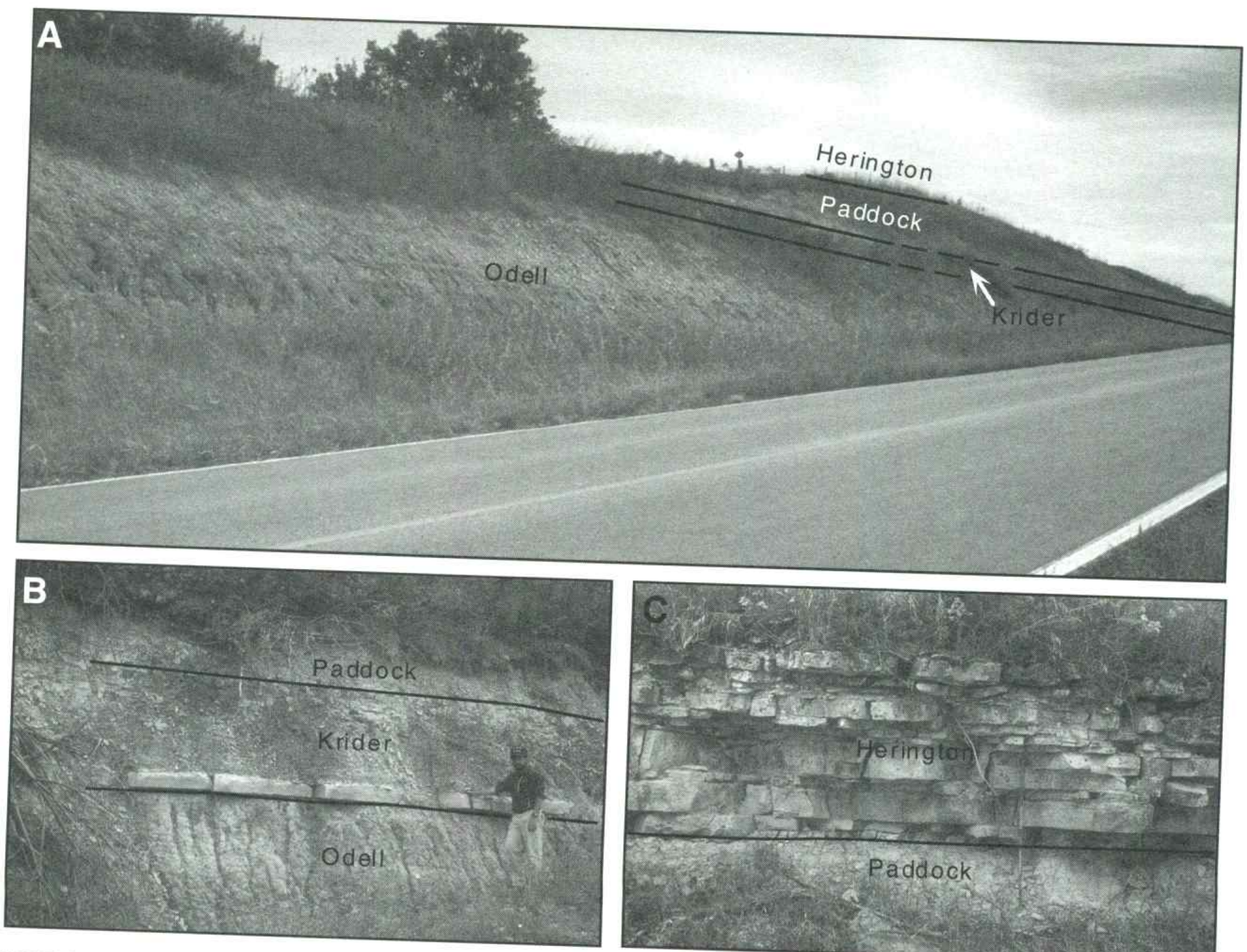


FIGURE 38—A) Odell to Herington outcrops along N–112 in Gage County (measured section number 152). This roadcut is Condra and Upp's (1931) type locality of the Krider and Paddock, and is where they described the Odell. B) The upper Odell to basal Paddock section along the road in sec. 31, T. 1 S., R. 5 E. north of Hanover in Washington County, Kansas (near measured section number 145). The upper carbonate in the Krider is obscured by weathering. C) The upper Paddock and Herington along the road at measured section number 146 north of Hanover in Washington County, Kansas; the rod is divided into 20-cm segments.

The Krider here is 5.5 ft (1.7 m) thick and consists of two units of thin-bedded, yellow-orange, shaly dolomudstone separated by dark-gray to yellow-orange mudrock. Casts of pectinids, and rare specimens of *Aviculopecten* spp. and *Septimyalina* spp. occur in these beds at this location, but these fossils locally are more abundant at other outcrops in this area. The contact with the Paddock is somewhat gradational over a thickness of a few inches. The Paddock is 9.5 ft (2.9 m) thick and consists of sparsely fossiliferous mudrocks and shales, with rare bryozoans and casts of pectinids. The rocks are dark gray to yellow in the lower half (where the fossils occur), and mottled light brown and yellow (and unfossiliferous) in the upper half. The contact with the Herington is sharp and conformable. Only 7.5 ft (2.3 m) of Herington are exposed here and consist of thin-bedded, yellow, shaly dolomudstone (fig. 38C) with golf-ball-size vugs (presumably dissolved evaporite nodules). A thin (few-mm) shale near the base contains ostracodes, and laminae and thin layers of biowackestone to packstone in the basal 1 ft 4 inches (0.4 m) of the section contain *Permophorus* spp., *Bellerophon* spp., *Myalina* spp., and *Aviculopecten* spp. A total of 10 ft (3.1 m) of Herington are exposed at a nearby roadcut along K–148, 2.2 mi (3.5 km) south of the intersection of K–148 and US–36, in the NW NW sec. 10, T. 3 S., R. 5 E., in Washington County. The contact with the Wellington is not exposed at this locality, but the Wellington is exposed in the surrounding hills. Hence, 10 ft (3.1 m) appears to be the maximum thickness of the Herington in this area of Kansas. The top 2.5 ft (0.8 m) of strata here have been added to the 7.5 ft (2.3 m) of exposed section in sec. 31, T. 1 S., R. 5 E. so as to produce the composite thickness of the Herington shown in fig. 39B.

Krider and Paddock Members

The Krider and Paddock were named and formally described by Condra and Upp (1931 [their measured section number 24]) from roadcut exposures immediately south of the Krider railroad siding in Gage County, Nebraska, the same locality at which they described the Odell (fig. 37A). This locality is our measured section number 152 (fig. 37B), at which the units are fairly well exposed. Accordingly, designation of a principal reference section is not warranted. Condra and Upp (1931) described the Krider here as being 6 ft (1.8 m) thick, and consisting of two limestones (each 1.5 ft thick [0.5 m]) separated by 3 ft (0.9 m) of shale. At this same locality, however, we measured only 4 ft 10 inches (1.5 m) of Krider and noted

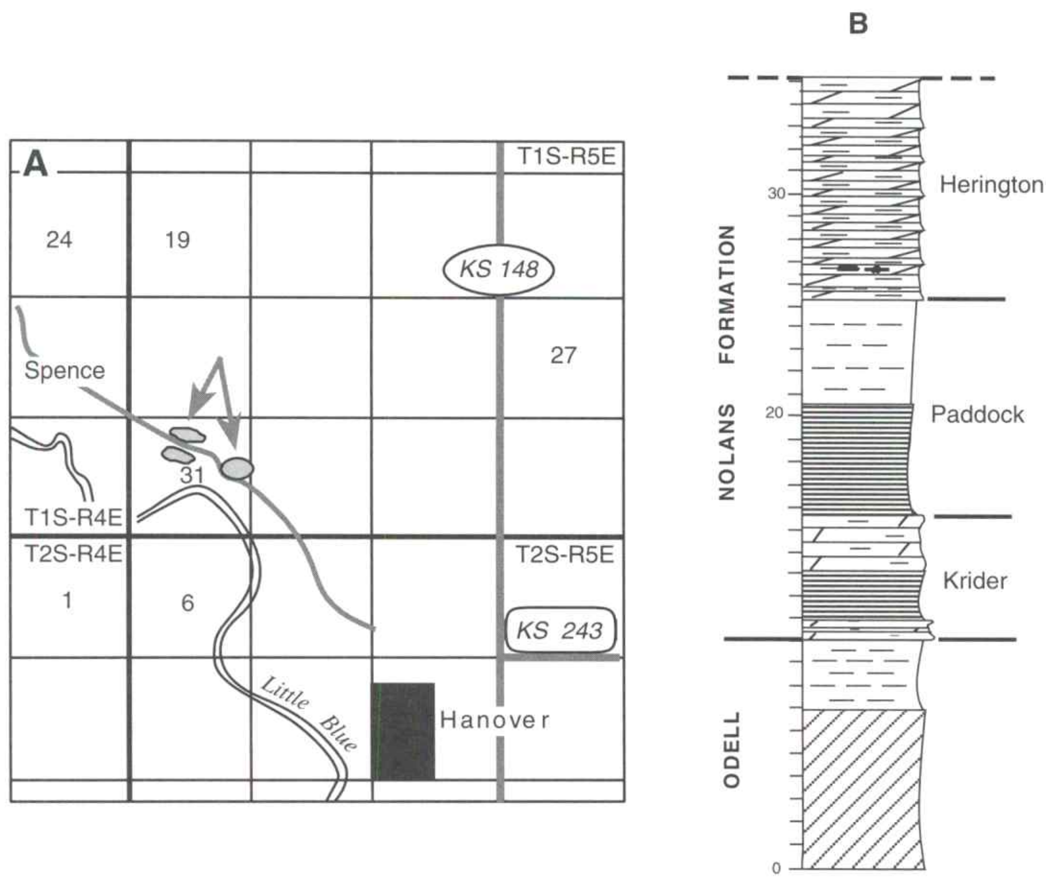


FIGURE 39—A) Location of principal reference section of the Nolans Limestone in Washington County, Kansas. B) Lithostratigraphy of the upper Odell and Nolans here. An additional 2.5 ft of Herington (shown in this diagram) that are not exposed in sec. 31 are exposed at a roadcut along K–148 in the NW sec. 10, T. 3 S., R. 5 E. in Washington County, south of Hanover; together, these localities are our measured section numbers 145 and 146.

that the carbonates in the section were thin-bedded, shaly dolomudstones rather than limestones (figs. 37B, 38A), with some lingulids, *Myalina* spp. and *Aviculopecten* spp., and casts of pelecypods. Farther south, in central and southern Kansas, the Krider instead is limestone. Hence, we refer to this member as the Krider Member rather than as the Krider Limestone. The Paddock here is 11 ft (3.4 m) of badly weathered mudrock and shale rather than 14 ft 2 inches (4.3 m) as reported by Condra and Upp (1931). The basal 4 ft (1.2 m) are splotchy medium gray and yellow with some pectinid casts, whereas the upper 7 ft (2.1 m) are yellow and apparently unfossiliferous. Only 4 ft (1.2 m) of poorly exposed and badly weathered Herington are now exposed at this locality (Condra and Upp reported 6 ft exposed [1.8 m]), and consist of thin-bedded, unfossiliferous, yellow, shaly dolomudstone with calcite-lined dissolution vugs (presumably dissolved evaporite nodules).

Herington Member

The Herington Member was named by Beede (1908), but the specific location of his type locality for the unit is unclear. Several workers (e.g., Jewett, 1941; Chaplin, 1988) suggested that it is around the town of Herington, in Dickinson County, from which the unit logically must have been named. In his paper, however, Beede (1908, p. 255) described the section from ". . . the McCarty place, two miles northwest of Marion, Kan." (in Marion County), and did not specifically designate or otherwise mention a type locality by the town of Herington or anywhere else. We located the old McCarty place, where the Herington is very poorly exposed in a shallow, mostly filled quarry directly east of Marion County Road 853, in the SW sec. 30, T. 19 S., R. 4 E. The lower Herington is also exposed less than 1 mi (1.6 km) to the north, along an unmeasured roadcut in the SE sec. 24, T. 19 S., R. 3 E. If the McCarty place was Beede's type locality, then it is no longer a suitable reference section for the Herington.

The Herington is fairly well exposed at many localities around the town of Herington, and it is likely, but not absolutely certain, that Beede (1908) did name it for exposures in this area. We therefore propose to designate a principal reference section for the Herington to be the roadcut along the east side of US–77, in the SW sec. 24, T. 16 S., R. 4 E., Dickinson County, Kansas (fig. 35A), which is our measured section number 102 (fig. 40). The Herington here sharply and conformably overlies the Paddock, and 8 ft 8 inches (2.6 m) are exposed; the contact with the overlying Wellington is not exposed. This thickness, however, likely is close to the maximum thickness of the Herington in this area as suggested by regional mapping. The basal 4 ft 2 inches (1.3 m) is thin-bedded, unfossiliferous, light-yellow, shaly dolomudstone, and toward the top, thin layers of dolomitic mudrock, both with scattered golf-ball-size dissolution vugs (presumed dissolved evaporite nodules). The overlying 1 ft 4 inches (0.4 m) consist of thin interbeds of yellow dolomitic mudrock, shaly dolomudstone with large vugs, and porous dolobiopackstone, the latter with molds and casts of pelecypods and coiled gastropods. This skeletal-rich unit is better developed in the other outcrops to the immediate north, along the west side of the road. As illustrated later, we have traced this fossiliferous zone across most of central and southern Kansas. The upper 3 ft 2 inches (1.0 m) consist of thin-bedded, unfossiliferous, yellow, shaly dolomudstone and dolomitic mudrock. Where we have seen the Herington–Wellington contact at other localities, it varies from sharp to gradational (Mazzullo and Teal, 1994). Except for in southern Cowley County, the Herington everywhere else that we have examined it is dolomite rather than limestone. Hence, we refer to this unit as the Herington Member, or the Herington Dolomite Member.

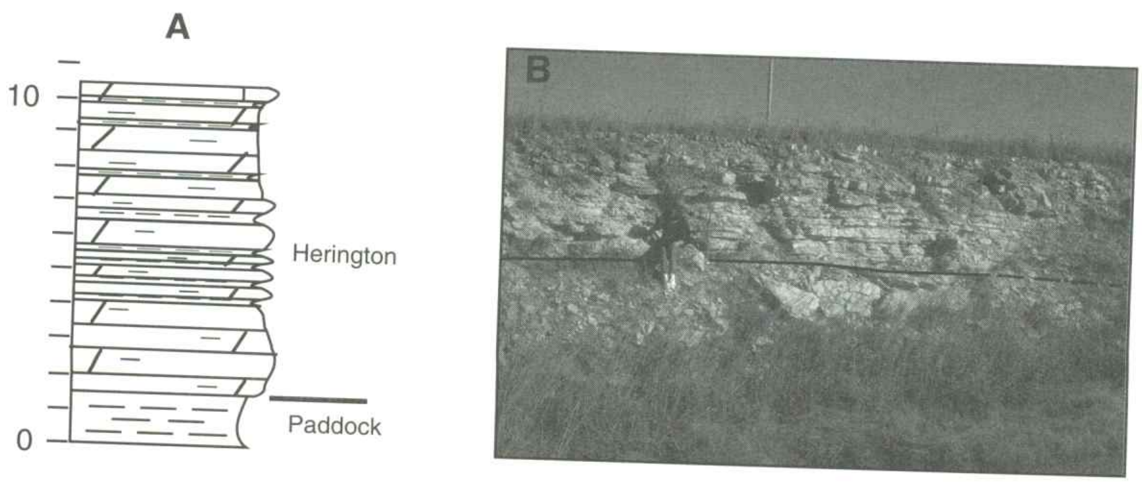


FIGURE 40—A) Lithostratigraphy of the Herington at the principal reference section in Dickinson County, Kansas (measured section number 102, sec. 24, T. 16 S., R. 4 E.). B) Roadcut of the upper Paddock and Herington at this locality, east side of US–77.

Regional Stratigraphy and Depositional Facies

In this part of the paper we discuss regional aspects of the stratigraphy, thickness, and depositional facies of each of the formations and component members of the Chase Group. The lithologic legend shown in fig. 6 pertains to the various cross sections that follow, although additional symbols for specific sedimentary, diagenetic, and biotic attributes have been added to ensuing illustrations. Packstones and grainstones are collectively referred to in the following discussions as carbonate sands, and are highlighted in blue in cross section figures; micritic carbonates refer to lime mudstones and biowackestones.

Discussions of the source of siliciclastics, directions of transgressions, and thickness trends refer to present-day geographic coordinates. Paleogeographic reconstructions (Scotese and McKerrow, 1990; Golonka et al., 1994) place the study area slightly north of the paleoequator during deposition of the Chase Group, with North America rotated clockwise with respect to its present position. At that time, potential source areas for siliciclastics would have included the Appalachian–Ouachita mountains trend and the Wichita Mountains to the east-southeast and south, the craton to the north, and Rocky Mountain uplifts to the west (Rascoe and Adler, 1983).

Structural and Sedimentologic Framework

Outcrops of the Chase Group directly overlie the buried Nemaha Ridge and immediately adjacent areas along the edges of the Central Nebraska, Forest City, Salina, and Sedgwick basins (figs. 1, 41). The Nemaha Ridge is a structural feature that was uplifted during the Late Mississippian to Early Pennsylvanian (Merriam, 1963). Its core of Precambrian crystalline rocks is overlain by strata of Cambrian to Early Permian age, although lower Paleozoic strata are absent locally on higher parts of the structure (Merriam, 1963). The Nemaha Ridge is within a few hundred feet of the surface and is quite wide in northern Kansas and southeastern Nebraska, and is progressively more deeply buried and becomes narrower in southern Kansas, where the top of the Precambrian is 3,500–4,000 ft (1,068–1,220 m) below the surface. The Nemaha Ridge is bounded on the east by the Humboldt fault zone (down-to-east), and throughout most of Kansas, an adjoining syncline along which Paleozoic rocks have been structurally depressed. In south-central Kansas, this syncline is referred to as the Walnut syncline (Mazzullo and Teal, 1994; Mazzullo et al., 1995). In northern Kansas and Nebraska, the western side of the Nemaha Ridge is bounded by a down-to-west fault which is not known with certainty to extend any farther south than central Riley County (fig. 41). In subsequent discussions this fault in northern Kansas and Nebraska is referred to as the western bounding fault, which defines the eastern edge of the

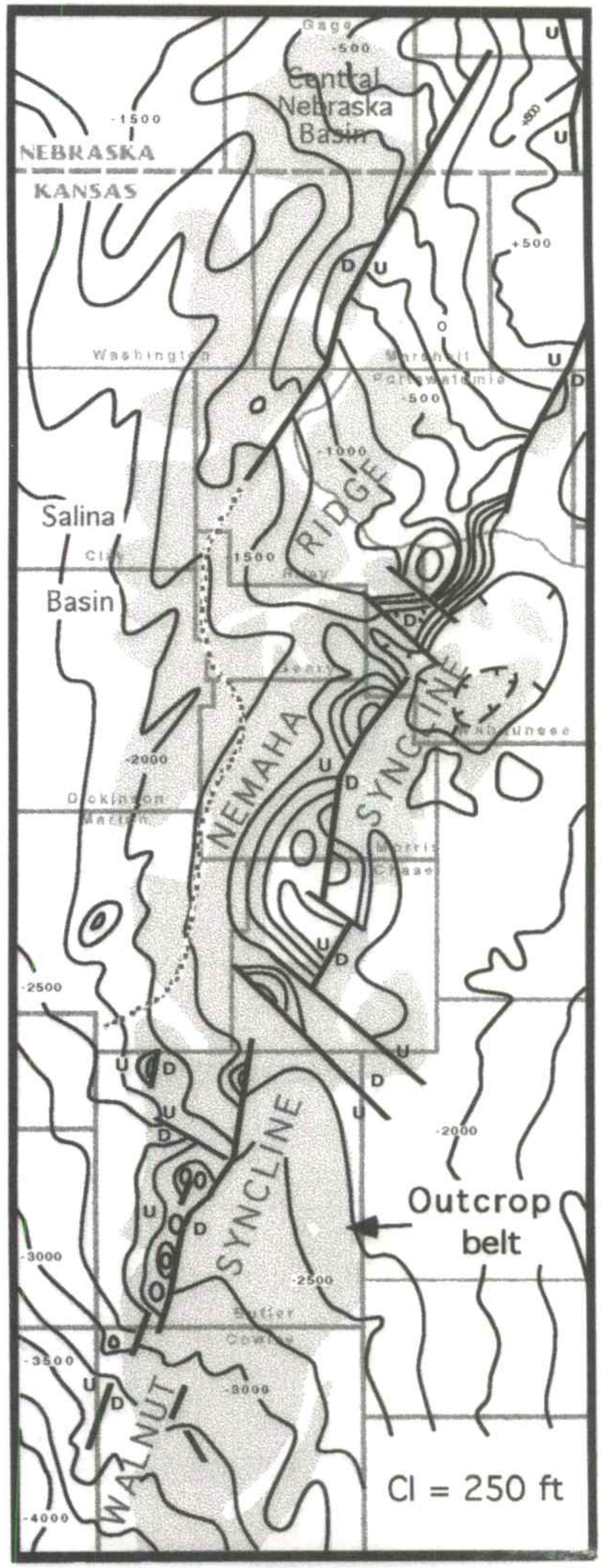


FIGURE 41—Structure on top of the Precambrian along the Nemaha Ridge (from Burchett et al., 1985); contours are in feet above mean sea level. The stippled line running through Riley, Geary, Morris, and Marion counties represents the transition between the Nemaha Ridge and the Salina basin.

Central Nebraska basin and the northern part of the Salina basin.

Chase Group outcrops in Gage, western Marshall, Washington, western Riley, and Clay counties are considered in the following discussions to occur within these basins. The western edge of the Nemaha Ridge is not clearly defined, however, in central and southern Kansas where a bounding fault apparently is not present. Rather, in this area the ridge passes indistinctly westward into the Salina and Sedgwick basins. This transition is illustrated in fig. 41. Outcrops of the Chase Group in Butler and Cowley counties clearly overlie both the Walnut syncline and the Nemaha Ridge. In contrast, Chase Group outcrops in central-eastern Marion, westernmost Morris, and Dickinson counties are, in the following discussions, considered to be located along the transition between the Nemaha Ridge and the Salina basin. Outcrops in Sumner County overlie the transitional zone between the Nemaha Ridge and the Sedgwick basin. According to several authors (DuBois and Wilson, 1978; Burchett et al., 1985; Stander, 1989; Steeples, 1989; Marshak and Paulsen, 1996), movement along the Nemaha Ridge and the Humboldt fault zone, and subsidence of Paleozoic strata to the east within the Walnut syncline, have continued to the present, and periodically affected deposition of strata during the Pennsylvanian and Permian (e.g., Nelson and Lumm, 1984; Carlson, 1989a,b; Heckel, 1994; Mazzullo et al., 1995).

Strata of the Chase Group were deposited on a broad ramp that dipped gently to the west and to the south in the study area (Mazzullo and Teal, 1994; Mazzullo et al., 1995, 1996). The thicknesses of each of the formations and members within the Chase Group generally increase to the west, presumably into the relatively more rapidly subsiding Central Nebraska, Salina, and Sedgwick basins. Local thickness variations, however, are superimposed on this general westward-thickening trend and are discussed in detail in ensuing sections of this paper. Five principal sedimentary facies are inferred in Chase Group strata (fig. 42A): (1) terrestrial facies—which include: (a) unfossiliferous red and green shales and/or mudrocks, commonly with paleosols (including paleocaliche) and/or rooted horizons; and (b) unfossiliferous, typically red, and locally green, shales and/or mudrocks with nodules composed of mixtures of anhydrite, calcite, and quartz (partially replaced evaporites), and locally, cauliflower quartz geodes interpreted as replaced evaporites (e.g., Ulmer–Scholle and Scholle, 1994). These deposits are interpreted as terrestrial sabkha, and possibly, also some proximal marginal-marine sabkha facies; (2) marginal-marine facies—including (a) sparsely fossiliferous to locally unfossiliferous yellow, light-gray, brown, dark-green, and black shales and/or mudrocks. These rocks are interpreted to have been deposited in coastal shallow-marine environments. The commonly varved to wavy-laminated black, dark-green, and mottled-black dark-green shales, in particular, locally may be lagoonal and/or swamp deposits, or alternatively, lower intertidal to shallow subtidal deposits. They variously resemble some modern muddy deposits on North Sea tidal flats (e.g., Reineck, 1975; Evans, 1975) and some modern salt-marsh deposits (e.g., Reineck, 1967; Frey and Basan, 1978); (b) shaly lime mudstones and/or dolomudstones, thin-bedded to laminated, and variously with presumed cyanobacterial laminites and desiccation cracks, fenestral fabric, local intraclasts, lenticular to wavy bedding of polymictic lithologies (i.e., lime mud and carbonate sand), general paucity of fossils (where they are present, they commonly are dominated by high-spired gastropods), and in some sections, nodules of anhydrite-calcite-quartz, cauliflower chert nodules, and locally, calcite- or quartz-replaced, nodular-mosaic textures (former evaporites). Such rocks are interpreted as tidal-flat (including hypersaline sabkha) deposits. Some of these strata are characterized by a hierarchal ordering of lamina thickness that resembles the tidal rhythmites described by Archer (1991) and Archer et al. (1994); (3) tidal-influenced, shallow-subtidal marine deposits—grainstones with herringbone cross stratification (i.e., bimodal-bipolar dip directions), burrows, and locally, lime pebble intraclasts with desiccation cracks. These rocks are interpreted mainly to be tidally influenced, nearshore, shallow-marine deposits (e.g., tidal bars), although locally, some sections may include intertidal facies *per se*; (4) shallow-subtidal marine facies—richly fossiliferous wackestone to grainstone (the latter commonly cross stratified), commonly bioturbated, either limestone or dolomite, deposited in shelf environments of moderate- to high-wave energy; and (5) more offshore marine facies—generally lime mudstone to fine-grained wackestone and some packstone, typically cherty and commonly shaly, associated with condensed sections (maximum flooding surfaces) of fossiliferous, calcitic, light-colored mudrock and/or shaly limestone. These beds are interpreted as relatively deeper-water, offshore-marine deposits.

Definitions of Sequence Stratigraphic Terminology

Three principal depositional-facies systems tracts were recognized in those cycles referred to as depositional sequences by Van Wagoner et al. (1988), and specifically in carbonate rocks, by Sarg (1988). They are the lowstand, transgressive, and highstand systems tracts (hereafter abbreviated to LST, TST, and HST, respectively [fig. 42B]). Heckel (1977, 1984, 1986, 1994), Watney et al. (1995), and others applied these same terms to midcontinent Pennsylvanian cyclothems. In addition, they also recognized regressive systems tracts (RST) within these cyclothems, a term that was not included as a systems tract in classic sequence stratigraphic architecture. We likewise follow these workers in describing LST, TST, HST, and RST's in Chase Group strata but do not necessarily restrict their usage to any particular order of cycle in this section. Hence, clarification of the usage of these systems-tract terms, and of the term "cycle" as used in this paper, is in order.

Insofar as systems-tract terms are descriptive and mutually relative, we concur with Heckel (1984, 1986, 1994) that the term HST is not totally appropriate, and that the term RST should be applied to some portions of cyclically deposited strata. For example, where facies within a marine HST sensu Van Wagoner et al.(1988) and Sarg (1988) progressively shallow upward, such a pattern of sedimentation actually defines a section that is objectively recognized as being regressive, regardless of the causative process for development of such a facies pattern. The fact is that shallowing-upward sections could be progradational or aggradational deposits formed during sea-level stillstand or relative rise of sea level. Where a

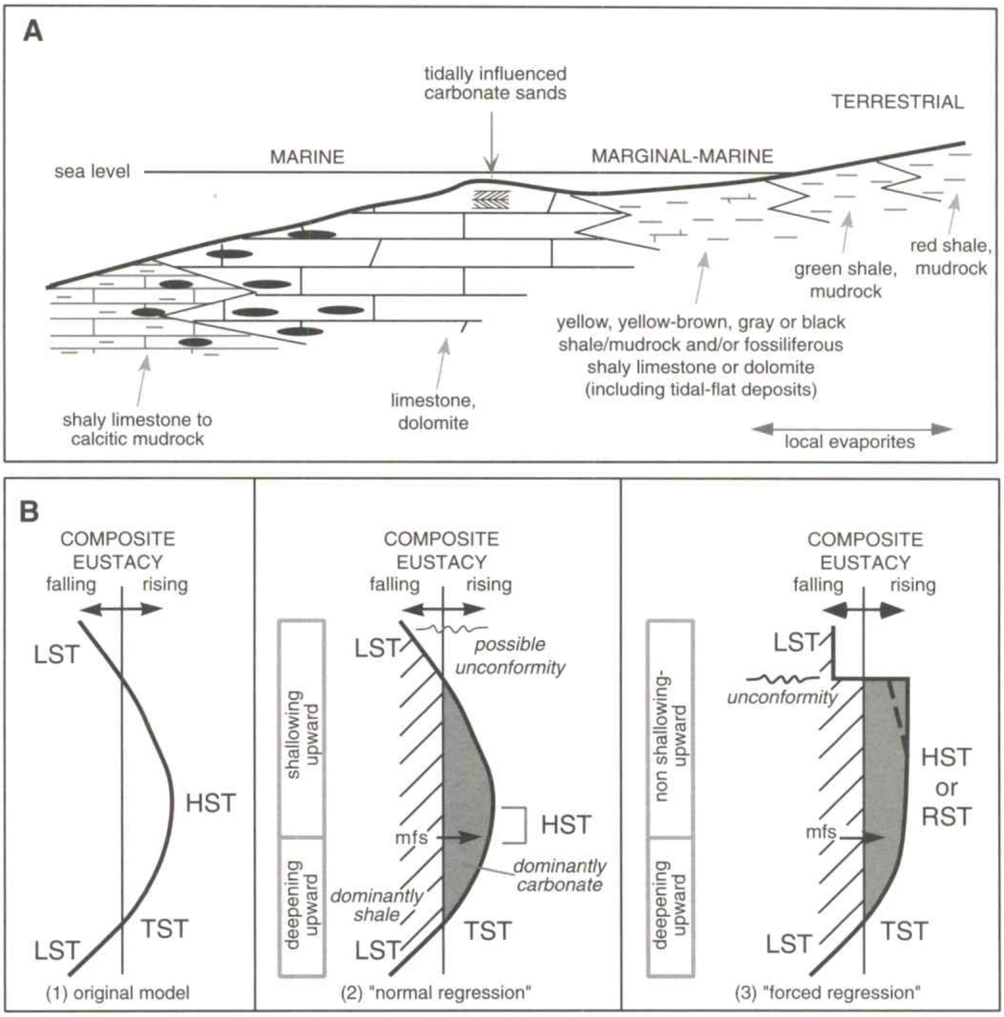


FIGURE 42—A) Idealized representation of inferred facies and depositional environments of Chase Group strata. B) (1) Position of lowstand (LST), transgressive (TST), and highstand (HST) systems tracts in depositional sequences following Van Wagoner et al. (1988); (2) normal regression, wherein a regressive systems tract (RST) defines sections that shallow upward above a prominent flooding surface, and which grade upward to terrestrial deposits; (3) forced regression, wherein deposits of a HST are abruptly terminated by an unconformity resulting from rapid sea-level drop (Posamentier et al., 1992). Such sections can also include RST facies.

pronounced unconformity does not define the top of the shallowing-upward cycle, such a stratigraphy would be an example of "normal regression" (e.g., Posamentier et al., 1992). Although the section is deposited during highstand, it nevertheless is still regressive in terms of its facies character. Alternatively, shallowing-upward sections can also be generated during slow, prolonged relative sea-level fall; in such instances both the strata and the history of sea level are regressive. Instead, if sea-level fall was rapid and abruptly terminated a marine phase of deposition, then a pronounced unconformity could truncate marine deposits of either aggradational or regressive character, depending on initial water depth and the balance between sedimentation rate and changes in accommodation. This situation would equate to the "forced regression" of Posamentier et al. (1992)(fig. 42B).

As discussed in the following sections of this paper, a complex hierarchy of cyclicity is recognized within the Chase Group, from long-term, low-frequency cycles (e.g., the second-order cycles of Vail et al., 1977) to relatively high-frequency fourth-, fifth-, and even higher-order cycles (e.g., Goldhammer et al., 1991). We therefore define a cycle as any stratal section of relative transgressive-regressive facies character. Any order of cyclicity ostensibly can be described in terms of facies-systems tracts, although important details of the architecture of stratal sections become progressively more obscured and generalized when such terms are applied to progressively lower-frequency cycles. In the following discussions, therefore, we restrict our references to LST, TST, HST, and RST's to being architectural components of mesoscale cycles that are at a scale of resolution between that of depositional sequences and meter-scale cycles. Accordingly, with the exception of the Florence and Fort Riley Formations, these mesoscale cycles are nearly always members, or parts thereof, of formations. Our usage of this term "mesoscale" will become apparent in ensuing discussions.

In outcrops of the Chase Group where facies gradually shallow upward following a prominent flooding event (e.g., a maximum flooding surface), we recognize such a section to be an RST regardless of the causative process of its deposition (fig. 42B). In such cases, we consider that the HST is restricted to the maximum flooding surface and some thickness of immediately overlying strata. The marine tops of such RST's can be unconformities which could represent forced regressions (fig. 42B). Alternatively, they may grade conformably upward through marginal-marine and into terrestrial facies, and therefore, represent normal regression (fig. 42B). In contrast, where strata overlying prominent flooding surfaces, including maximum flooding surfaces, do not gradually shallow upward, we regard such sections as HST's (fig. 42B). Cycles or sequences in the Chase Group with such HST's commonly are abruptly terminated by prominent unconformities and marked facies dislocation, and therefore, also represent forced regression (fig. 42B).

Furthermore, we wish to make it clear that we generally recognize two distinct types of LST deposits based on our general model of ramp facies shown in fig. 42A: (1) maximum lowstand, which always involves deposition of terrestrial facies, including unfossiliferous red and green shales, mudrocks, and paleosols. In ensuing figures and discussions, such lowstand deposits are abbreviated as tLST; and (2) marine lowstand, which involves maintenance of marine conditions, although very shallow, and deposition of marginal-marine facies composed of generally fossiliferous shale and/or mudrock and some carbonates. Such deposits are abbreviated as mLST. The premise here is that relative highstands are always represented mainly by carbonates, whereas relative lowstands are always represented by siliciclastics. We have never observed a situation where the opposite is true in regional mapping of Chase Group deposits.

Wreford Limestone

The Wreford Limestone was traced from the Kansas–Oklahoma border (Cowley County) to northernmost Kansas (Marshall County), but we were unable to locate measurable outcrops of this formation in Nebraska or in Nemaha County, Kansas. Throughout Kansas the Wreford varies in thickness from 28 to 41 ft (8.5–12.5 m), and there are no consistent regional trends in its thickness except that its maximum thickness appears to be in Marshall County, on the edge of the Salina basin (figs. 43B, 44, 45). Previous studies indicated a similar range in thickness of the Wreford in Kansas and Nebraska (Fath, 1921; Bass, 1929; Condra and Upp, 1931; Jewett, 1941; Moore et al., 1951a,b; O'Connor et al., 1953; Walters, 1954; Bayne, 1962). Because deposition of Pennsylvanian strata supposedly had reduced antecedent topography along the Nemaha Ridge to a relatively flat surface (Elias, 1937; Merriam, 1963), it does not appear that the structural or paleotopographic configuration as mapped on the top of the Precambrian exerted any control on the regional thickness of the Wreford in the study area. However, the component members of the formation vary in several important aspects across the state, including their thickness, and these are illustrated in ensuing figures.

Relative to terrestrial facies in the underlying lower Speiser and in the overlying Wymore, the Wreford Limestone and the upper fossiliferous beds in the Speiser represent a long-term cycle of marine deposition, including both carbonate and siliciclastic facies. Based on our facies and sequence stratigraphic models (fig. 42A), the Threemile and Schroyer Members are interpreted as major HST phases of dominantly marine carbonate deposition, each of which is a transgressive-to-regressive facies package, whereas the intervening Havensville is a major lowstand phase of marginal-marine deposits (mLST).

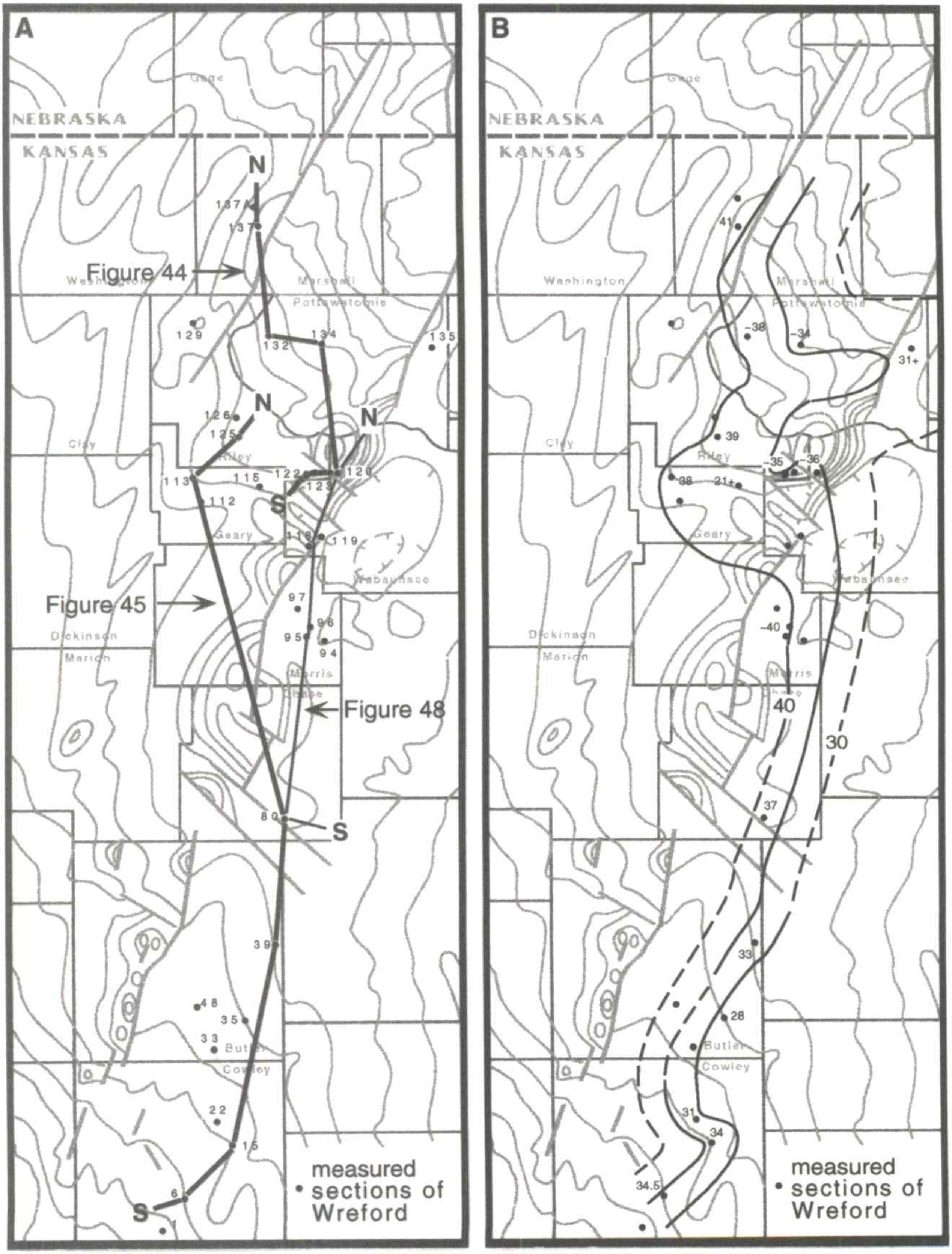


FIGURE 43—A) Locations of cross section figs. 44, 45, and 48. Gray-line base map in this and ensuing maps is structure on top of the Precambrian (CI = 250 ft [76 m]). B) Isopach of the Wreford Limestone (CI = 5 ft [1.5 m]).

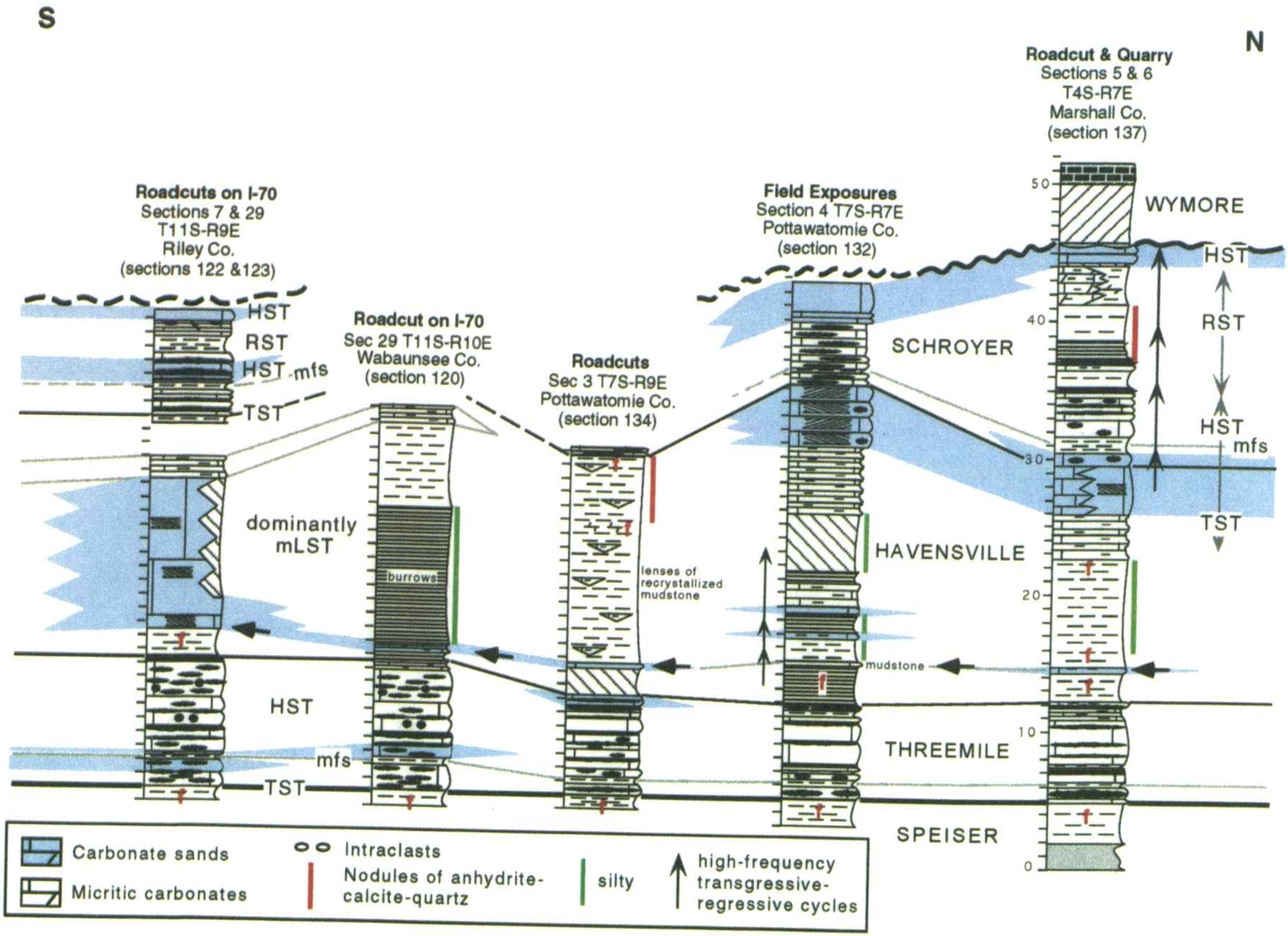


FIGURE 44—Section through part of northern Kansas showing stratigraphy and facies in the Wreford Limestone. Bold arrows point to regionally occurring carbonates (minor transgressive-regressive cycles) in the Havensville. Vertical scale in this and ensuing cross section figures is in feet. TST, HST, RST, and mfs in this and ensuing cross section figures refer to transgressive, highstand and regressive systems tracts, and maximum flooding surface, respectively; additional legend at base of figure. See fig. 6 for lithologic legend for this and all ensuing figures.

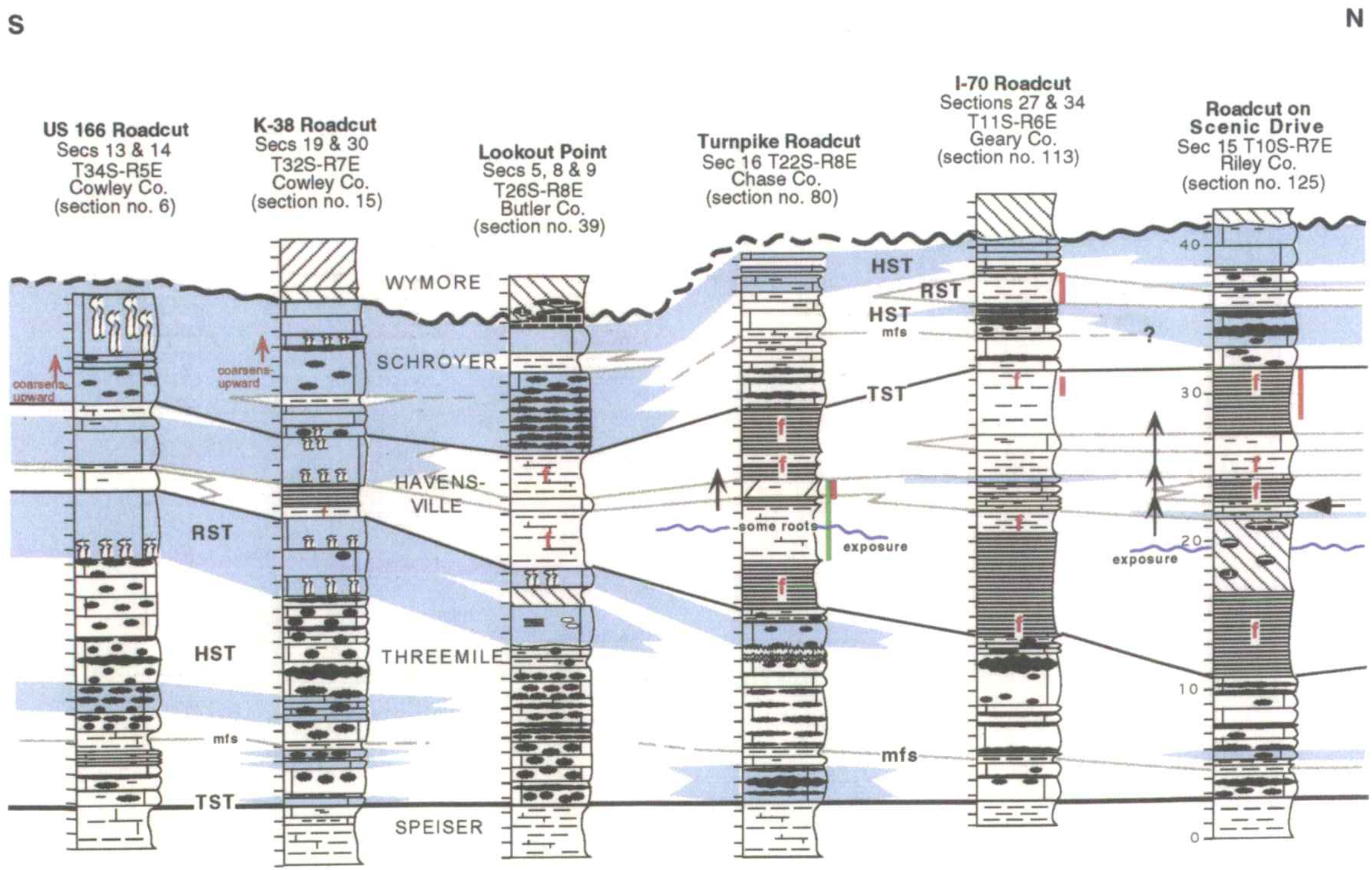


FIGURE 45—Section through central and southern Kansas showing stratigraphy and facies in the Wreford Limestone (symbols as in fig. 44). Bold arrow on the right points to thin section of regionally correlative limestones within the Havensville.

Threemile Member

A lobe of thickened Threemile section ("reef" facies, discussed below) occurs in adjoining parts of Morris, Wabaunsee, and Geary counties (fig. 46B). Aside from this lobe, the thickness of the Threemile Member generally increases from north to south from about 5.5 to 7.5 ft (1.7–2.3 m) in Marshall and Pottawatomie counties, to 21 ft (6.4 m) in southern Cowley County (fig. 46B). The regional thickness trend of the Threemile indicates a slight increase in accommodation from north to south during its deposition, toward the relatively more rapidly subsiding Anadarko basin (e.g., Watney et al., 1989; Heckel, 1994). An area of relatively thin Threemile strata in adjoining parts of Riley, Geary, Wabaunsee, and Pottawatomie counties sits atop a high on the top of the Precambrian and represents a somewhat positive area during deposition (fig. 46B).

A thin, calcitic mudrock (locally shaly limestone) a few feet above the base of the member is interpreted as a maximum flooding surface (Mazzullo et al., 1995) at the top of the TST (figs. 44, 45). The TST is overlain by a section of dominantly cherty, offshore, and relatively deep-marine limestones, the HST, locally with some lenses of carbonate sand that occur most commonly in south-central Kansas. These sands compose high-frequency shallowing-upward cycles that do not appear to be regionally correlative across the study area. However, both the TST and HST are regionally correlative throughout the study area, and with only local exceptions (i.e., sporadic lenses of carbonate sand), depositional facies within each tract (i.e., relatively shallow-marine facies in the TST, deeper-water facies in the HST) remain mostly unchanged across the state. That is, there is no evidence of progressive and pervasive regional shallowing or deepening of facies within each of these systems tracts in any direction. Hence, there does not appear to have been much depositional or tectonically induced relief along the outcrop belt during deposition of the lower and middle Threemile.

In northern Kansas the cherty HST of the Threemile is overlain either sharply but conformably, or gradationally by marginal-marine siliciclastics of the Havensville mLST (figs. 44, 45, 46A). The top of the Threemile is picked at the highest occurrence of cherty limestones where the contact is gradational. In this area the Threemile–Havensville contact appears to define a marked facies dislocation that records a forced regression, but one that did not involve subaerial exposure. In contrast, the cherty HST of the Threemile is rather abruptly overlain by a southward-thickening section of non-cherty to only slightly cherty carbonate sands in eastern Pottawatomie County and southward from central Wabaunsee County to the Kansas–Oklahoma border (figs. 44, 45, 46A). These beds, assigned to the upper Threemile, are variably porous to nonporous, and cross stratified or bioturbated, and they are interpreted as shallow-water, high-energy deposits of an RST (Mazzullo et al., 1995). The basal contact of these sands with the cherty HST, and the upper contact with the Havensville, are sharp but conformable to gradational. Where sharp, the basal contact of these sands also defines a marked facies dislocation and a forced regressive event, without subaerial exposure, which may correlate to that in northern Kansas.

The RST sands in the upper Threemile, as well as the underlying HST and TST of the member, show pronounced thickening southward from Chase County. This thickness trend defines a prominent marine depocenter in south-central Kansas (fig. 46A), which may extend into northernmost Oklahoma, but which then changes facies farther south in northern Oklahoma to terrestrial siliciclastics (e.g., Lutz–Garihan and Cuffey, 1979; Chaplin, 1988, 1994, 1996). Based on available outcrop data, the thicker Threemile section in this depocenter appears to sit directly atop the Walnut syncline (fig. 46A,B). Although the sand section thins to the north, it is traced along the length of the Walnut syncline as far north as Pottawatomie County, and sands are present on only part of the Nemaha Ridge in east-central Pottawatomie and northwestern Wabaunsee counties (fig. 46A). Sands are not present, however, in the outcrops farther to the west in Marshall, western Pottawatomie, Riley, most of Geary, and western Morris counties, where instead, only cherty HST facies in the upper Threemile are found beneath the Havensville (fig. 46A). Lack of Threemile outcrops along the axis of the Nemaha Ridge in central and southern Kansas (fig. 46A) precludes determination of the basinward extent of these sands.

The areal distribution of shallow-water carbonate sands in the upper Threemile (fig. 46A) can be interpreted in two ways. First, that the sands were deposited throughout the study area, but subsequently were eroded from along the axis of the Nemaha Ridge prior to the deposition of the Havensville. This interpretation would invoke the presence of an unconformity at the top of the cherty Threemile for which there is no evidence. In addition, basal Havensville strata are mostly marginal-marine rather than terrestrial deposits as would be expected immediately above an unconformity. The interpretation that we presently favor (fig. 47) is that deposition of the sands was restricted mainly to the Walnut syncline, and that their western limit of occurrence is a depositional pinchout against the Nemaha Ridge. Hence, they represent a downdip wedge of marine deposits that likely is temporally equivalent to marginal-marine facies, and locally perhaps also terrestrial facies, in the lower Havensville. Interbedding of the Threemile and Havensville at many localities support this contention. The updip pinchout of the sands could mark the approximate paleotopographic location of a stillstand of sea level during relative sea-level fall from Threemile into Havensville time. This interpretation could suggest that the Walnut syncline was subsiding and submerged, whereas the Nemaha was a more positive area of marginal-marine deposition, perhaps because of minor uplift late in Threemile time. Heckel (1994)

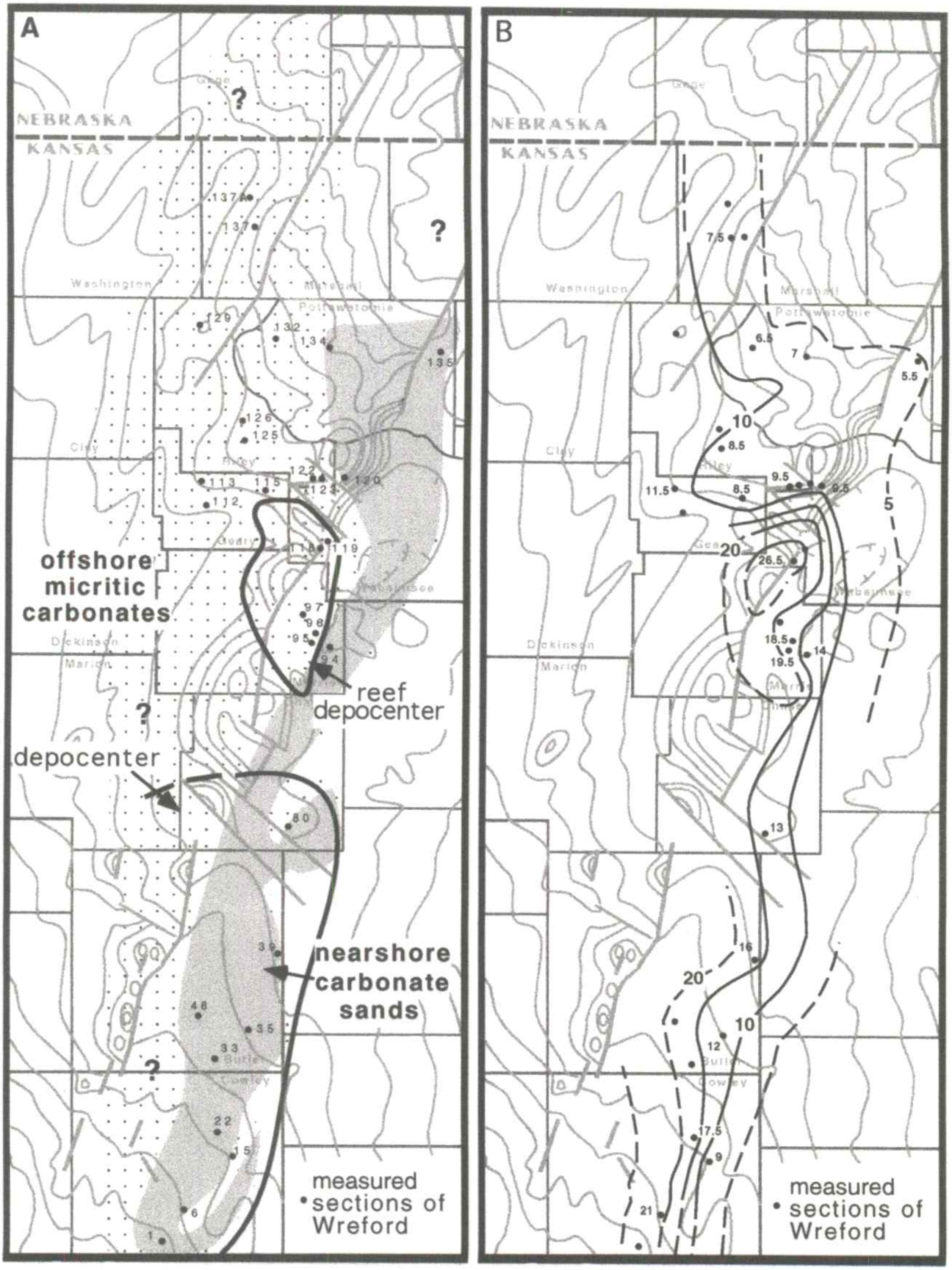


FIGURE 46—A) Inferred facies and depocenters in the Threemile Member. B) Isopach of Threemile Member (CI = 5 ft [1.5 m]).

presented evidence of intermittent reactivation of the Nemaha Ridge in northern Kansas during the Desmoinesian.

"Reefing" in the Threemile

The Threemile section thickens to a maximum of about 26.5 ft (8.1 m) in eastern Morris and parts of adjoining Wabaunsee and Geary counties (figs. 46B, 48). Hattin (1957) and Mudge et al. (1958) interpreted these rocks as reef facies, but they mapped a more extensive trend than we have. Because of very poor exposures at some of the localities they described, and which we examined, we were unable to substantiate the areal extent that they indicated for this supposed reef. Conversely, we found that what Hattin (1957) had called "reef" facies at other localities are actually the southward-thickening section of carbonate sands in the upper Threemile (figs. 44, 45).

Whether this mapped buildup represents one reef, as it appears by its isopach (fig. 46B), or a series of coalesced reefs can not be resolved on the basis of field exposures. The presumed reef rocks in the Threemile are non-cherty to slightly cherty, commonly soft and "chalky," very porous and vuggy limestone (fig. 49A), and the unit most definitely has a reeflike geometry (fig. 48). Lithology is typically biowackestone to packstone, and the dominant biota are fenestrate bryozoans with accessory ramose bryozoans, echinoid fragments, crinoids, brachiopods (*Composita* spp., *Chonetes* spp., and *Reticulatia* spp.), and locally, rugose corals and gastropods. Hence, this unit may be a bryozoan mud-mound or bioherm. Similar reefal deposits are common in many Lower Permian rocks (e.g., Bosence and Bridges, 1995). To the north, the supposed reef facies appears to pass laterally into, and hence, likely is a facies of, the Havensville (fig. 48). Postulated temporal equivalence of the Threemile and Havensville was considered above. To the south and west, presumed reef facies appear to pass laterally into carbonate sands near the top of the Threemile, and perhaps into the lower Havensville, thus suggesting a coeval relationship between these members (fig. 48). This thick reef section is not

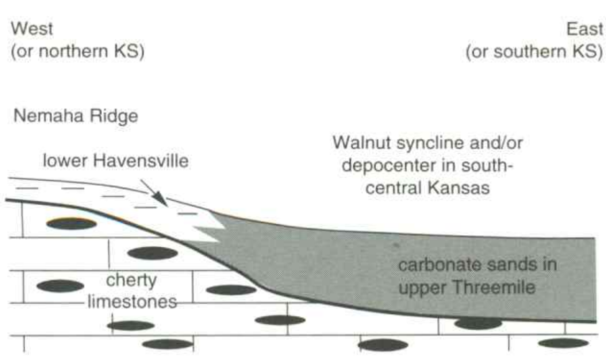


FIGURE 47—POSSIBLE FACIES RELATIONSHIP BETWEEN THE LOWER HAVENSVILLE AND CARBONATE SANDS IN THE UPPER THREEMILE IN THE WALNUT SYNCLINE AND IN SOUTH-CENTRAL KANSAS.

believed to be partly coeval with the basal Schroyer as might be imagined from inspection of fig. 48 because we have found that the Havensville is always present, albeit thinned, below the Schroyer.

The reef or reefs are localized on the edge of the Humboldt fault zone and are present on both the Nemaha Ridge and in the adjoining syncline (fig. 46). The dramatic increase in thickness of the buildup here, which is included within the HST and RST of the Threemile, indicates localized, abnormally high accommodation rates, which in turn, suggest the existence of a local depocenter partly atop the Nemaha and partly within the syncline to the east. The buildup(s) possibly were initiated on a slight topographic high that may have resulted from either uplift along the Humboldt fault zone and concurrent downwarp in the syncline, or compactional draping of underlying strata around the fault zone. There is no definitive evidence that the reef was ever subaerially exposed during or subsequent to its deposition.

Havensville Member

The thickness of the Havensville decreases from north to south, from a maximum of 23.5 ft (7.2 m) in northwestern Pottawatomie County, on the axis of the Nemaha Ridge, to from 3.5 to 6 ft (1.1–1.8 m) in southern Butler and Cowley counties, within the Walnut syncline (figs. 44, 45, 50B). This thickness trend is the opposite of the Threemile and suggests a depocenter of increased accommodation on the Nemaha Ridge and the eastern edge of the Salina basin, in parts of Riley, Wabaunsee, Pottawatomie, and southern Marshall counties. This area appears to have been a slightly positive area during deposition of the Threemile (figs. 46B, 50B). This trend also suggests a dominant source of siliciclastics from the north-northeast. A minor, subdued embayment of slightly thicker Havensville section occurs in southern Chase and northeastern Butler counties, within the Walnut syncline and possibly extending westward over the Nemaha Ridge. The member is only a few feet thick over the Threemile reef in Morris, Wabaunsee, and Geary counties (fig. 50).

The Havensville is interpreted as an overall mLST, with a relatively thin TST at the top, composed dominantly of marginal-marine shale and some limestone. On the basis of some presumed paleosols, Miller and West (1993) and Miller et al. (1996) inferred eustatically and/or climatically controlled deposition of cycles of marginal-marine and terrestrial deposits in the Havensville throughout northern Kansas. We examined the same outcrops as they did, and many others throughout the state, and did not find evidence of regionally persistent terrestrial facies, including paleosols, in this member. Rather, we recognized only minor and noncorrelative terrestrial deposits. Green shales and/or mudrocks with paleocaliche, for example, occur at one locality in Riley County (measured section number 125), and light-colored mudrocks with some rootcasts

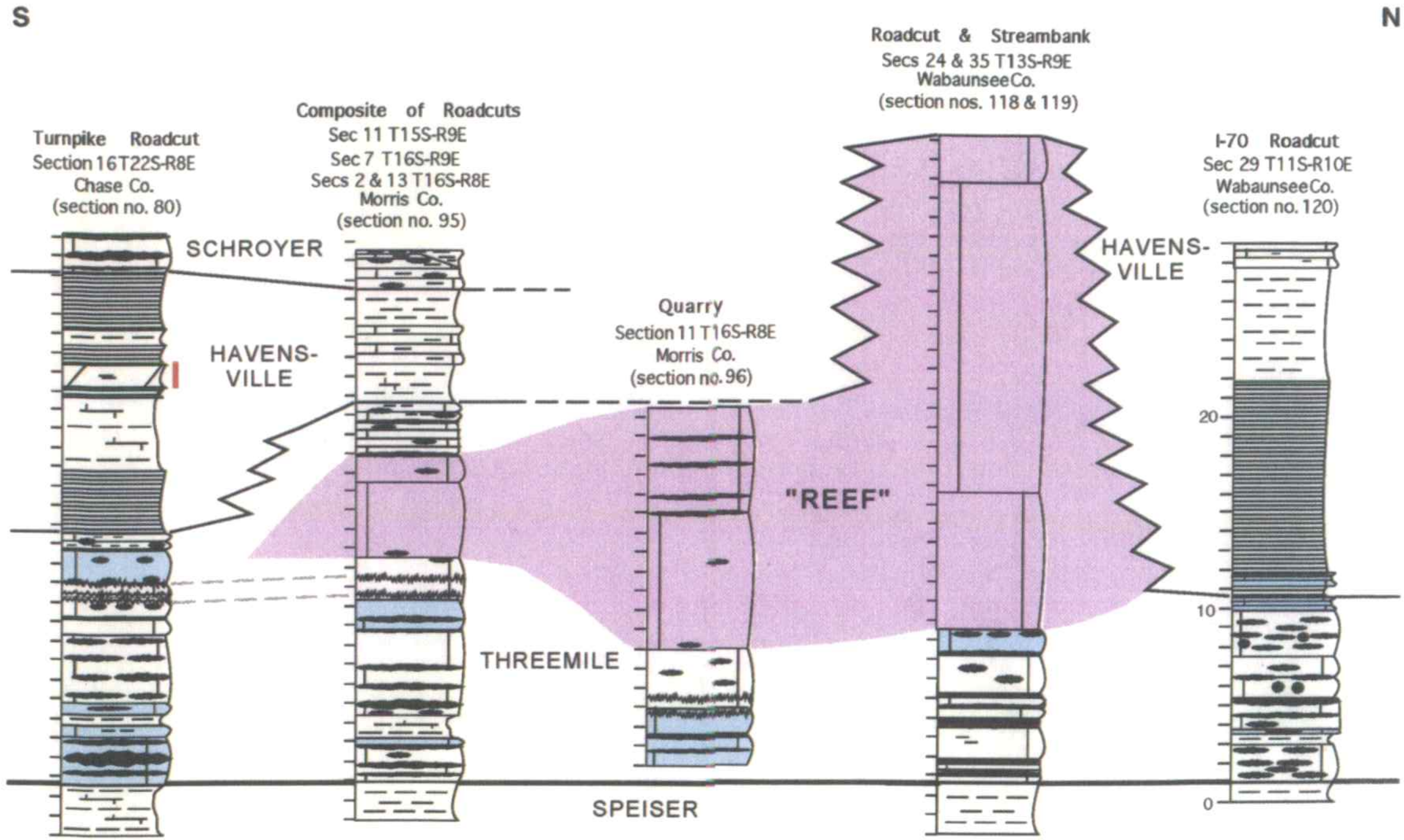


FIGURE 48—Section illustrating development of "reef" facies in the Threemile in Wabaunsee and Morris counties. The reef may be a facies of the Havensville but is not known to have grown into the Schroyer. Location of section shown in fig. 43A.

(terrestrial?) and other pedogenic features occur in approximately the same horizon at measured section number 80 in Chase County (fig. 45). These localities, however, are separated by outcrops in which equivalent horizons are represented instead by fossiliferous mudrocks, shaly limestones, and dark-colored, marginal-marine shales (fig. 45). To the immediate southeast of measured section number 125, approximately equivalent units are cross stratified limestones (e.g., at sections 122 and 123, fig. 44). Northward from Wabaunsee County, this section is variously fossiliferous to unfossiliferous, marginal-marine, silty mudrocks and some limestones (fig. 44). The Havensville passes farther south to dominantly marine carbonates with no evidence of exposure (fig. 45). Hence, the sporadic distribution of terrestrial facies in the Havensville appears to argue for dominant autogenic rather than eustatic or climatic allogenic controls on deposition of terrestrial facies in the section.

Several high-frequency transgressive-regressive cycles of marine to marginal-marine facies during deposition of the Havensville are suggested by the occurrence of beds of fossiliferous marine limestone in the section throughout the study area (figs. 44, 45). The stratigraphically lowest such cycle is correlated throughout northern Kansas and may correlate to the basal bed of the thick section of cross stratified sands at measured section number 122 in Riley County (fig. 44). However, we did not identify a limestone in the same stratigraphic position farther to the south, where instead, strata are fossiliferous mudrocks (fig. 45). Nonetheless, this lowest cycle, assuming a lithofacies change from limestone to fossiliferous shale and/or mudrock in a north-to-south direction, may be of allogenic origin. The immediately overlying, two additional transgressive-regressive cycles that are clearly identified at, for example, measured section number 132 in Pottawatomie County are not similarly recognized in surrounding outcrops (figs. 44, 45). This zone of limestone, however, may correlate to the regionally correlative zone of fossiliferous, marine limestone in about the middle of the member as traced from Riley County southward to Butler County (identified by the horizontal, bold arrow at measured section 125 in fig. 45).

Although this zone may be of allogenic origin, it composes only one high-frequency cycle at, for example, measured section number 80 in Chase County, whereas two such cycles are recognized at measured section number 125 in Riley County (fig. 45). Likewise, an additional cycle occurs above this zone only in Riley and

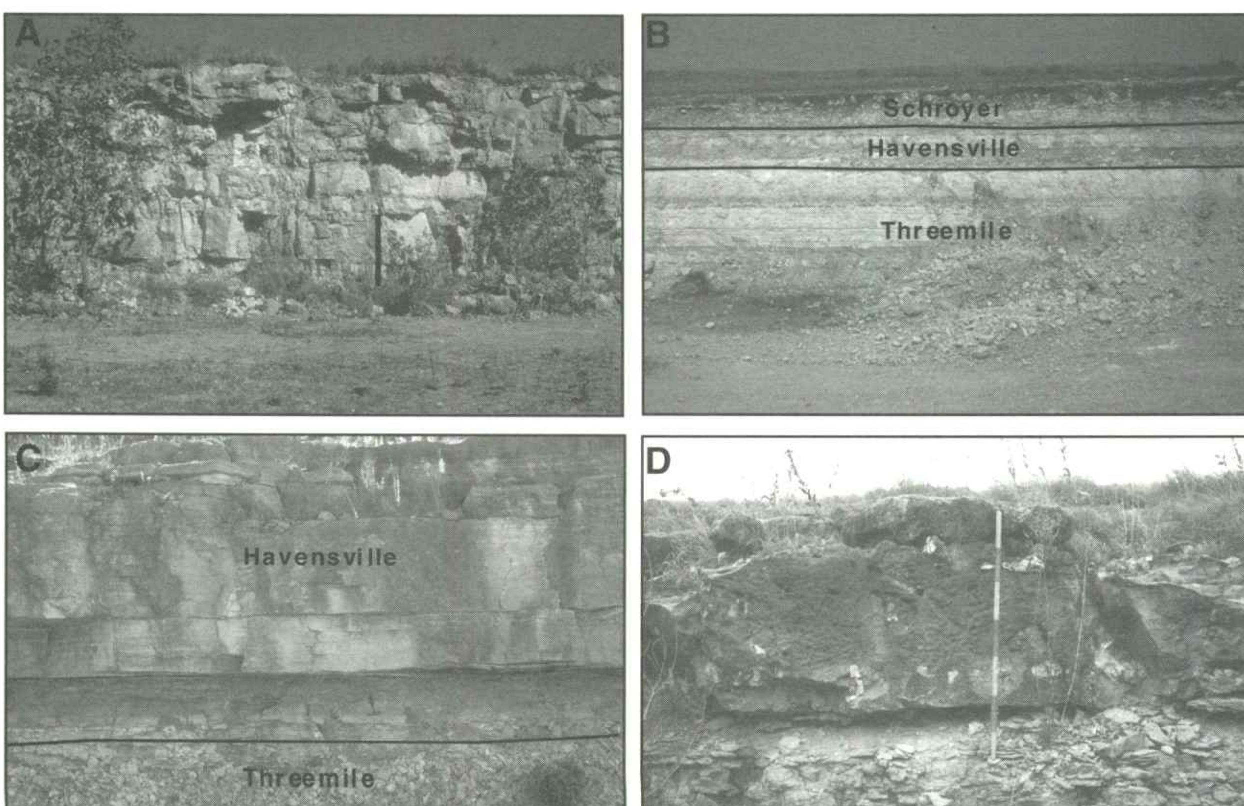


FIGURE 49—A) Quarry exposure of the non-cherty, Threemile "reef" at measured section number 96, Morris County, Kansas; length of scale 5 ft (1.5 m). B) Roadcut along new US–166 in Cowley County (measured section number 6) showing limestone-dominated Havensville section (which is about 6 ft [1.8 m] thick). C) Roadcut along I–70 (south side) in Riley County, Kansas (measured section number 122) showing thick carbonate sands in the basal to middle Havensville; hammer for scale. D) Roadcut along K–38 in Cowley County (measured section number 15) showing carbonate sands at the top of the Schroyer; rod divided into 20-cm segments.

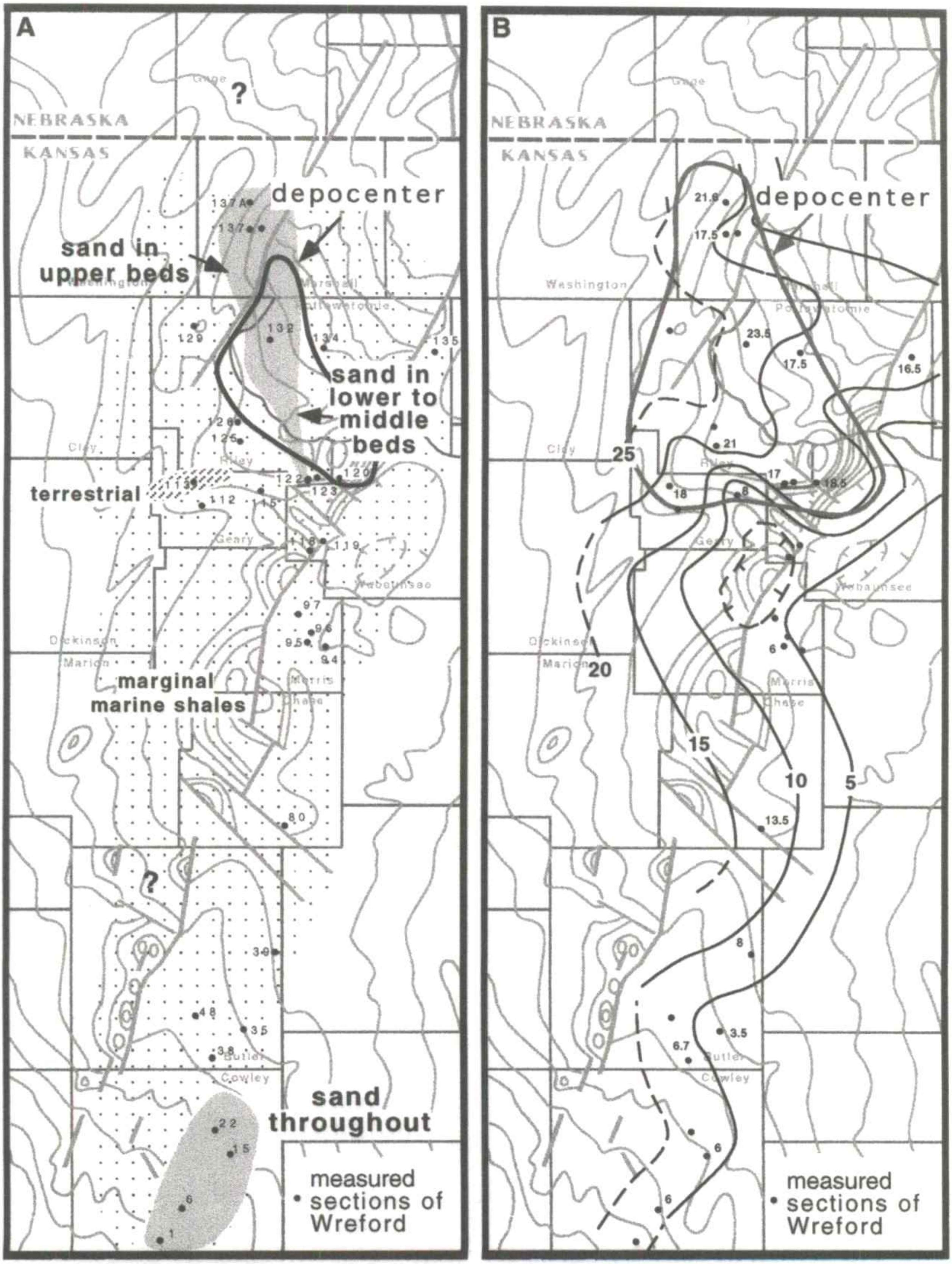


FIGURE 50—A) Inferred facies and depocenters in the Havensville. B) Isopach of the Havensville (CI = 5 ft [1.5 m]).

Geary counties (fig. 44). These stratigraphic characteristics, therefore, also suggest some degree of autogenic control on sedimentation of these higher-frequency cycles.

Farther south, in southern Cowley County, the Havensville changes facies to limestone, specifically, carbonate sands (figs. 45, 49B). These limestones also were included within the Havensville by Bayne (1962). The Havensville Member is not readily identified in this area unless one recognizes this facies change, which may be the reason why Chaplin (1996) did not subdivide the Wreford Limestone into its component members in Oklahoma. The area of occurrence of carbonate sand in the Havensville defines a wholly marine embayment within the southern portion of the Walnut syncline that contrasts the dominantly marginal-marine facies to the north (fig. 50A). Relatively thick sections of carbonate sand overlying lime mudstone occur in the upper Havensville in Marshall and western Pottawatomie counties, and thick sands also occur in the lower to middle Havensville in southeasternmost Riley County (figs. 44, 49C). Together, these areas define a prominent depocenter of increased accommodation for the deposition of marine strata, at these respective times, that sits atop the Nemaha Ridge. This depocenter is coincident with the depocenter of maximum thickness of the entire Havensville (fig. 50). These depocenters extend northwestward into Marshall County, where they merge into the eastern edge of the Salina basin.

At measured sections 132, 137, and 137A in Pottawatomie and Marshall counties (fig. 44), the carbonate sands at the top of the Havensville are cross stratified. At the former locality (fig. 9), the dip directions of the stacked cross stratified sets are bimodally and nearly bipolarly oriented (fig. 51), which suggests deposition in a tide-dominated environment. At these three localities the

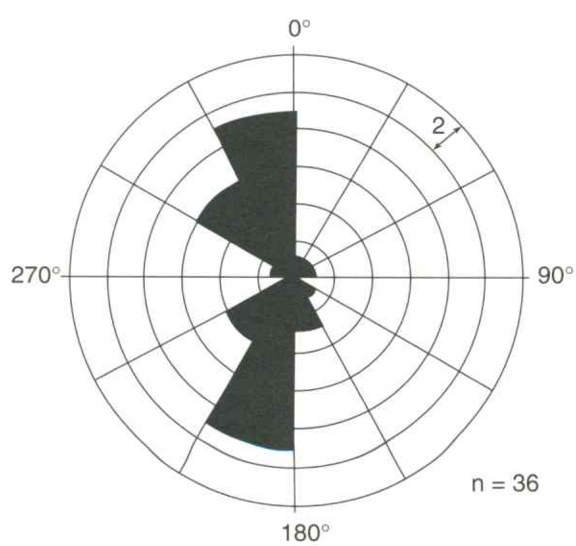


FIGURE 51—Rose diagram of cross strata dip directions in carbonate sands in the upper Havensville at measured section number 132 in Pottawatomie County, Kansas.

sands overlie thin-bedded, shaly lime mudstones with conspicuous lenticular bedding (fig. 9) which, in turn, overlie unfossiliferous green or yellow shales and mudrocks. The overlying Schroyer at these localities consists of cherty, micritic limestones. This lithofacies pattern is interpreted as a progressive TST to HST of terrestrial and/or marginal-marine facies, through peritidal deposits, and culminating in relatively deeper-water, cherty carbonate facies. The section of partly cross stratified carbonate sand in the lower to middle Havensville at measured section number 122 in southeastern Riley County (figs. 44, 49C) varies in thickness along the length of the outcrop from 2 ft to 10 ft 8 inches (0.6–3.3 m). This limestone is not present either to the immediate east (fig. 44) or west (e.g., measured section 125 in Riley County) of this locality, where instead, presumably coeval strata are marginal-marine facies (e.g., fig. 45).

Schroyer Member

Regional thickness of the Schroyer is fairly uniform in a north-to-south direction across the study area (fig. 52B), which suggests uniform subsidence in this direction during deposition. The member thickens to the west, from about 5 to 16 ft (1.5–4.9 m), and its maximum thickness occurs at measured section number 137 in Marshall County, in the Salina basin (fig. 52B). Slight thickening of the member at measured section number 135 in eastern Pottawatomie County, relative to nearby outcrops, occurs within the syncline to the immediate east of the Humboldt fault zone. The region of relatively thin Schroyer section in adjoining parts of Morris, Geary, and Riley counties sits atop the axis of the Nemaha Ridge, and defines a slightly positive area during deposition. This feature was present during deposition of the Threemile, but was part of a depocenter during deposition of the Havensville (compare figs. 46B, 50B). The anomalously thick Schroyer section in Marshall County (16 ft [4.9 m] at measured section number 137) is located along the eastern edge of the Salina basin.

Throughout most of central and northern Kansas (in Chase, Geary, and Riley counties), the Schroyer includes a readily recognizable TST and maximum flooding surface overlain by an HST of relatively deep-water, cherty limestones. This section is overlain by marginal-marine shale and/or mudrock, and in turn, by non-cherty, non-porous, shallow water carbonate sands (e.g., at measured sections 113, 122, 123, and 125; figs. 44, 45). A relatively thick lens of shallow-water sand occurs within the upper part of the HST in this area, and together with the overlying marginal-marine siliciclastic strata here, documents a pronounced phase of shallowing and development of an RST. The areas of deepest water during deposition of the HST therefore appear to have been centered in Chase County and in adjoining parts of Pottawatomie and Marshall counties, where no such sands are present in the cherty HST (figs. 44, 45). Inferred paleowater depth for

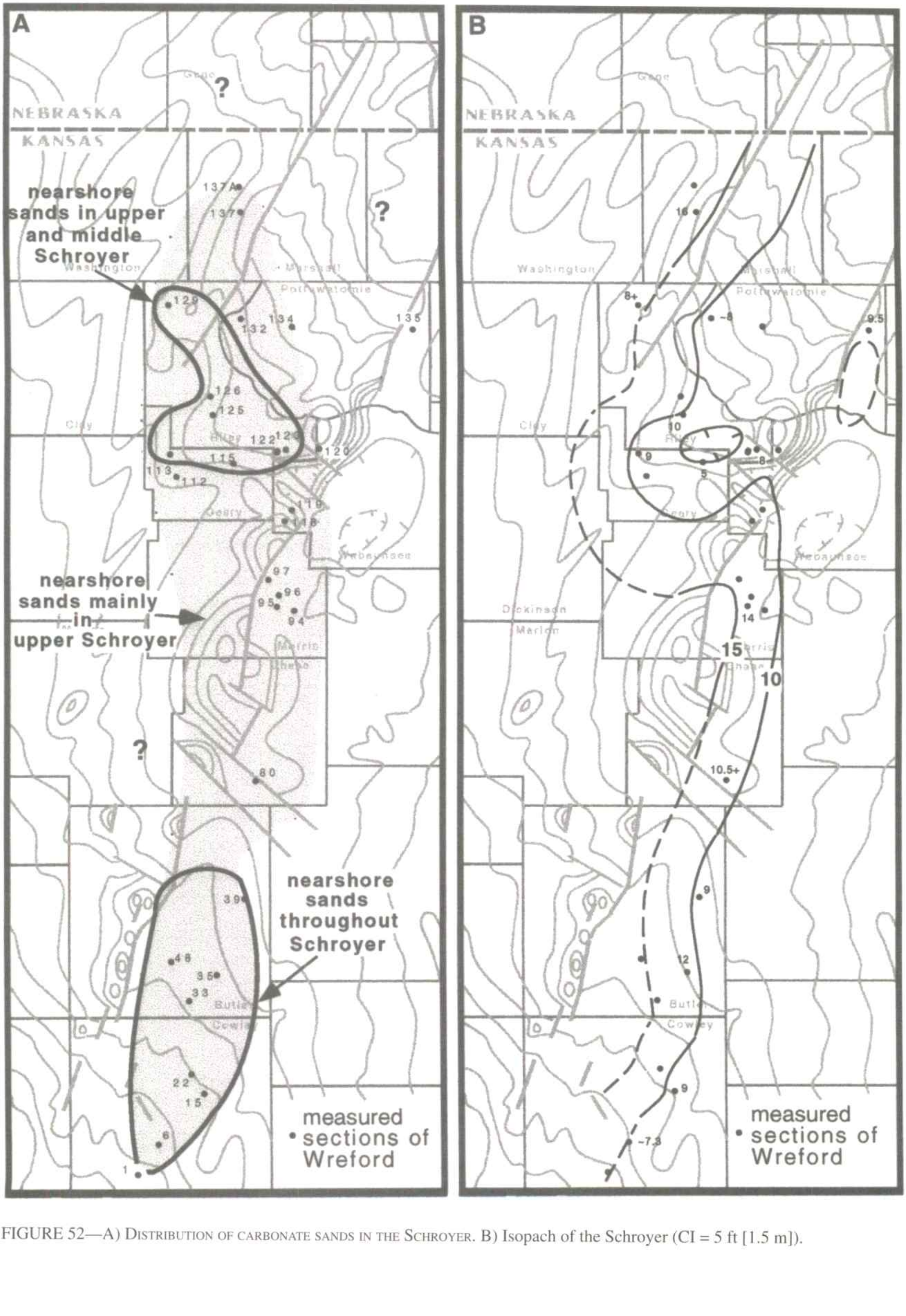


FIGURE 52—A) Distribution of carbonate sands in the Schroyer. B) Isopach of the Schroyer (CI = 5 ft [1.5 m]).

these cherty HST limestones is believed to have been less than that during deposition of the HST facies in the Threemile Member (Mazzullo et al., 1995). In south-central Kansas the entire Schroyer, including the cherty to non-cherty (upsection) TST and HST is dominated by (locally porous) carbonate sands (figs. 45, 49D), and so, defines an area of relatively long-lived, shallow-water deposition (fig. 52A). At measured section number 39 in Butler County, the pronounced shallowing RST phase inferred in central-northern Kansas may be represented by the section of gray, marginal-marine shales that occurs between the cherty HST limestones below and the non-cherty carbonate sands above, at the top of the member (fig. 45). Farther south, in Cowley County, shallowing at this approximate stratigraphic level may be suggested by HST sections that coarsen upward. The section at locality 137 in Marshall County that includes cherty, HST limestones overlain by shale likewise may correlate to this shallowing RST phase. Accordingly, the fact that this RST can be recognized throughout most of the study area would suggest that it may be of allogenic origin. However, no such shallowing is readily evident at measured section number 132 in Pottawatomie County (fig. 44).

Instead of gradually shallowing upward above this RST, facies at the top of the Schroyer throughout the study area instead are shallow-water carbonate sands that, according to our facies model (fig. 42), are interpreted to represent another HST, that is, another relatively high-frequency transgressive cycle (figs. 44, 45). These sands were deposited both in the Walnut syncline and on the Nemaha Ridge (fig. 52A), and they are conspicuously vertically burrowed and porous in Cowley County (figs. 45, 49D). Inasmuch as this transgressive event is traced throughout the study area, it appears to be of allogenic origin. This section does not necessarily shallow upward so as to be recognized as an RST. Rather, it is abruptly truncated by a prominent unconformity that is recognized at most localities in the study area by: (1) the commonly irregular upper surface of the member, which at many localities is either partially replaced or overlain by paleocaliche (fig. 53A); and (2) the presence of green shale within interparticle pores and vugs in the limestones at the top of the Schroyer (Mazzullo et al., 1995).

Throughout most of the study area, the RST and overlying HST in the upper Schroyer generally appear to record a relatively simple history of minor flooding, deposition of carbonate sands, and forced regression. In contrast, the depositional history of the thickened RST section at locality 137 in Marshall County is much more complex because several shallowing cycles are inferred here (fig. 44). These additional cycles may suggest local autogenic and/or tectonic controls during deposition of the RST at this locality.

Matfield Shale

Regional Thickness Trends

The thickness of the Matfield Shale generally increases from south to north, from about 25 to 41 ft (7.6–12.5 m) in Cowley County, within the Walnut syncline, to 49–66 ft (14.9–20.1 m) in Marshall and Gage counties, on the eastern edge of the Central Nebraska and Salina basins (fig. 54B). The relatively thick (~50 ft [15.3 m]) Matfield section in adjoining parts of northwestern Butler, southwestern Chase, Marion, and western Morris counties occurs in the transition zone between the Nemaha Ridge and the Salina basin. The excessive thicknesses of the formation reported by Bass (1929) and Bayne (1962) in Cowley County (55–65 ft [16.8–19.8 m]), and by Byrne et al. (1959) in Marion County (80 ft [24.4 m]), were not verified by our studies. Anomalously thick Matfield sections occur in four areas: (1 and 2)—atop the northwest-southeast-trending graben in northwestern Wabaunsee-southeastern Riley counties, and apparently, also in the graben in southern Chase County (measured sections 124 and 83–84, respectively). In these areas the formation is about 50–51+ ft thick (15.3–15.6 m). Thickness of underlying strata in these areas is not known; (3)—in a northwest-southeast-trending embayment in northeastern Butler County, within the Walnut syncline, where the formation is at least 48 ft (14.6 m) thick (fig. 54B). In this area the underlying Schroyer is not anomalously thin (fig. 52B), although the area may have been somewhat of an embayment during deposition of the Threemile and the Havensville (figs. 46, 50); and (4)—in southernmost Cowley County, where the formation is 41 ft (12.5 m) thick. In this area the underlying Schroyer is not anomalously thin (fig. 52B). The formation thins toward the Humboldt fault zone and the Nemaha Ridge in south-central Butler County and is relatively thin atop the Nemaha Ridge in the southwestern part of this county (fig. 54B).

The Wymore and Blue Springs Members of the Matfield Shale are interpreted as a long-term, dominantly tLST, whereas the intervening Kinney Member represents a dominantly marine HST. Details of this stratigraphy, however, are considerably more complex, and are discussed and illustrated below in figs. 56–58 and 61, the locations of which are shown in fig. 54A. The regional persistence of the dominantly marine Kinney section suggests fundamental allogenic control on its deposition.

Wymore Member

Maximum thickness of the Wymore occurs in Gage County, Nebraska (about 25 ft or more [7.6 m]) along the eastern edge of the Central Nebraska basin, and the member thins to a minimum of 5 ft (1.5 m) in southern Cowley

County, within the Walnut syncline (fig. 55A). This trend may suggest a dominant source of siliciclastics from the north-northeast and may reflect decreased rates of accommodation from north to south during deposition of the Wymore. The east-west-trending area of relatively thin Wymore section in Marshall and northern Riley and Pottawatomie counties suggests a slightly positive feature in this area, atop both the Nemaha Ridge and the Salina basin, during deposition of this member; this area was not a positive feature during deposition of the Schroyer (fig. 52B).

Wholly terrestrial LST facies in the Wymore, represented by unfossiliferous red and green shales/mudrocks and paleosols, occur in Marshall and Riley counties, and are in direct contact with the overlying marine Kinney (fig. 56). Such a relationship suggests rapid transgression, with the initial marine flooding surface occurring at the base of the Kinney (e.g., evident at measured sections 137 and 138, fig. 56). Similar relationships are also noted at some localities in Butler County (e.g., measured section number 35, fig. 58). At most localities south of central Riley County, facies at the top of the Wymore instead are mostly unfossiliferous, light-colored shales and mudrocks interpreted as marginal-marine facies. Sparsely fossiliferous mudrocks occur within the upper Wymore only at measured section 110B in Geary County (fig. 56). In these areas the base of the TST instead is believed to occur within the uppermost Wymore rather than at the base of

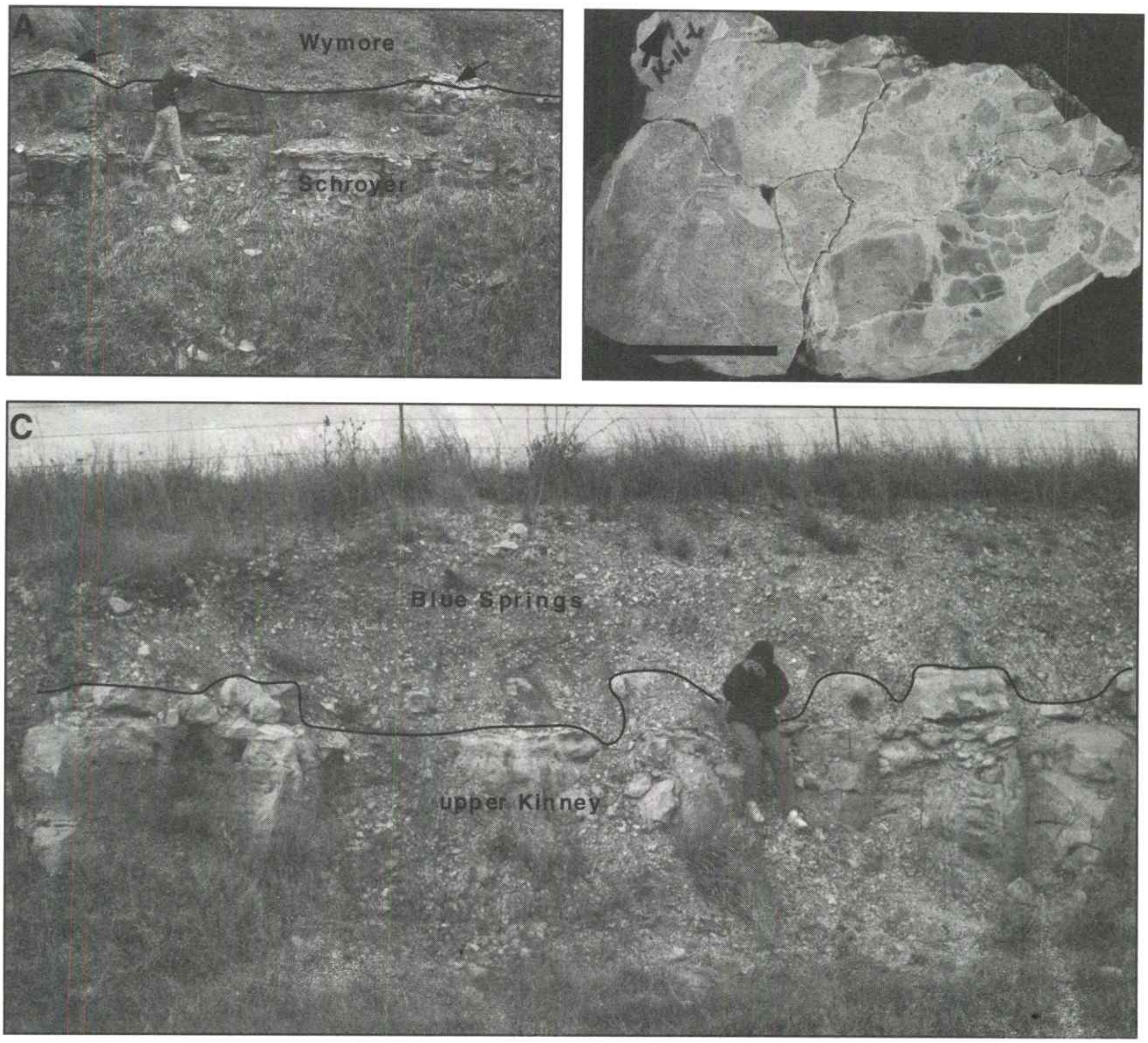


FIGURE 53—A) Roadcut along US–54 at measured section number 39 in Butler County, Kansas, showing uneven, unconformable top of the Schoyer; arrows point to thick paleocaliche at the top of the member and within the basal Wymore. B) Slab showing intraclasts with pendant cements (small arrows) at the top of the Kinney; bold arrow points to stratigraphic top (length of scale 3 inches (7.6 cm). Sample from measured section number 48, Butler County, Kansas. C) Roadcut along 82nd Street in Butler County (measured section number 38) showing uneven, unconformable top of the Kinney and inferred dolines. The dolines are filled with green shale, whereas the overlying Blue Springs is red shale.

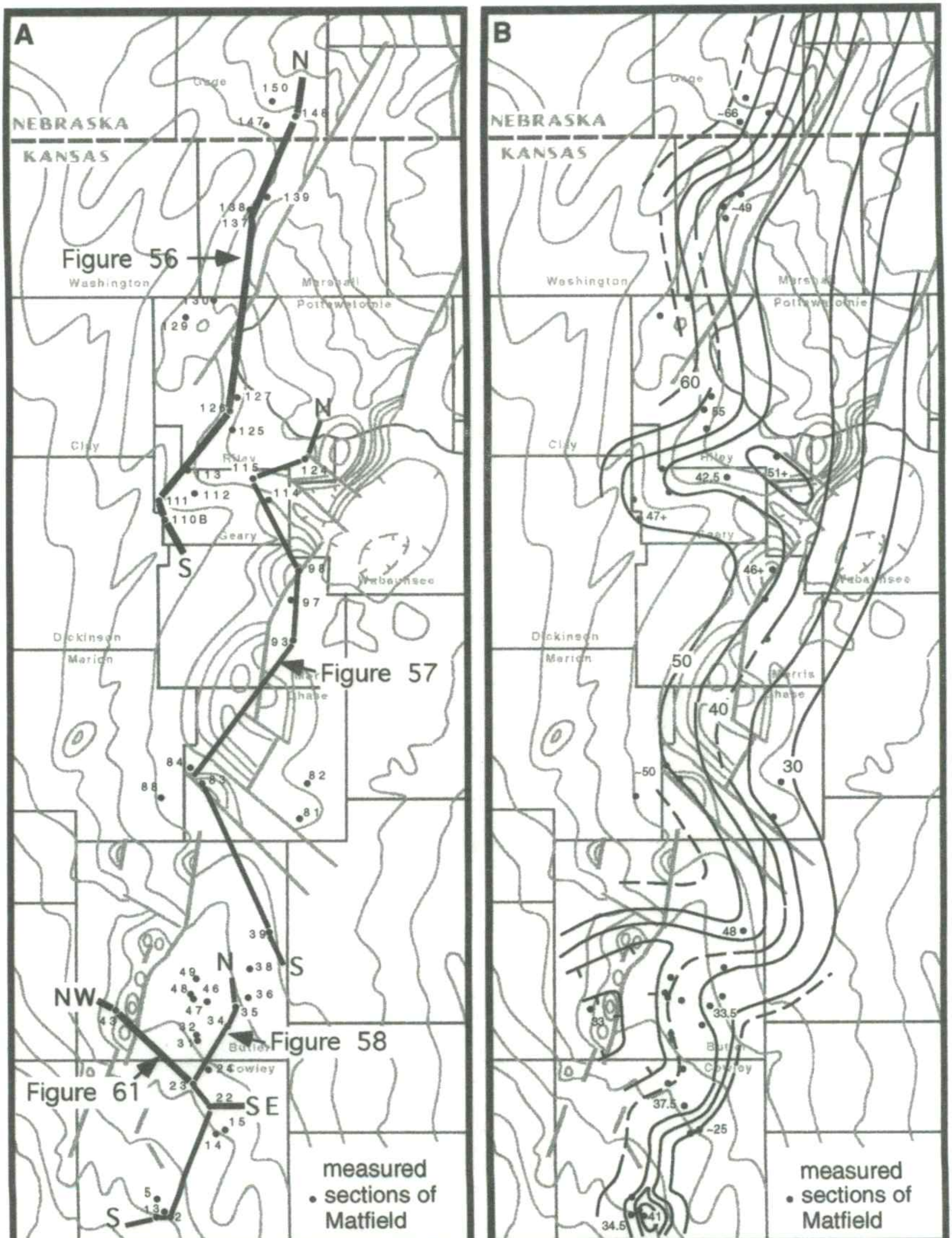


FIGURE 54—A) Location of cross section figs. 56–58 and 61. B) Isopach of Matfield Shale (CI = 5 ft [1.5 m]).

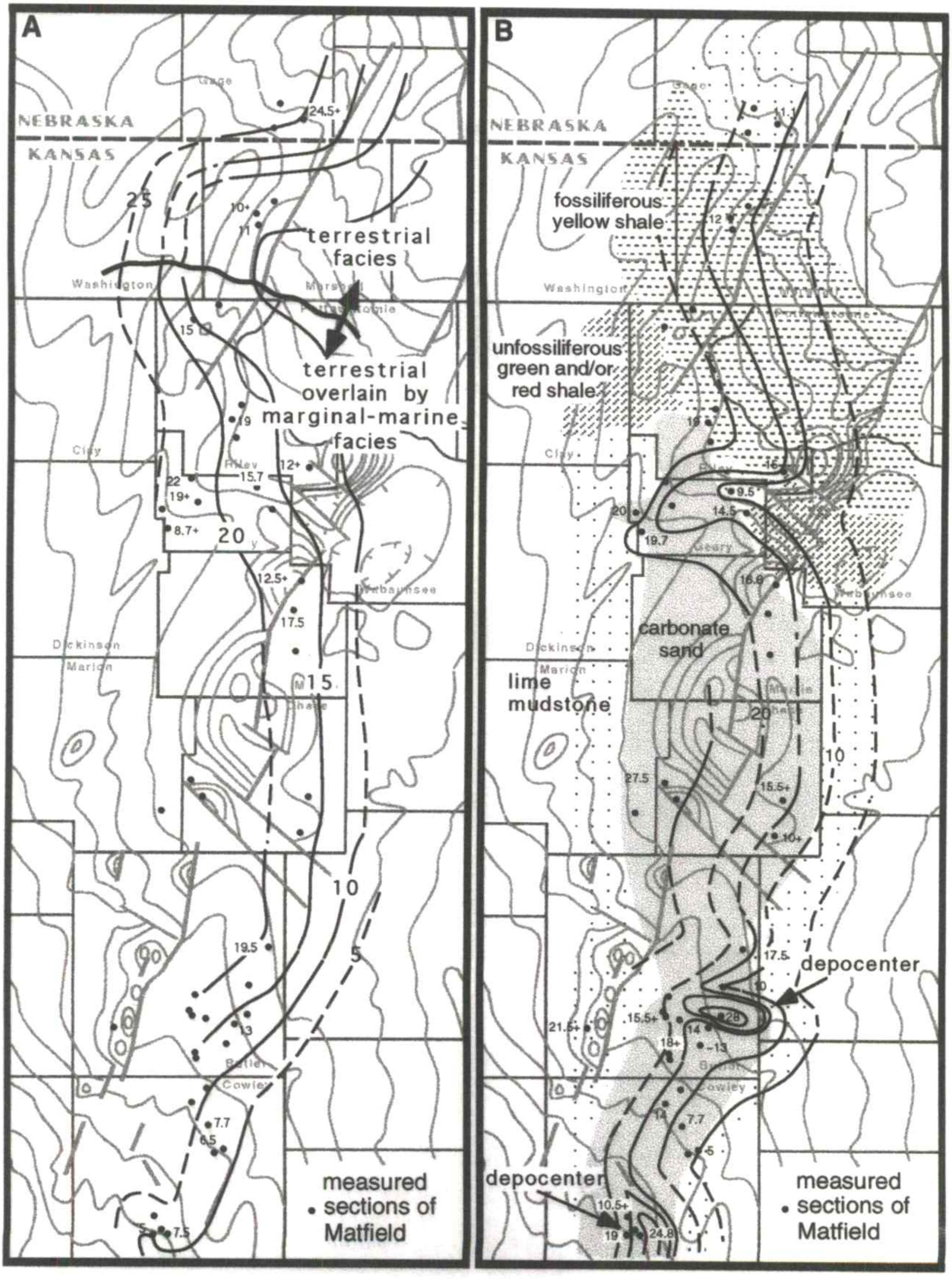


FIGURE 55—A) Isopach of the Wymore (CI = 5 ft [1.5 m]), and distribution of facies. B) Isopach of the Kinney (CI = 5 ft [1.5 m]), and inferred facies in the upper beds of the member.

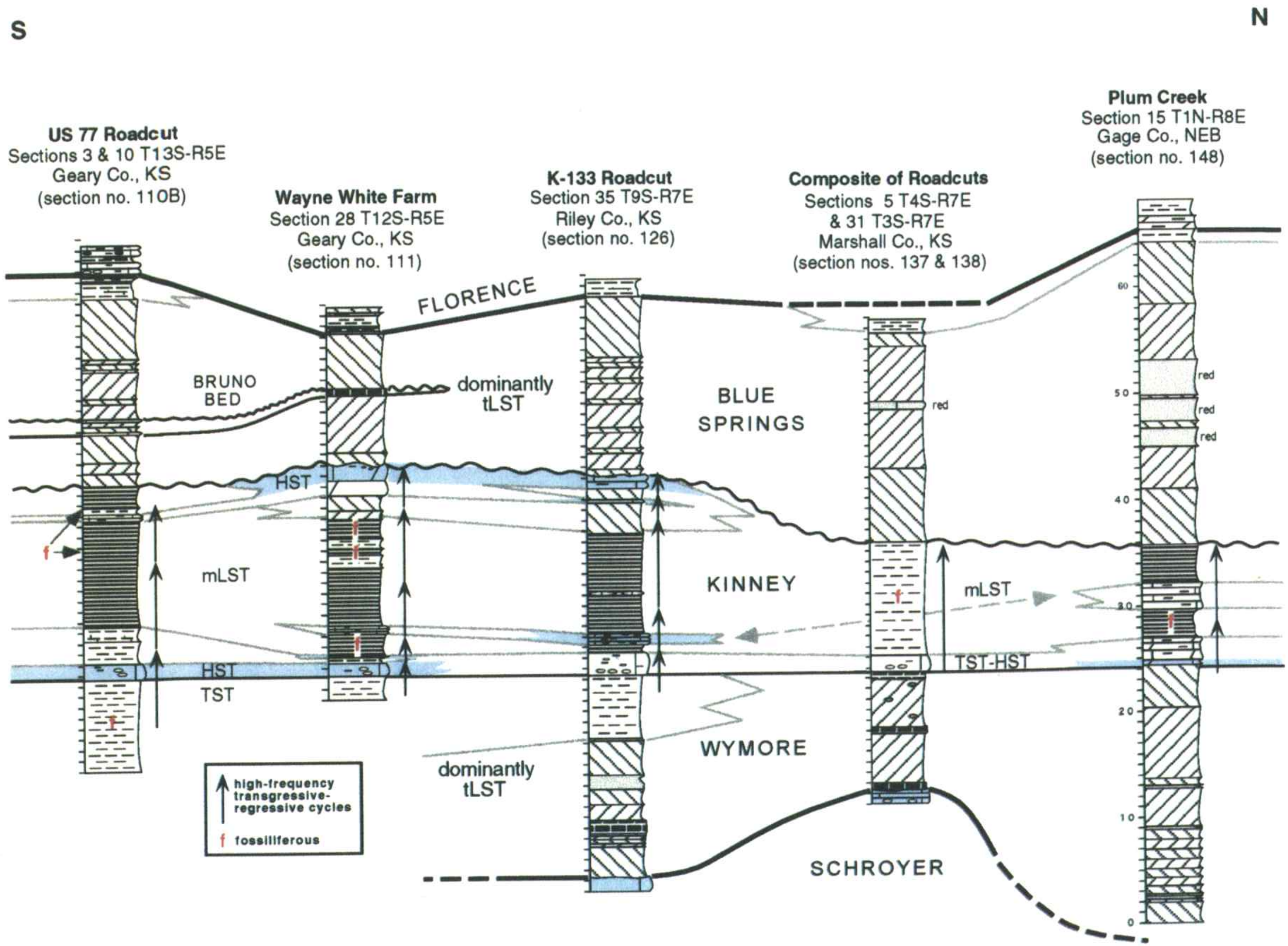


FIGURE 56—Section in part of northern Kansas and Nebraska illustrating stratigraphy and inferred facies of the Matfield Shale. Note erosional pichout of the Bruno bed, and unconformity at the top of the carbonate sands in the upper Kinney. Dashed, arrowed line with question marks is a conceptually possible correlation of limestones in the Kinney. Fossiliferous siliciclastics and high-frequency transgressive-regressive cycles are shown.

the Kinney. Such contrasting positions of the initial flooding surface may suggest transgression from south-southwest to north-northeast in the study area. Alternatively, they may indicate some degree of tectonic or compactional-induced subsidence late in Wymore time in that area southward from Riley County so that it was low, and hence, was flooded earlier than areas to the north. The southward change from totally terrestrial siliciclastic strata in the Wymore, to terrestrial strata overlain by inferred marginal-marine shales and mudrocks at the top of the member, however, does not coincide with location in respect to the Nemaha Ridge or the Walnut syncline (fig. 55A).

Four thin beds of limestone occur within the Wymore and are enclosed by terrestrial shales and mudrocks, at measured section number 115 in Geary County (fig. 57; see Appendix for details). The stratigraphically lowest and highest limestone beds here are unfossiliferous, shaly lime mudstones, the uppermost bed containing plant debris. The middle bed also is shaly and contains ostracodes. These beds may be freshwater limestones; the ostracodes in the middle bed currently are under study. If these limestones instead are marine, then they might indicate short-lived, high-frequency marine transgressions that occurred for some unknown reason only at this locality, a distribution that would argue against allogenic control on their deposition. A 2-inch (5.1-cm)-thick bed of unfossiliferous, brecciated limestone with calcite-lined vugs and secondary calcite veins occurs about 6 ft (1.8 m) below the top of the Wymore at measured section number 126 in Riley County (fig. 56), and it likely represents replaced evaporites (terrestrial or sabkha?). Other than these occurrences, limestones are not found in the Wymore anywhere else in the study area.

Kinney Member

Except for three anomalous areas, the thickness of the Kinney is mostly uniform in a north-to-south direction across the study area; the member generally thickens westward from about 5 to 27.5 ft (1.5–8.4 m)(fig. 55B). Deposition of the relatively thin (9.5 ft [2.9 m]) Kinney at measured section 115 in Geary County defines the apex of an apparent east-west-trending, slightly positive area atop the Nemaha Ridge which was not in existence during deposition of the Wymore (figs. 55A, B). However, a similar slightly positive feature was present at this location during deposition of the Schroyer (fig. 52B). This thinning, which roughly coincides with a southwest-plunging nose on the top of the Precambrian, also is reflected in the isopach of the Matfield Shale (fig. 54B). The positive area that existed immediately to the north, in Marshall County, during deposition of the Wymore was not present in Kinney time (figs. 55A, B). A small positive area may also be present in central-southern Butler County (figs. 54B, 55B). The thick Kinney at measured section 36 in southeastern Butler County (28 ft [8.5 m]), and at section 2 in southernmost Cowley County (24.8 ft [7.6 m]), defines local depocenters of increased accommodation within the Walnut syncline (fig. 55B).

The stratigraphy and facies of the Kinney are highly complex. Superimposed on its relative highstand position within the Matfield Shale, the overall tripartite lithologic subdivision of the member (carbonate-siliciclastic-carbonate), notwithstanding local facies changes, is traced throughout most of the study area (figs. 56–58), and therefore, appears to have been allogenically controlled. This motif involved two relative highstands, represented by the lower and upper carbonates, separated by a relative lowstand of marginal-marine facies (mLST). Possible short-term emergence during deposition of the mLST may be indicated at four widely separated localities in the study area: (1–3)—in presumably correlative strata in the upper part of the unit at measured sections 34 in Butler County (fig. 58), 98 in Morris County (fig. 57), and 111 in Geary County (Appendix), where the otherwise sparsely fossiliferous section contains thin lenses of unfossiliferous, red shale and/or mudrock; and (4)—at measured section number 84 in Chase County (fig. 57), where relatively abundant calcite nodules occur in a zone about 8 ft (2.4 m) above the base of the Kinney, which is stratigraphically below the section containing red shale at the above-mentioned localities. These nodules may be paleocaliche, although whether they are Permian or of more modern vintage is uncertain. The inability to trace this possible exposure surface regionally may suggest that it is not of allogenic origin. Superimposed on the tripartite cyclicity of the Kinney, however, is the erratic occurrence of from one to five, higher-frequency, transgressive-regressive cycles within the member, which are not correlated uniformly throughout the study area (figs. 56–58). Together, such a hierarchy of cyclicity, and the only local occurrence of possible emergence in the mLST, document the complex interplay between eustatic and local autogenic (and possibly, tectonic) controls on deposition of the Kinney Member.

Correlation of the tripartite Kinney section, and recognition of the top of the member at the highest occurrence of limestone, are relatively straightforward southward from measured section number 115 in Geary County (figs. 56–58). Northward from here, however, such relationships are more complex, and resolution of Kinney stratigraphy is complicated by the fact that only few outcrops that expose the Kinney and bounding strata can be found (fig. 56, and Appendix). The tripartite subdivision of the Kinney is not recognized, for example, at measured sections 124 in Riley County (fig. 57) and 137–138 in Marshall County (fig. 56) where the upper carbonates are absent. Instead, the section between the basal limestone of the member and the base of the section of red and/or green shales/mudrocks in the Blue Springs at these localities consists entirely of mLST shales. The tripartite subdivision of the Kinney is only poorly developed at measured sections 126 in Riley County and 110B in Geary

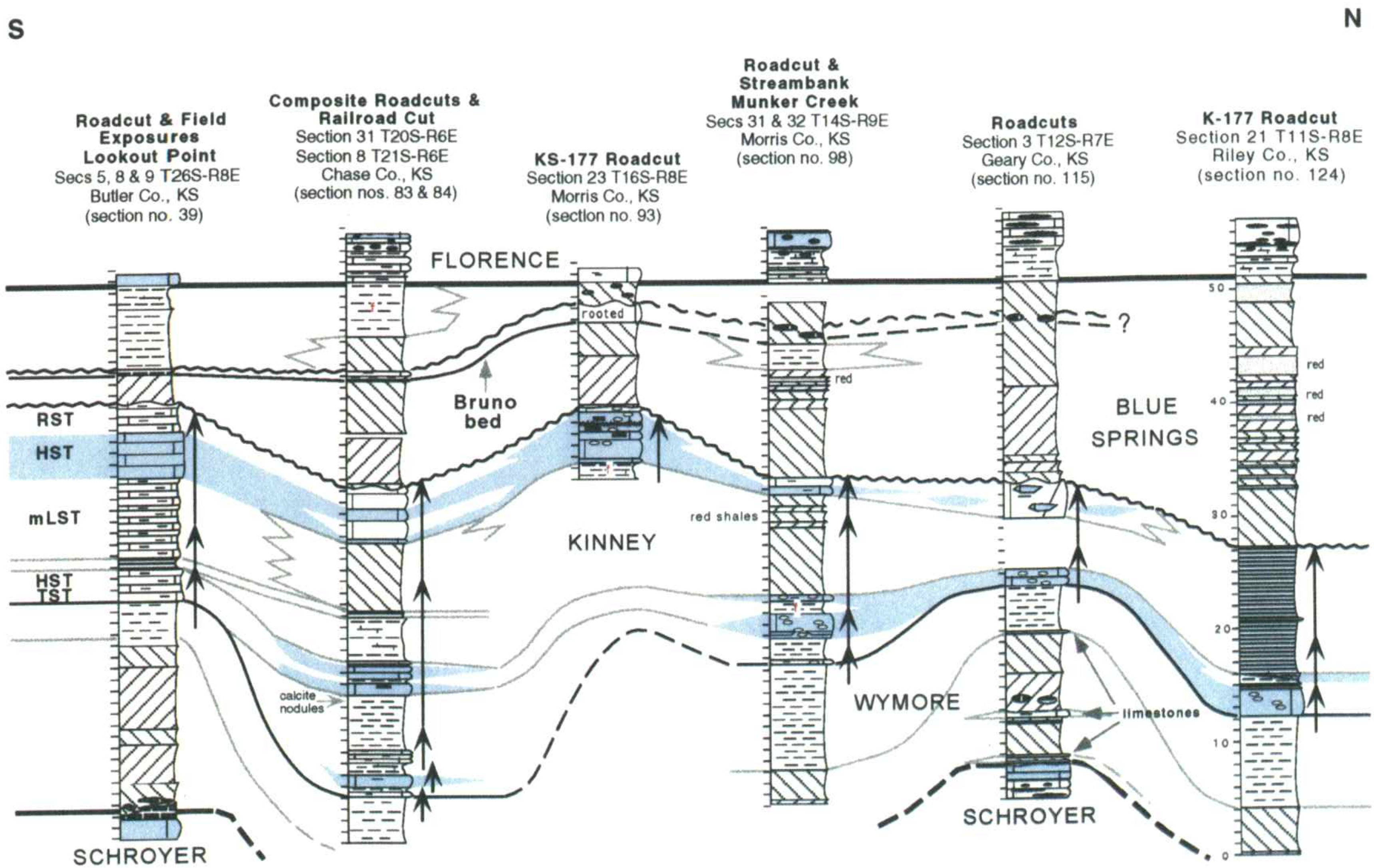


FIGURE 57—Section from Riley to Butler County showing stratigraphy, inferred facies, and correlation of units within the Matfield Shale. Additional legend as in fig. 56.

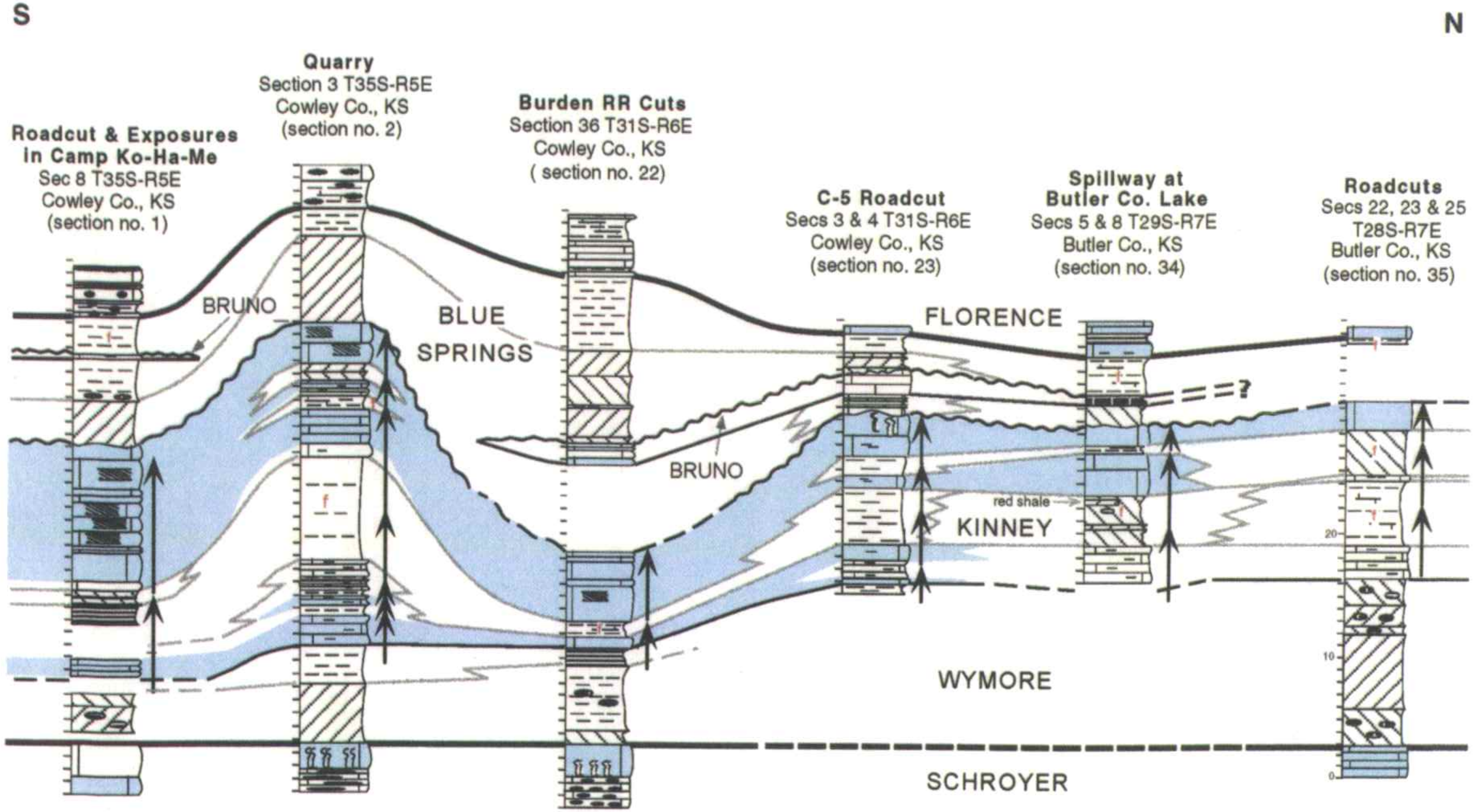


FIGURE 58—Section through south-central Kansas showing stratigraphy, inferred facies, and correlation of units within the Matfield Shale. Additional legend as in fig. 56.

County (fig. 56). Yet, carbonates once again are present at the top of the member to the west, and down-paleodip of, these two and other localities; compare the following sections that illustrate these dip relationships: (a) measured sections 126 and 110B versus 111 (fig. 56). At the latter locality the upper Kinney is dolomitized and is interpreted as a nearshore-marine facies that contrasts the more open-marine carbonate sands farther downdip; and (b) measured section 124 versus 115 (fig. 57). Based on these observable relationships, we contend that the upper Kinney changes facies from carbonate sands, in central to southern Kansas, to marginal-marine shales in northern Kansas (fig. 55B). Interbedding of these contrasting lithologies at several localities (e.g., measured section number 110B in Geary County) supports this contention. The upper limestone locally changes facies via interbedding with terrestrial to marginal-marine, green shales and/or mudrocks (e.g., measured section 126 in Riley County [fig. 56]). Unless these facies relationships are recognized, picking the top of the member is most difficult as was noted by Condra and Upp (1931) and Jewett (1941). One would be tempted to pick the top of the member, for example, at the top of the lower limestone at those localities where the upper limestone was absent (e.g., at measured sections 124 and 137–138). Such a pick is erroneous, however, and we defend our facies model of Kinney stratigraphy on the basis of the following observable field relationships: (1) local interbedding of marginal-marine shales and limestones; (2) the lower limestone is regionally correlative and is always overlain by a siliciclastic-dominated mLST section (locally with interbedded carbonates that could further complicate the issue [fig. 57]) that also is regionally correlative. Throughout most of Kansas, this mLST lies beneath the upper limestone; and (3) the upper limestone and its presumed marginal-marine equivalents (and locally, terrestrial shales/mudrocks) both overlie this mLST tract, and in turn, both are always overlain by a regionally correlative section of terrestrial red and green shales in the basal Blue Springs. Hence, we agree with Jewett (1941) that the Kinney is a "zone" of carbonates and fossiliferous shales/mudrocks that contrasts the dominantly unfossiliferous terrestrial deposits of the immediately underlying Wymore and the overlying Blue Springs members. For these reasons we pick the top of the Kinney at the top of the marginal-marine shales at the principal reference section in Nebraska, rather than at the top of the subjacent limestone (figs. 12B, 56).

Basal transgressive beds of the Kinney are intraclastic (lime pebbles) and locally oncolitic limestones northward

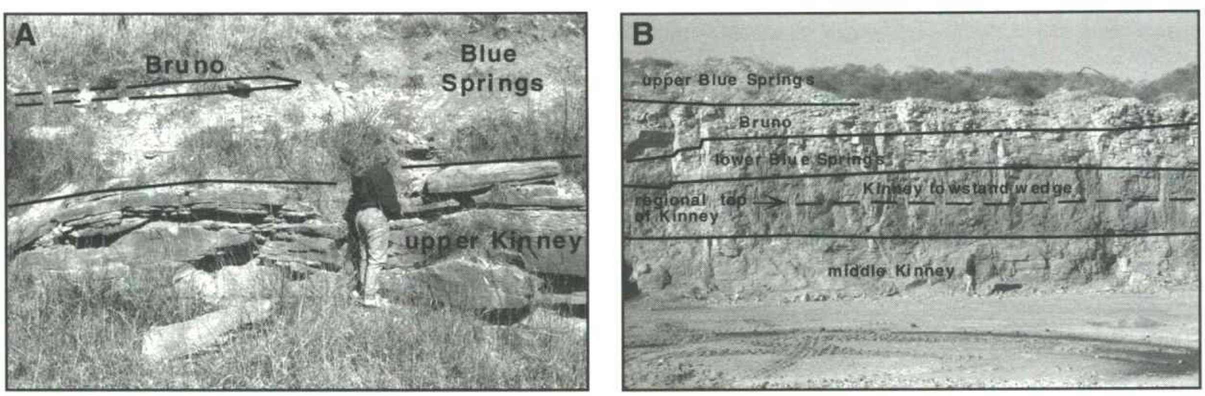


FIGURE 59—A) Outcrop along abandoned railroad track showing erosional truncation of the Bruno bed: measured section number 3, Cowley County, Kansas. B) Outcrop of the Kinney, Bruno, and Blue Springs at Bannon quarry, measured section number 43, Butler County, Kansas. Note that the top of the regionally recognized Kinney here is overlain by an additional section of Kinney, which represents part of the lowstand marine wedge shown in fig. 61.

from measured section number 81 in Chase County. In contrast, they are prominent *Derbyia*-rich limestones, locally with abundant *Composita* spp., southward from Chase to Cowley County (figs. 56-58). The maximum flooding surface and HST of the member are obscure, but are believed to occur within the middle to upper part of this basal carbonate unit (fig. 56). The middle Kinney consists mainly of marginal-marine siliciclastics northward from Geary County, and interbedded marginal-marine siliciclastics and limestones, and at some localities terrestrial green and red siliciclastics, southward to Cowley County (figs. 56-58). Porous and non-porous, HST carbonate sands, and locally, RST sections that fine-upward and also shallow-upward from carbonate sand to lagoonal or peritidal mud facies, occur in the upper Kinney over a large part of the study area southward from Riley County (e.g., measured section 39, fig. 57). The sand tract passes westward to presumably more offshore, micritic limestones (fig. 55B). The section of carbonate sands thickens to the south to a maximum of about 11 ft (3.4 m) in southernmost Cowley County (figs. 56–58), defining a small depocenter of increased accommodation within the Walnut syncline that may have been a minor depocenter during deposition of the Wymore (fig. 55). In central Kay County, Oklahoma, marine facies of the Kinney are represented by only a few inches of non-porous, pelecypod-rich carbonate sand which are underlain and overlain by a thick section of red beds (Mazzullo and Teal, 1994; Mazzullo et al., 1995). As discussed above, facies at the top of the Kinney in northern Kansas instead include marginal-marine siliciclastics, and locally, terrestrial shales/mudrocks (fig. 55B). It does not appear that sands were deposited and then removed by erosion in these areas. Rather, we call upon facies changes to explain their absence.

A prominent unconformity is recognized at the top of the Kinney at most localities where the upper carbonates are present (figs. 56–58). Evidence of this unconformity, which documents abrupt forced regression, includes: (1) green shale within interparticle pores and vugs in the rocks; (2) apparent erosional thinning of these beds (figs. 56, 57); (3) the local presence of residual lag gravels, with pendant calcite cements on the undersides of component lime clasts (fig. 53B); and (4) at several localities, an irregular upper contact with small dolines filled with green shale (e.g., fig. 53C). Erosion along this unconformity may account for the removal of RST facies, which are present only locally in south-central Kansas (fig. 57). Where marginal-marine shales instead occur at the top of the member in northern Kansas and Nebraska, the unconformity is indicated by the presence of a prominent paleosol at the Kinney–Blue Springs contact. The Kinney is everywhere directly overlain by terrestrial red and green shales and/or mudrocks in the basal Blue Springs.

Blue Springs Member and Bruno bed

The thickness of the Blue Springs Member ranges from 5 ft to 28 ft 5 inches (1.5–8.6 m), and generally increases from east to west across the study area (fig. 60A). Maximum thickness appears to occur on the edge of the Central Nebraska and Salina basins in northern Riley, Marshall, and Gage counties (fig. 60A). This overall trend suggests, as was the case for the Wymore, maximum accommodation in the north and a dominant supply of siliciclastic sediments from the north-northeast; similar increase in accommodation in this area is not apparent during deposition of the Kinney (fig. 55B). This regional trend, however, is interrupted by several localities at which the member is anomalously thick, and as many as five additional depocenters apparently existed during deposition of these strata (fig. 60A): (1 and 2)–one in north-central Cowley County and another in central Butler County, atop the Walnut syncline, at which locations the member is at least 22 ft (6.7 m) thick. These depocenters are separated by a sharply defined, intervening positive area in south-central Butler County within which the member is anomalously thin (5–7.5 ft [1.5–2.3 m]). The depocenter in Cowley County appears to have formed during deposition of the Blue Springs insofar as only this member appears to be thick at this location (compare figs. 55A,B and 60A). Increased thickness of the member here is related to an expanded section of limestones (i.e., the Bruno, discussed below). The depocenter in Butler County, which instead is infilled by siliciclastics, may have begun to form during deposition of the Kinney (fig. 55B); (3)–a depocenter in southern Geary and western Morris counties, where the eastward-thickening member is at least 22 ft (6.7 m) thick atop the transition zone between the Nemaha Ridge and the Salina basin. This area, also infilled with siliciclastics, also may have begun to form during deposition of the Kinney (fig. 55B); and (4 and 5–the grabens in southern Chase and in adjoining parts of Riley and Wabaunsee counties, along the edge of the Nemaha Ridge, where the siliciclastic-dominated member is at least 13 ft and 24 ft thick (4 and 7.3 m), respectively. Because of the lack of outcrops exposing the entire Matfield Shale at these locations, whether or not these grabens were depocenters prior to Blue Springs time is uncertain (fig. 55).

Facies in the Blue Springs from Gage County, Nebraska, southward to Morris County, Kansas, are represented by tLST beds: unfossiliferous, red and green shales, mudrocks, and shaly siltstones (figs. 56, 57). Similar facies persist farther south, although the upper few feet of the member are mostly fossiliferous mLST siliciclastics in south-central Kansas (figs. 57, 58). These pelecypod-dominated strata are a conspicuous, readily mappable horizon in this area of the state (Mazzullo and Teal, 1994; Mazzullo et al., 1995).

As discussed in the first part of this paper, a thin but conspicuous bed of carbonate, the Bruno, at or above the middle of the Blue Springs is recognized at many localities

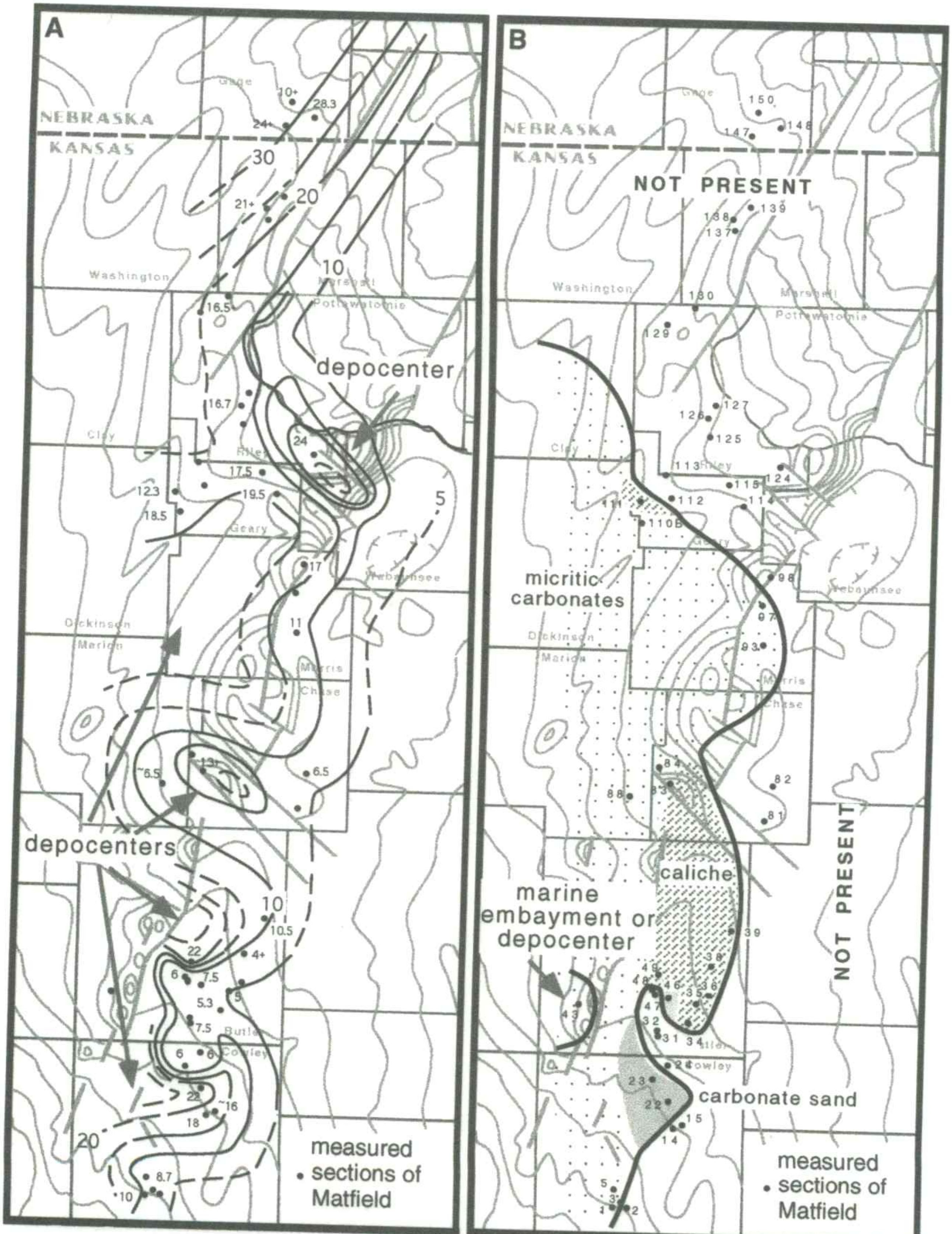


FIGURE 60—A) Isopach of Blue Springs Member (CI = 5 ft [1.5 m]) showing locations of depocenters. B) Distribution of the Bruno bed and inferred facies therein.

southward from Geary County; to the north, presumed equivalent strata are represented by a zone of terrestrial siltstones (figs. 56–58). At some localities in Geary and Morris counties (measured sections 115 and 98, respectively), for example, the Bruno-equivalent horizon appears to be terrestrial shales/mudrocks with incipient paleocaliches (fig. 57). Red siltstones and limestones are interbedded at some localities (e.g., at measured section number 110B: fig. 56). Marine lithologies in the Bruno (fig. 60B) include fossiliferous and bioturbated lime mudstone to shaly biowackestone with brachiopod and pelecypod fragments. At one locality in Cowley County (measured section number 22 [fig. 58]), the unit consists of biopackstone and grainstone dominated by foraminifers, with accessory crinoids, pelecypod and brachiopod fragments, and high-spired gastropods. The Bruno is rooted at some localities (e.g., measured section number 93, Morris County [fig. 57]) and partially to entirely calichified at others (e.g., measured sections 111 in Geary County and 39 and 34 in Butler County). An unconformity at its top is indicated by the presence of: (1) paleocaliche; (2) intraclasts and/or lenses of red and green shale filling vugs and/or dispersed within a carbonate matrix; (3) rootcasts; (4) locally, an irregular, erosional upper contact (e.g., measured section 23, Cowley County [fig. 58]); and (5) erosional truncation of the unit between closely spaced outcrops (e.g., fig. 59B). At measured section number 110B in Geary County, the Bruno consists of two thin beds of lime mudstone (each 3 inches, or 7.6 cm, thick), with streaks of green shale that are separated, underlain, and overlain by terrestrial red and green shales (fig. 56). These relationships suggest that, at least locally, there are multiple unconformities within this unit related to forced regressions within a Bruno section composed of two high-frequency cycles.

An exposure of the Kinney and Blue Springs at the Bannon quarry in southwestern Butler County (measured section number 43 [fig. 59C]) provides the opportunity to view the stratigraphy of this section along a generally dip-parallel cross section from Cowley into Butler County (fig. 61). That the strata exposed in this quarry are within the Matfield Shale is confirmed by detailed mapping in the area (Mazzullo and Teal, 1994). At the relatively updip outcrops at the Burden railroad cut in Cowley County (measured section 22), for example, upper beds of the tripartite Kinney are cross stratified and bioturbated, generally nonporous carbonate sands overlain by about 7 ft (2.1 m) of concealed lower Blue Springs section described by Condra and Upp (1931, p. 40) as gray shale. The overlying 1 ft 9 inches (0.5 m) of presently exposed limestone includes a basal fining-upward bed of biopackstone to mudstone overlain by 0.5 ft (0.15 m) of white, nonporous foraminiferal grainstone. This section was specifically referred to as the Bruno in Condra and Upp's (1931) definition and description of this unit, the total exposed thickness of which they reported to be 2.5 ft (0.8 m). The Bruno is overlain here by terrestrial red and green shales and mudrocks, and then, by unfossiliferous yellow-reddish-brown mudrocks, in the upper part of the Blue Springs. We correlate the tripartite Kinney at this location based on stratal architecture, lithology, and biota to that at measured section 23, a few miles to the northwest and downdip of the Burden railroad cuts (fig. 61). The Kinney here is unconformably overlain by 1 ft 4 inches (0.4 m) of interbedded, unfossiliferous red and green shales and lime mudstones with green and red shale-filled vugs and fissures, followed by 1 ft 8 inches to 2 ft (0.5–0.6 m) of soft, platy-bedded biowackestone to packstone with green shale-filled fissures and vugs at its unconformable top. In turn, this section is overlain by 2 ft 8 inches (0.8 m) of Blue Springs strata which include, in ascending order, unfossiliferous green, red, and yellow shale and mudrock beneath the Florence. We correlate the soft, platy-bedded limestones and overlying siliciclastics to the Bruno and upper Blue Springs, respectively, at the Burden railroad-cut exposures (fig. 61). We suggest that the underlying section of interbedded lime mudstones and red-green shales (directly above the unconformity at the top of the Kinney) at measured section number 23 represents a facies transition within the lower Blue Springs, beneath the Bruno, from terrestrial strata to the southeast, east and north, to bioturbated, light-colored, marginal-marine mudrocks and shaly lime mudstones at the Bannon quarry to the west, which is the farthest downdip outcrop of the Kinney and Blue Springs in the study area (fig. 61). This aspect of correlation is discussed further in the next paragraph. However, this section possibly could be included within the Bruno if the Bruno downlapped onto the top of the Kinney, but we have no definitive outcrop information with which to evaluate this possibility. Future subsurface studies in this area may assist in resolving this particular issue.

The basal 7.5 ft (2.3 m) of exposed section at the Bannon quarry are lithologically and biotically identical to the middle Kinney limestone-dominated section at, for example, Lookout Point in Butler County (measured section number 39 [fig. 57]) and other exposures in south-central Kansas. Likewise, the overlying 6 ft 8 inches (2 m) of porous, foraminiferal carbonate sand at the quarry, which are prominently vertically burrowed in the upper 3 ft (0.9 m), are lithologically and biotically correlated to the upper Kinney at, for example, measured sections 23 and the Burden railroad-cut exposures in Cowley County (fig. 61), Lookout Point (measured section number 39 [fig. 57]), and elsewhere in south-central Kansas (Mazzullo and Teal, 1994; Mazzullo et al., 1995). It is the top of these strata that are regionally recognized as the unconformable top of the Kinney throughout a large part of the study area (e.g., figs. 57, 58). However, these strata at the quarry are apparently conformably overlain by an additional section that consists of a 6 ft 4 inches (1.9-m)-thick bed of locally cross stratified and vertically burrowed biowackestone to porous biopackstone that grades upward to shaly lime mudstone, with no evidence of an unconformity at its top.

By lithologic correlation, these beds are considered to be an "extra" section of the Kinney not recognized elsewhere in the study area; the top of these beds is therefore considered to be the top of the expanded Kinney Member at this locality. In turn, the Kinney is overlain by 5 ft 4 inches (1.6 m) of bioturbated but otherwise unfossiliferous, yellow-gray mudrock and shaly lime mudstone which we recognize to be in the lower Blue Springs Member (fig. 61). By correlation based on regional stratigraphic position, biota, and lithology, the overlying Bruno here is 4 ft (1.2 m) of thick-bedded, bioturbated lime mudstone, with scattered crinoids and fragments of pelecypods and brachiopods. It is overlain by 3 ft (0.9 m) of exposed unfossiliferous, terrestrial red beds of the upper Blue Springs.

We interpret the inferred stratigraphic architecture of the upper Kinney, lower Blue Springs, Bruno, and upper Blue Springs as follows. The unconformity that we recognize at the top of the Kinney at most localities in the study area indicates forced regression and subaerial exposure. The apparent absence of an unconformity at the top of the correlative carbonate sand section at the Bannon quarry indicates that this area was not then subaerially exposed. The occurrence of the additional 6 ft 4 inches (1.9 m) of Kinney section here, conformably overlying the otherwise regionally correlative top of the Kinney, is believed to represent a lowstand wedge of marine sediments deposited in a marine embayment during regional exposure elsewhere in the study area. The apparent absence of an unconformity at the top of this expanded Kinney section suggests this area was topographically low enough that it was not subaerially exposed. In fact, these marine strata are overlain here by inferred marginal-marine, bioturbated mudrocks in the lower Blue Springs, which contrast the dominantly terrestrial facies of the lower Blue Springs to the south, east, and north of this embayment. It is in this regard that we consider the interbedded lime mudstones and red-green shales at measured section number 23 to represent the facies transition between terrestrial and marginal-marine strata in the lower Blue Springs in this area (fig. 61). The overlying Bruno is interpreted as a short-lived, transgressive marine phase (or phases) that covered much of southern and central Kansas (fig. 60B). This unit is thin over much of Kansas, but thickens to 4 ft (1.2 m) at Bannon quarry (fig. 61). Hence, the lower Blue Springs and Bruno at the

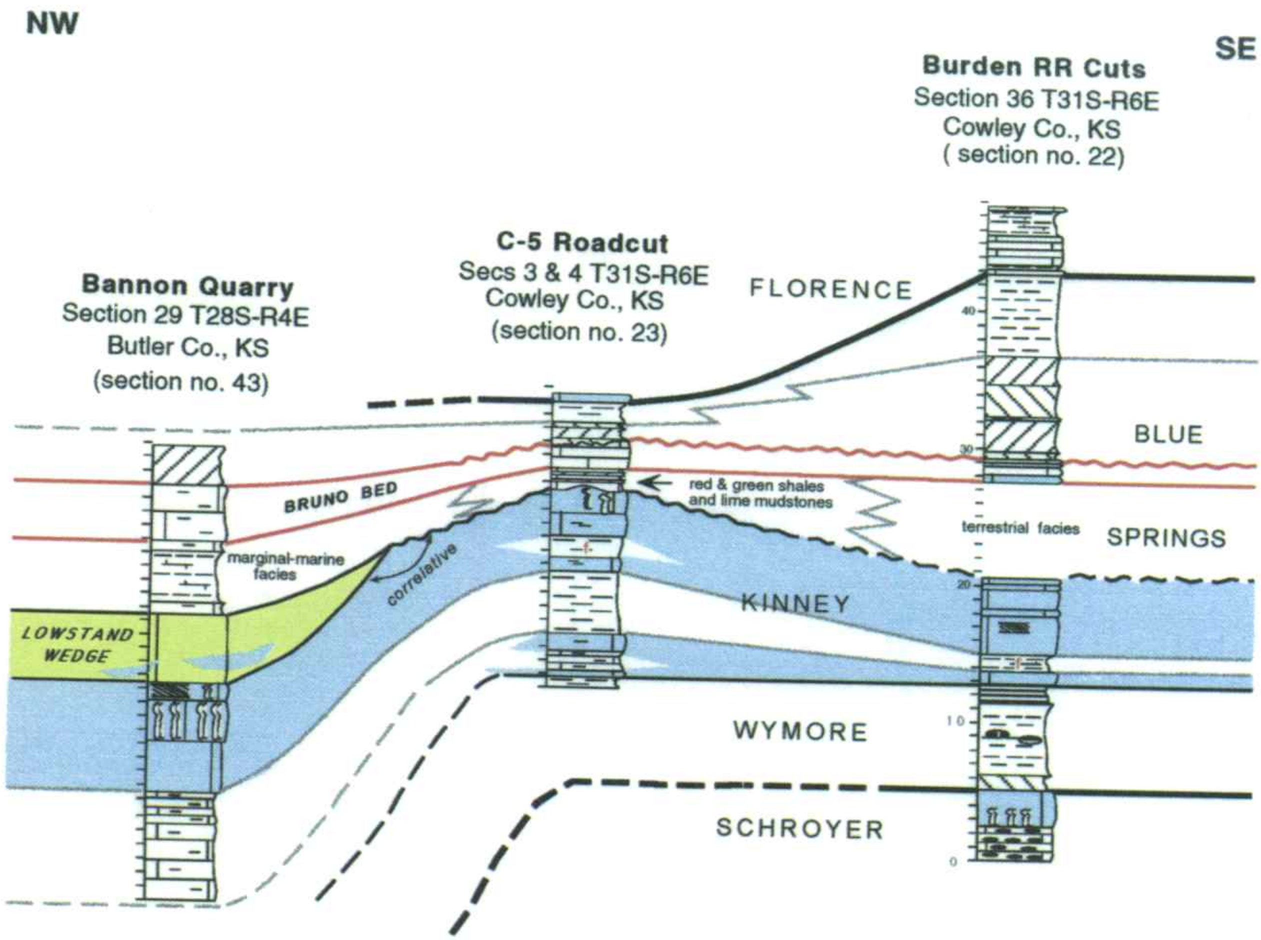


FIGURE 61—Dip-parallel section illustrating inferred lowstand carbonate wedges in Kinney and Bruno, and stratigraphic relationships of the Bruno limestone in south-central Kansas.

Bannon quarry also are nearshore-marine facies. To the southeast, east, and north of Bannon quarry, the Bruno was variously preserved as marine deposits, or was calichified, or it was removed by erosion during a subsequent sea-level lowstand (forced regression), thus accounting for its erratic regional distribution and presence of an unconformity at its top. Red siltstones at the approximate stratigraphic level of the Bruno in northern Kansas and Nebraska (fig. 56) may represent coeval stream or eolian deposits, or alternatively perhaps, areas from which the Bruno was deposited and then totally removed by erosion. Ensuing deposition of terrestrial strata followed by incipient transgression culminate the depositional history of the Blue Springs Member.

The regional extent of the marine embayment in which the Kinney through Bruno lowstand wedges were deposited is not known because of the lack of other Kinney outcrops similarly situated along the western margin of the outcrop belt. Structure on the Precambrian shows that at the Bannon quarry, this embayment is located atop the flank of a high on the Nemaha Ridge (fig. 60B).

Florence Formation

The revised Florence Formation includes the basal non-cherty Cole Creek Member, a middle cherty unit, and where it is present, the upper Oketo Shale Member (e.g., figs. 62A and B, locations of which are shown in fig. 63). Where the Oketo is absent, the upper Florence generally consists of a relatively thin section of non-cherty limestones. The Cole Creek Member is traced from Gage County, Nebraska, to southern Cowley County, Kansas. It varies in thickness across the study area from about 1.8 to 8.2 ft (0.5–2.5 m), and is thickest from central Butler to central Cowley County. It either pinches out by nondeposition in southern Cowley County, or changes facies to cherty shales here (i.e., in the basal Florence at measured section number 1 [fig. 62B]). From the intraformational correlations shown in fig. 62, particularly between measured sections 14 to 83–89 and 130–131 to 136, it appears that the top of the member is a viable stratigraphic datum rather than an irregularly occurring facies change from cherty to non-cherty lithologies. Facies in the Cole Creek generally are represented by fossiliferous mudrocks and micritic limestones, although carbonate sands occur locally in its lower half, and compose nearly half of the member in central Cowley County. Pelecypods are ubiquitous in these rocks, along with various genera of brachiopods, gastropods, and crinoids. The member is interpreted (Mazzullo et al., 1995) as a deepening-upward TST. In south-central Kansas the base of the TST occurs within the fossiliferous mudrocks of the upper Blue Springs Member. Farther to the north, however, light-colored, but unfossiliferous, mudrocks and/or shales of a tLST occur at the top of the Blue Springs from Marion to Gage County (fig. 62). In this area the base of the TST instead is picked at the base of the Florence. Therefore the Florence sea seems to have transgressed from the south-southwest to the north-northeast across the study area.

The overlying Florence is traced throughout the study area and is dominantly cherty and micritic throughout. Like the cherty Threemile and Schroyer, its biota is dominated by bryozoans. Lenses of shallow-water carbonate sand occur near the base of the unit northward from Marion and Chase counties, and also at stratigraphically higher levels at several localities in Butler, Chase, and Morris counties (fig. 62). Fusulinids generally occur in both cherty, micritic limestones and in carbonate sands in the lower to middle part of this unit at many localities in the study area (fig. 62), and clearly are not restricted in their occurrence to beds only a few feet above the base of the cherty section as indicated, for example, by Moore et al. (1951b) and Moore (1964). A thin (generally less than 1 ft [0.3 m]) bed with abundant rugose corals (*Lophophyllidium* spp. and *Heritschia* spp.) a few feet below the top of the Florence is a regionally persistent marker horizon in southern Butler and northern Cowley counties (figs. 62, 63). These corals, attached to commonly brecciated hardgrounds (fig. 64), likely represent a small biostrome. Northward shallowing of facies in the Florence, but still representing subtidal deposits, is indicated by increasing siliciclastic content, including the Oketo, and regional thinning; this shallowing is coincident with the change from limestone to dolomite (figs. 62, 63). The middle Florence is generally interpreted as an extended HST of relatively deeper-water, mostly noncyclic facies, although shallowing-upward cycles are developed at some localities (e.g., measured section number 46 in Butler County [fig. 62B]). Inability to correlate these high-frequency cycles for any distance laterally, however, suggests local autogenic controls on their deposition. The maximum flooding surface occurs toward the base of this middle cherty section (fig. 62). Restriction of siliciclastics to northern Kansas and Nebraska suggests a source area to the north or northeast, and periods of local-shallowing to marginal-marine environments of deposition. We cannot readily correlate these cycles with, for example, shallowing-upward carbonate cycles in central and southern Kansas, and accordingly, we suggest that they may be dominantly related to climatic changes and/or recurrent tectonism in the source area rather than to dominant allogenic controls on deposition.

The upper Florence is represented by the Oketo Shale Member and, where it is absent, a relatively thin section of generally non-cherty limestones (fig. 62). The Oketo is present northward from Marion County (fig. 62), where it varies in thickness from about 3 to 8 ft (0.9–2.4 m), and it is mostly silty. Although correlation of the unit southward from measured section number 139 in Marshall County into Marion County is fairly straightforward, recognition and correlation are somewhat less certain farther to the north of section 139, into Nebraska. As shown in fig. 62,

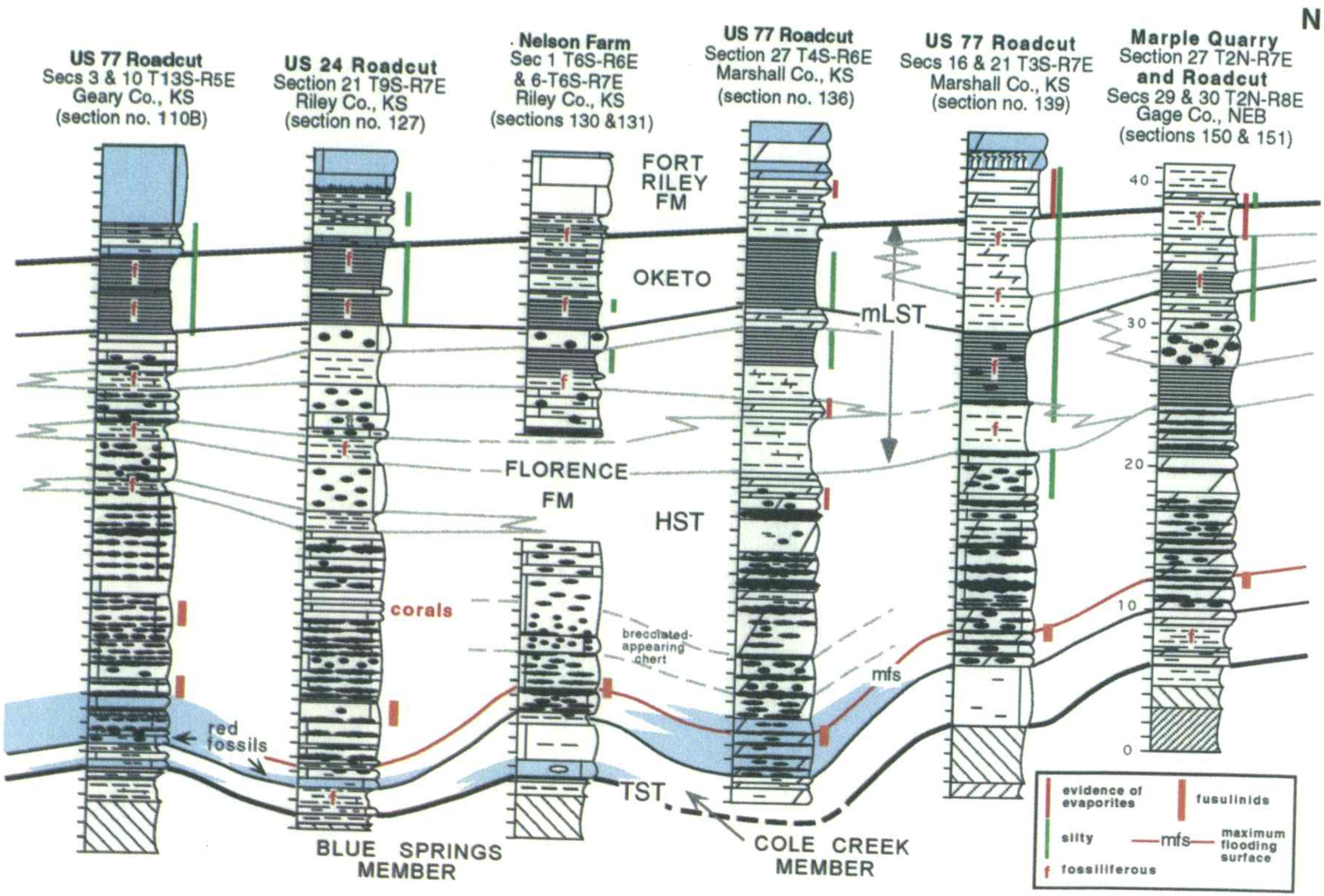


FIGURE 62—A and B [p.76]) Sections illustrating stratigraphy, facies, biota, and correlation of units within the Florence Formation across Nebraska and Kansas. Additional legend at base; see fig. 63 for location.

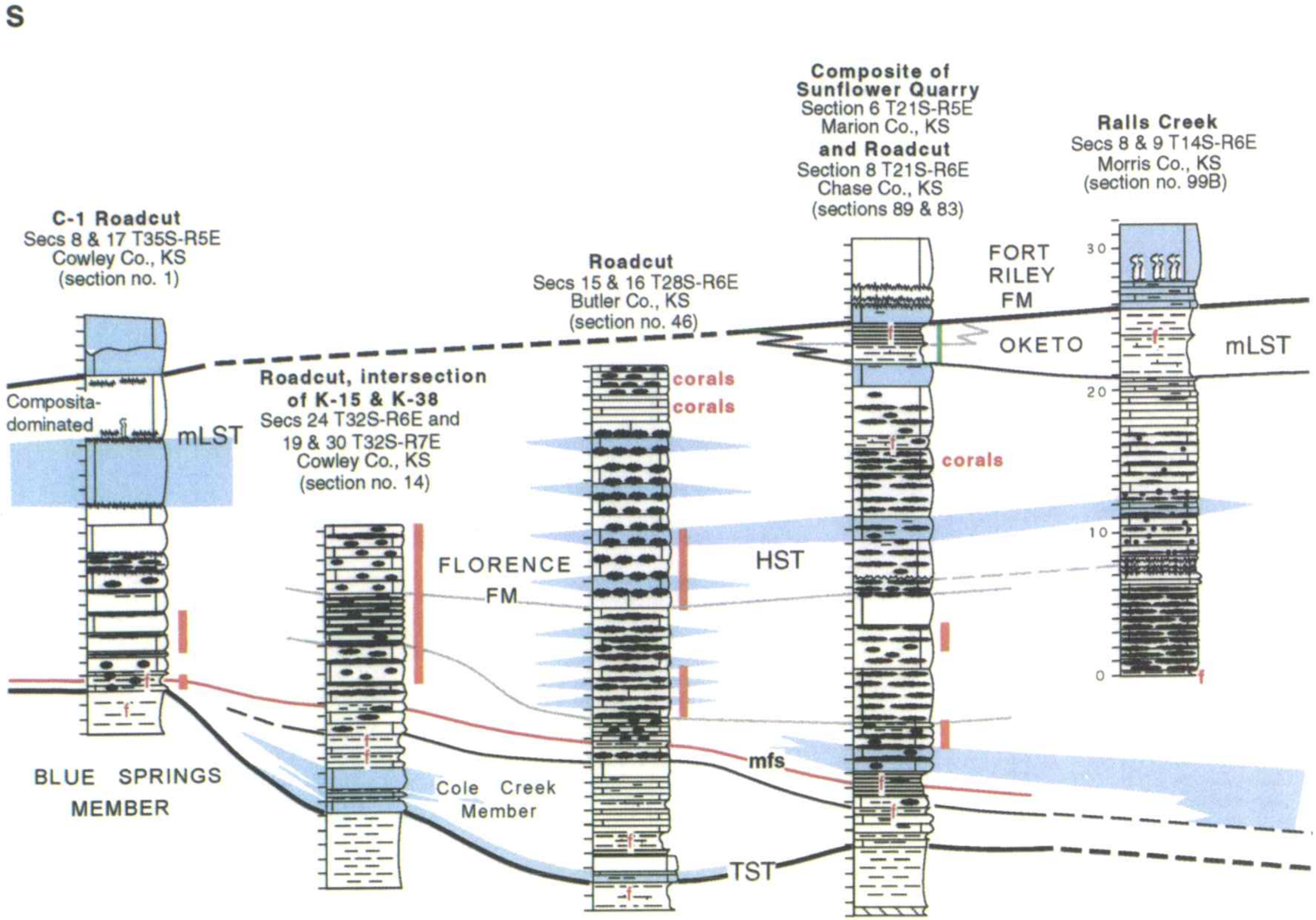

S
C-1 Roadcut
Secs 8 & 17 T35S-R5E
Cowley Co., KS
(section no. 1)
Composita-
dominated
mLST
Roadcut, intersection
of K-15 & K-38
Secs 24 T32S-R6E and
19 & 30 T32S-R7E
Cowley Co., KS
(section no. 14)
Roadcut
Secs 15 & 16 T28S-R6E
Butler Co., KS
(section no. 46)
corals
corals
Composite of
Sunflower Quarry
Section 6 T21S-R5E
Marion Co., KS
and Roadcut
Section 8 T21S-R6E
Chase Co., KS
(sections 89 & 83)
corals
Ralls Creek
Secs 8 & 9 T14S-R6E
Morris Co., KS
(section no. 99B)
FORT
RILEY
FM
OKETO
mLST
30
20
10
0
FLORENCE
FM
HST
mfs
TST
BLUE SPRINGS
MEMBER
Cole Creek
Member

FIGURE 62—B.

the Oketo in Gage County may be as much as 6 ft (1.8 m) thick by our correlation, which presumes that shaly dolomites in the middle of the unit are equivalent to dolomitic shales/mudrocks at the same stratigraphic position at measured section 139 in Marshall County. This correlation is strengthened by the common occurrence at both localities of crinoids, bryozoans, and *Derbyia*. These dolomitic zones, however, are not present to the immediate south, at measured section number 136 in southern Marshall County (fig. 62). Yet, the occurrence of more marine facies (i.e., shaly dolomite and dolomitic mudrock) in the middle of the Oketo in Marshall and Gage counties is in accord with its stratigraphy in Riley to Marion County, where fossiliferous marine limestones occur at approximately the same horizon (fig. 62). According to Condra and Reed (1959), however, the Oketo is only about 3 ft (0.9 m) thick in Nebraska, although more recently, Burchett (1988) suggested that the member is absent here; Condra and Upp (1931) did not recognize the Oketo at the time of their study. It is possible that only the upper 2 ft 2 inches (0.65 m) of mudrock beneath what we consider to be the Fort Riley at measured section 151 in Gage County is the Oketo, or conversely, that the entire upper approximately 6 ft 10 inches (2.1 m) of section here is Fort Riley, thus relegating the Oketo to the underlying 1.5 ft (0.5 m) of dark-colored siliciclastics (fig. 62). Either possibility, however, creates obvious problems in correlating the section of shaly dolomite at this location to the dolomitic mudrocks at section 139 in Marshall County (fig. 62). Until future studies resolve this issue, we will abide by the correlation shown in fig. 62.

The Oketo is interpreted to represent culmination of an mLST of marginal-marine facies, dominantly fossiliferous siliciclastics, within the Florence cycle. In northern Kansas and Nebraska, this dominantly shallow-water mLST phase of deposition composes much of the upper third of the formation (e.g., see measured sections 136, 139, 150, and 151, fig. 62A). We do not consider this section a true RST because facies do not gradually shallow upward. Rather, this mLST, like that in the Havensville, for example, is punctuated by periods of relatively deeper-water carbonate deposition (fig. 62A). Where the Oketo is absent in south-central Kansas, the abrupt onset of shallowing instead is variously suggested by: (1) deposition of relatively thick sections of carbonate sand and *Composita*-rich, shallow-water limestones, such as occur at measured section number 1 in Cowley County (fig. 62B); and/or (2) the general change from deposition of bryozoan-dominated, cherty, relatively deep-water limestones in the middle Florence to open-shelf, high- to moderate-energy, oncolitic limestones in the upper Florence and lower Fort Riley. Oncolitic limestones in the Florence are restricted in their occurrence to Cowley, Butler, and southern Marion counties, and some representative measured sections of such are shown in fig. 67; and, likely (3) deposition of the coral biostrome. Culmination of the Florence cycle did not result in subaerial exposure

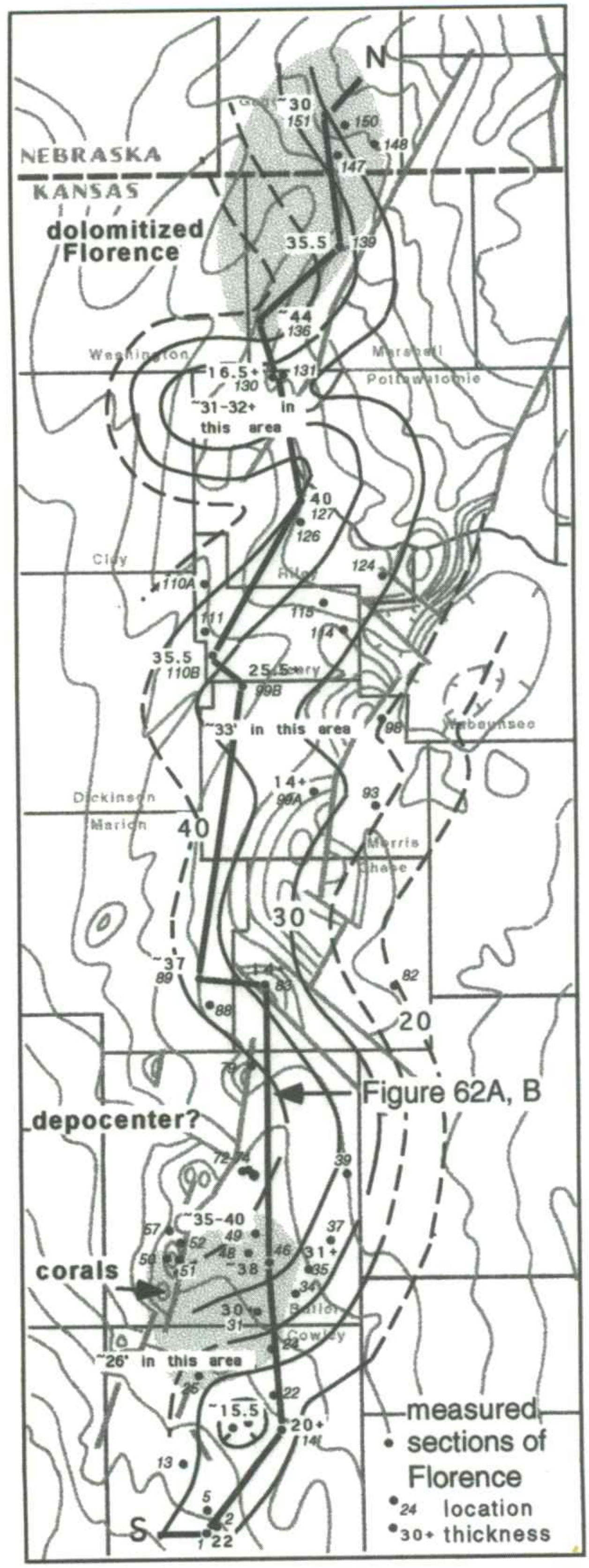


FIGURE 63—Isopach of the Florence (CI = 5 ft [1.5 m]), location of fig. 62, areal distribution of corals (near the top of the Florence), and dolomite in the Florence.

insofar as we have not found evidence of an unconformity, or even of terrestrial facies, at the top of the formation (either in the Oketo or in correlative limestones) anywhere in the study area. Rather, the mLST at the top of the formation, which extends into the basal Fort Riley, consists of marine deposits. Hence, a forced regression toward the end of Florence deposition is not indicated. The thick, expanded HST–mLST of the Florence is matched by a similarly extended HST–mLST in the overlying Fort Riley (e.g., figs. 66, 67, 69), and together, the Florence and the Fort Riley are by far the thickest marine cycles within the Chase Group. The significance of these observations is discussed in the concluding section of this paper.

By our correlations and stratigraphic assignments, the thickness of the Florence increases in an east-to-west direction from slightly greater than 20 ft to a maximum of about 44 ft (6.1–13.4 m), and this trend is more-or-less uniform in a north-to-south direction across the study area; a minimum thickness of 15.5 ft (4.7 m) occurs in a small area in central Cowley County (fig. 63). This thickness range generally agrees with that reported by previous workers (e.g., Fath, 1921; Bass, 1929; Jewett, 1941; O'Connor et al., 1953; Walters, 1954; Mudge et al., 1958; Byrne et al., 1959; Scott et al., 1959; Bayne, 1962). Maximum thickness of the formation is in Marshall County, on the eastern edge of the Salina basin, and a depocenter appears to exist in central Butler County, within the Walnut syncline and extending westward onto the Nemaha Ridge (fig. 63). This area also was a depocenter during deposition of the Blue Springs (fig. 60A). A prominent east-west-trending area of thin Florence section, interpreted as a positive area, extends across northern Riley and into Clay County, within the Salina basin; this feature may have begun to form during deposition of the Blue Springs (figs. 60A, 63).

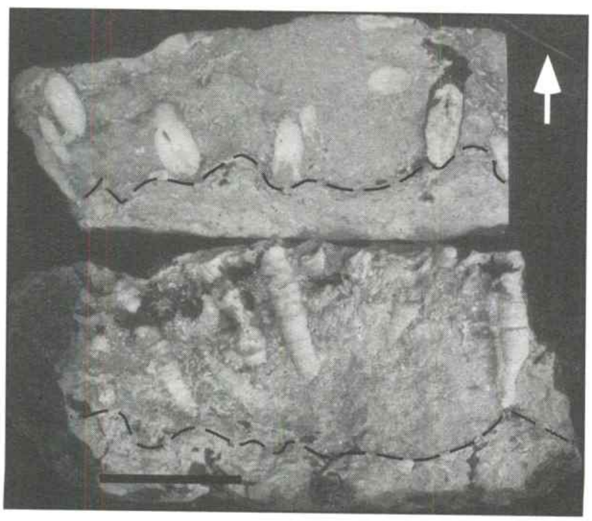


FIGURE 64—RUGOSE CORALS IN UPPER FLORENCE ATTACHED TO A HARDGROUND (DASHED LINE), LENGTH OF SCALE 2 INCHES (5.1 CM). White arrow points to stratigraphic top. Sample from measured section number 25, Cowley County, Kansas.

Fort Riley Formation

The thickness of the Fort Riley increases from about 16.5 to 20 ft (5.2–6.1 m) in northern Kansas, atop the Nemaha Ridge and along the edge of the Salina basin, to 42–47.5 ft (12.8–14.5 m) in Marion and Butler counties, and then thins to about 31 ft (9.5 m) in southernmost Cowley County, within the Walnut syncline (figs. 65A, 66, and 67, the locations of which are shown in fig. 65B). Maximum thickness of the formation in Marion County occurs in the transition zone between the Nemaha Ridge and Salina basin. A prominent area of thin Fort Riley section, interpreted as a positive feature, defines an east-west trend in adjoining parts of Riley, Clay, Washington, and Marshall counties atop both the Nemaha Ridge and the eastern edge of the Salina basin (fig. 65A). This area also was a slightly positive feature during deposition of the Florence (fig. 63). Bass (1929) and Bayne (1962) indicated that the Fort Riley is 55–65 ft (16.8–19.8 m) thick in Cowley County, although the maximum thickness that we have measured here is only about 38 ft (11.6 m). Mudge et al.'s (1958) estimate of 67 ft (20.4 m) in Morris County, and Jewett's (1941) estimate of 35 ft (10.7 m) in Riley County seem unreasonably excessive. Other than these instances, our measured thickness of the formation is within the range of values reported by other previous investigators.

Condra and Upp (1931) indicated that the Fort Riley is 27–30 ft (8.2–9.2 m) thick in Nebraska, and stated (p. 43) that it was "...prominently exposed..." in the Big Blue Valley from Beatrice southward to Barneston. Unfortunately, outcrops of this unit are no longer well exposed at all, and accordingly, we were unable to verify their estimate of its thickness. They indicated that insofar as the Fort Riley had been described previously, they felt no need for further description of it in Nebraska. This was an unfortunate decision on their part because the formation had, in fact, not been well described in the past, and a description of it within the context of its occurrence in the Barneston Formation (whose type locality is in Nebraska) would have been appropriate. They did, however, illustrate the Florence and Fort Riley in their fig. 4 photograph (p. 41) taken "...in [sic, a] quarry east of Wymore, Nebr." Based on the outcrop characteristics shown in this photograph and their general description of its location, we believe this quarry may be the one on the Marple Farm in sec. 27, T. 2 N., R. 7 E., in Gage County. The stratigraphy here (our measured section number 151) is compared to that indicated by Condra and Upp (1931) in the inset in fig. 66. They placed the Florence–Fort Riley contact just above a conspicuous bed of dolomite with abundant discontinuous layers of chert (at and just below the number 2 in their photograph), and we identified this same bed at the Marple quarry. The overlying section here, however, includes shales and cherty dolomites that they considered to be the Fort Riley, an assignment with which, therefore,

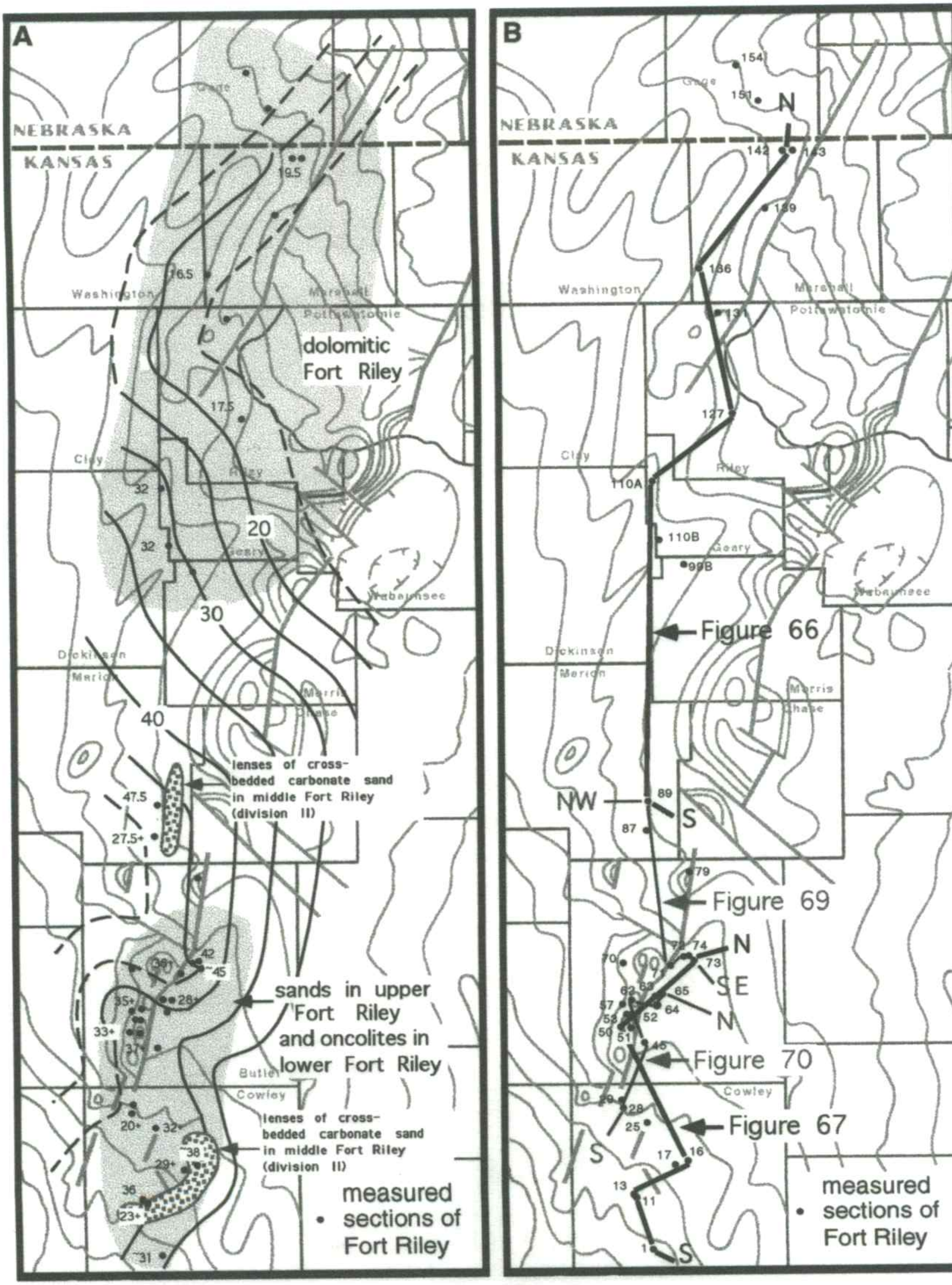


FIGURE 65—A) Isopach of Fort Riley (CI = 5 ft [1.5 m]) and areal distributions of mainly dolomitized Fort Riley sections, carbonate sands, and oncolites. B) Location of cross section figs. 66, 67, 69, and 70.

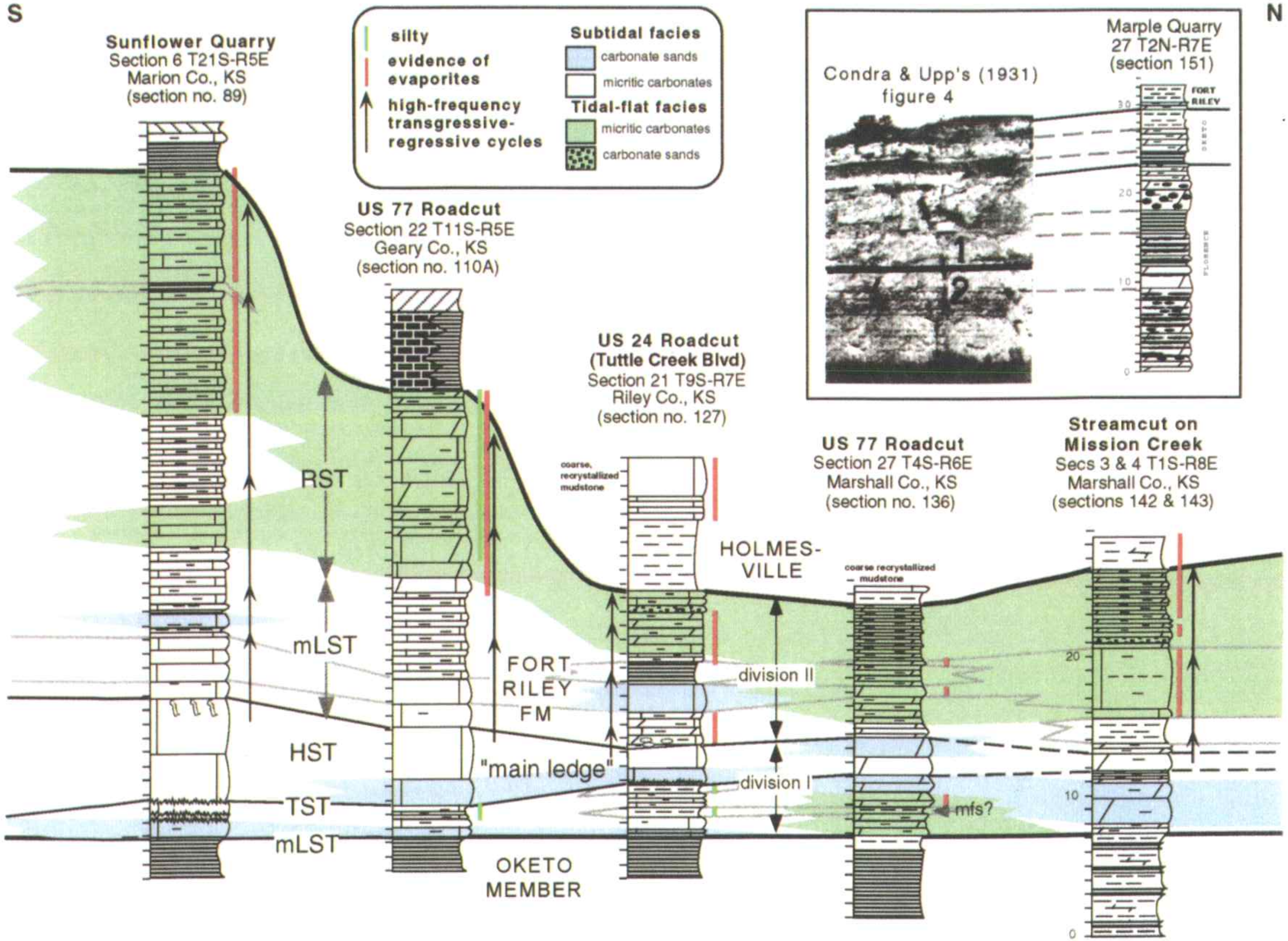


FIGURE 66—SECTION IN PART OF NORTHERN KANSAS SHOWING STRATIGRAPHY, FACIES, AND CORRELATION OF UNITS WITHIN THE FORT RILEY FORMATION; informal divisions I–IV are discussed in the text. The inset shows the exposure of the Florence and Fort Riley at the Marple quarry in Gage County, Nebraska (Condra and Upps [1931] fig. 4), which may be our measured section number 151. The line separating the numbers 1 and 2 in the photo is what they considered to be the Florence–Fort Riley contact. Our identification of this stratigraphy is shown in the accompanying columnar section.

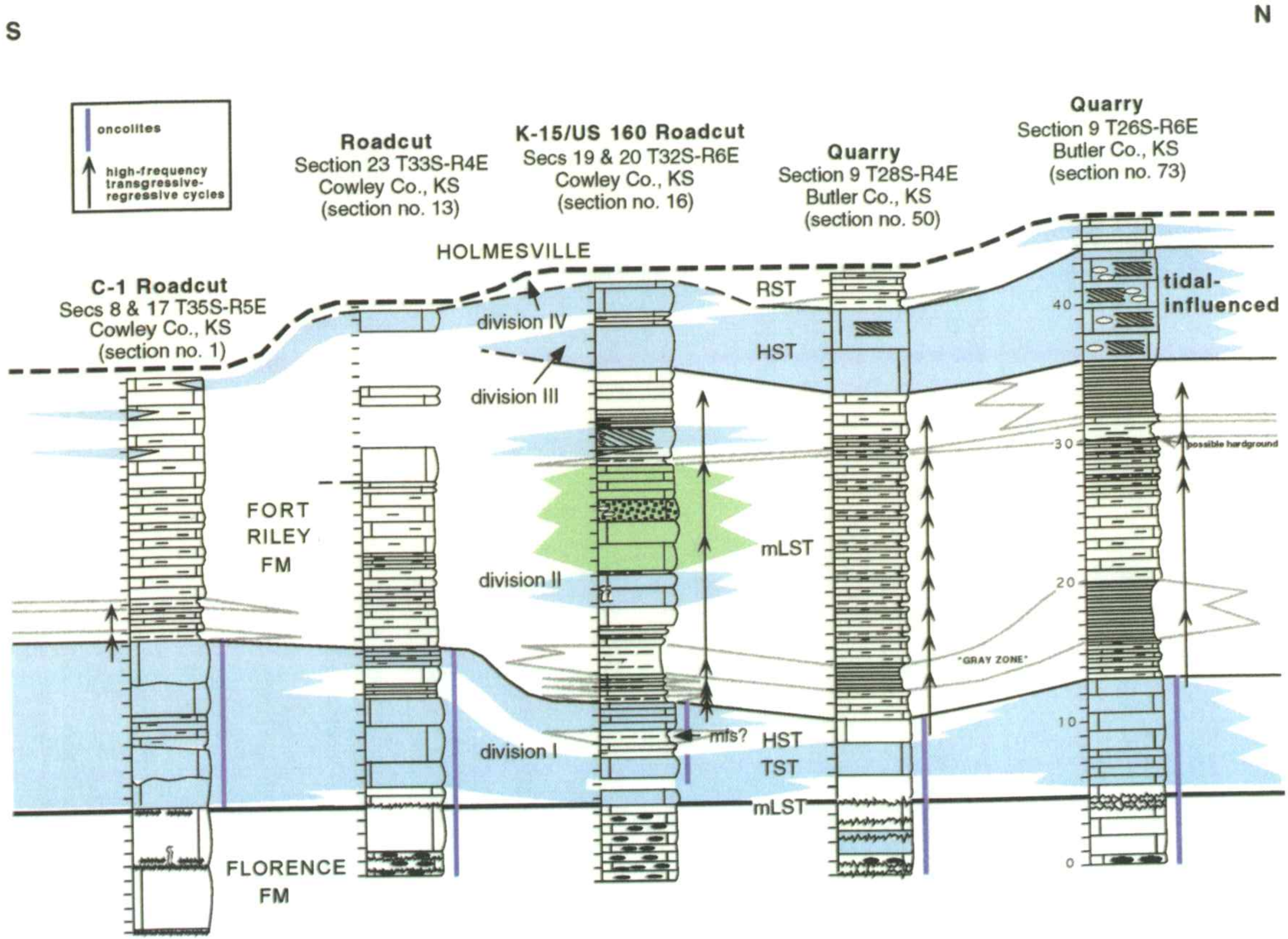


FIGURE 67—Section in south-central Kansas showing stratigraphy, inferred facies, and correlation of units in the Fort Riley; additional legend as in fig. 66.

we obviously disagree. About 5.5 ft (1.7 m) of what we consider to be the Oketo overlies these cherty dolomites in this quarry, above which only a few feet of shaly dolomite and mudrock within what we refer to as the (basal) Fort Riley are exposed.

The Fort Riley can be readily subdivided on the basis of lithology and weathering characteristics into an informal, four-fold division (I through IV) of strata in south-central Kansas (fig. 67). Division I is a massive-bedded, non-porous, dominantly oncolitic limestone section, from 6 to 12 ft (1.8–3.7 m) thick, that is traced from Butler County to Kay County, Oklahoma (fig. 65A; Mazzullo and Teal, 1994). This section typically is expressed topographically as a prominent ledge-former, and we believe it correlates to the mostly non-oncolitic "main ledge" and immediately underlying Fort Riley strata farther to the north (figs. 66, 67). Division II is regionally correlative in south-central Kansas and is a section of recessive-weathering, shaly limestones and mudrocks that is 15–23 ft (4.6–7.0 m) thick. Cross stratified carbonate sands occur locally within this division in central Cowley County (figs. 65A, 67) and were also recognized by Bayne (1962). A 2–4-ft (0.6–1.2-m)-thick section of medium- to dark-gray, sparsely fossiliferous shale to mudrock with *Orbiculoides* is a prominently developed, mappable bed just above the base of this division throughout Butler and northern Cowley counties; Mazzullo and Teal (1994) have referred to this unit as the "gray zone" (fig. 67). We believe this section correlates to the section of thin-bedded, dark, shaly carbonates or calcitic shales (labeled "dark" in fig. 66) above the main ledge in northern Kansas. Succeeding division III is as much as about 13.5 ft (4.1 m) of thick-bedded, porous carbonate sands (e.g., fig. 68A,B), and is traced from Butler County southward to northern and central Cowley County (fig. 65A). These strata are conspicuously cross stratified throughout much of Butler and northern Cowley counties (fig. 67). This division likewise is expressed topographically as a ledge-former and is characterized by conspicuous sinkholes throughout the region (Mazzullo and Teal, 1994). Only thin stringers of carbonate sand occur in southern Cowley County where this division is thin (fig. 67). Downdip (to the northwest) from Butler County into Marion County, the identity of division III is obscured because the Fort Riley thickens into the Sedwick basin, and upper Fort Riley strata are represented by low-energy, presumably more offshore, shaly carbonates overlain by peritidal carbonates (figs. 66, 69).

The uppermost Fort Riley (division IV) is not very well exposed throughout the study area because of its recessive character. Earlier workers such as Fath (1921), Bass (1929), and Bayne (1962) incorrectly, in our opinion, included these strata (e.g., figs. 68C, D) within the Holmesville, and accordingly, recognized only a tripartite division of the Fort Riley (sensu divisions I–III as described above). As discussed in the first part of this paper, we include these strata within the Fort Riley Formation. Division IV ranges in thickness from about 2 ft, to a maximum of 13 ft (0.6–4.0 m) at measured section number 45 in Butler County (figs. 67, 69, 70). Facies are dominantly thin-bedded, shaly, and sparsely fossiliferous (*Composita* and echinoid and pelecypod fragments) limestones. Thin beds of carbonate sand occur locally (figs. 67, 70), as well as tidal-flat carbonates with cryptalgal laminites (fig. 68E). At one locality in Butler County (measured section number 62), the contact between divisions III and IV is a prominent erosional scour with nearly 3 ft (0.9 m) of relief (fig. 68D). Above this erosion surface, division IV strata are very thin bedded, shaly lime mudstones with scattered small *Composita*. This section is conspicuous for its low-angle foresets and wedge-out of strata against the erosion surface (figs. 68D, 70). These beds may have filled a tidal channel, and their laminated appearance may be indicative of tidal rhythmites. An irregular contact between divisions III and IV also occurs at nearby measured section number 65 in Butler County (fig. 70), but elsewhere, the contact between these divisions appears to be conformable. Hence, the erosional surface at measured section number 62 is of only local extent, and therefore, is not considered to be a sequence boundary. Interestingly, both measured sections 62 and 65 are situated atop a very high part of the Nemaha Ridge in this area (fig. 65A).

Moore et al. (1944, 1951a) also recognized a four-fold division of the Fort Riley in northern Kansas on the basis of lithology. Although these divisions are in fact recognized in some parts of northern Kansas, we have found that they are not recognizable throughout all of this area. Also, the four divisions recognized by Moore et al. (1944, 1951a) do not exactly coincide with the four divisions that we recognize in south-central Kansas. For example, we recognize only divisions I and II, on the basis of gross lithology, northward from Butler County. The following discussions refer to fig. 66. At measured section number 110A in Geary County, for example, the basal few feet of the Fort Riley are thin-bedded and shaly limestones, and these facies persist, but as shaly dolomites, as far north as southern Marshall County. In northern Marshall County, however, this section instead is represented by thick-bedded carbonate. In turn, this section is overlain by the typically massive-bedded "main ledge" throughout much of northern Kansas, which includes some carbonate sands in Geary, Marshall, and Riley counties. This unit loses its identity in Marshall County, however, where it has changed to dolomite, and also is not recognized in Gage County, Nebraska (e.g., fig. 66 inset). Together, strata up to and including the "main ledge" compose the lower two divisions recognized by Moore et al., but we include them within division I because we correlate the "main ledge" to this division in Butler and Cowley counties. We note, however, that oncolitic limestones, which compose all of division I in south-central Kansas, are not present in this division north of Geary County.

Returning again to measured section number 110A (fig. 66), middle Fort Riley strata overlying the "main ledge" are mostly bedded, shaly limestones which in turn, are overlain by thicker-bedded dolomitic limestones and dolomites in the upper Fort Riley. Moore et al. (1944, 1951a) included these strata in their third and fourth divisions of the Fort Riley, respectively. This stratigraphy, however, is not recognized northward from Riley County, where instead, strata overlying the "main ledge" are mostly thin-bedded, shaly dolomites with some shales, and locally, thick beds of shaly dolomite. Carbonate sands, which compose division III in south-central Kansas, are not present in northern Kansas. We therefore include all strata above the "main ledge" within division II because, like division II strata in south-central Kansas, they mainly represent low-energy, marginal-marine facies. By these divisional assignments, we are not necessarily suggesting any temporal relationships among divisions between south-central Kansas and areas to the north; these divisions are merely of a descriptive, lithologic nature.

Fort Riley facies southward from Butler County are dominantly subtidal deposits, and a few feet of cross stratified carbonate sand and/or tidal-flat facies are

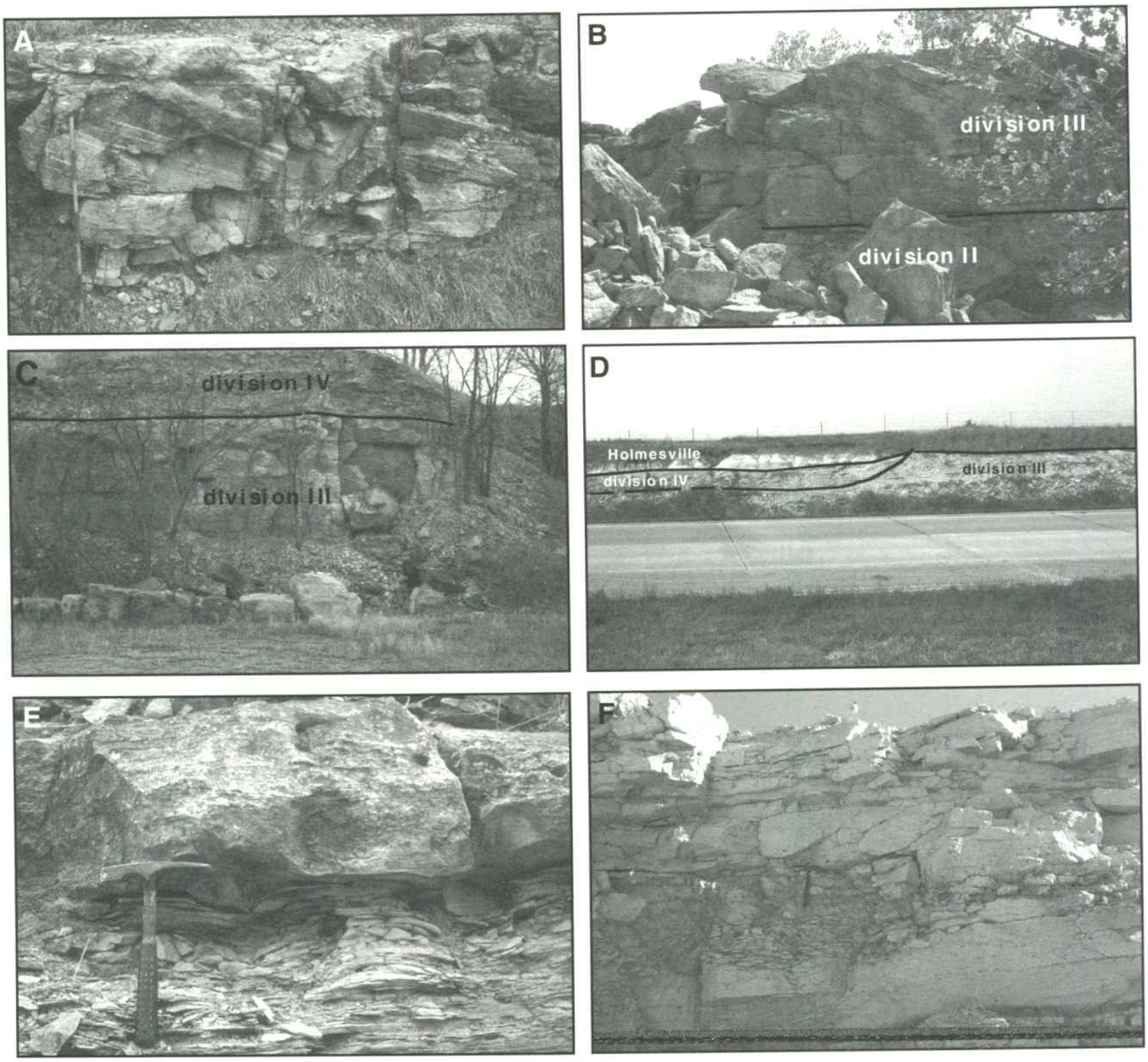


FIGURE 68—A) Large-scale, cross stratified sets in Fort Riley division III biograinstones (rod divided into 20-cm segments): roadcut along US–54 opposite El Dorado State Correctional Facility, measured section number 72, Butler County, Kansas. B) Quarry exposure of large-scale, cross stratified sets in Fort Riley biograinstone in division III, measured section number 73, Butler County, Kansas. Thickness of division III strata shown here is 7.3 ft (2.2 m). C) Division III and IV strata at Huff quarry, measured section number 65, Butler County, Kansas. D) Roadside exposure along US–54–K–77 and K–96, south side, showing erosional truncation between divisions III and IV in the Fort Riley (measured section number 62, Butler County, Kansas). For reference to scale, division IV strata here are a maximum of 4 ft (1.2 m) thick. E) Bed of cryptalgal laminite in division IV strata in Huff quarry (measured section number 65). F) Fenestral carbonates in the upper Fort Riley, Martin Marietta Sunflower quarry, Marion County, Kansas (measured section number 89, north end); hammer for scale.

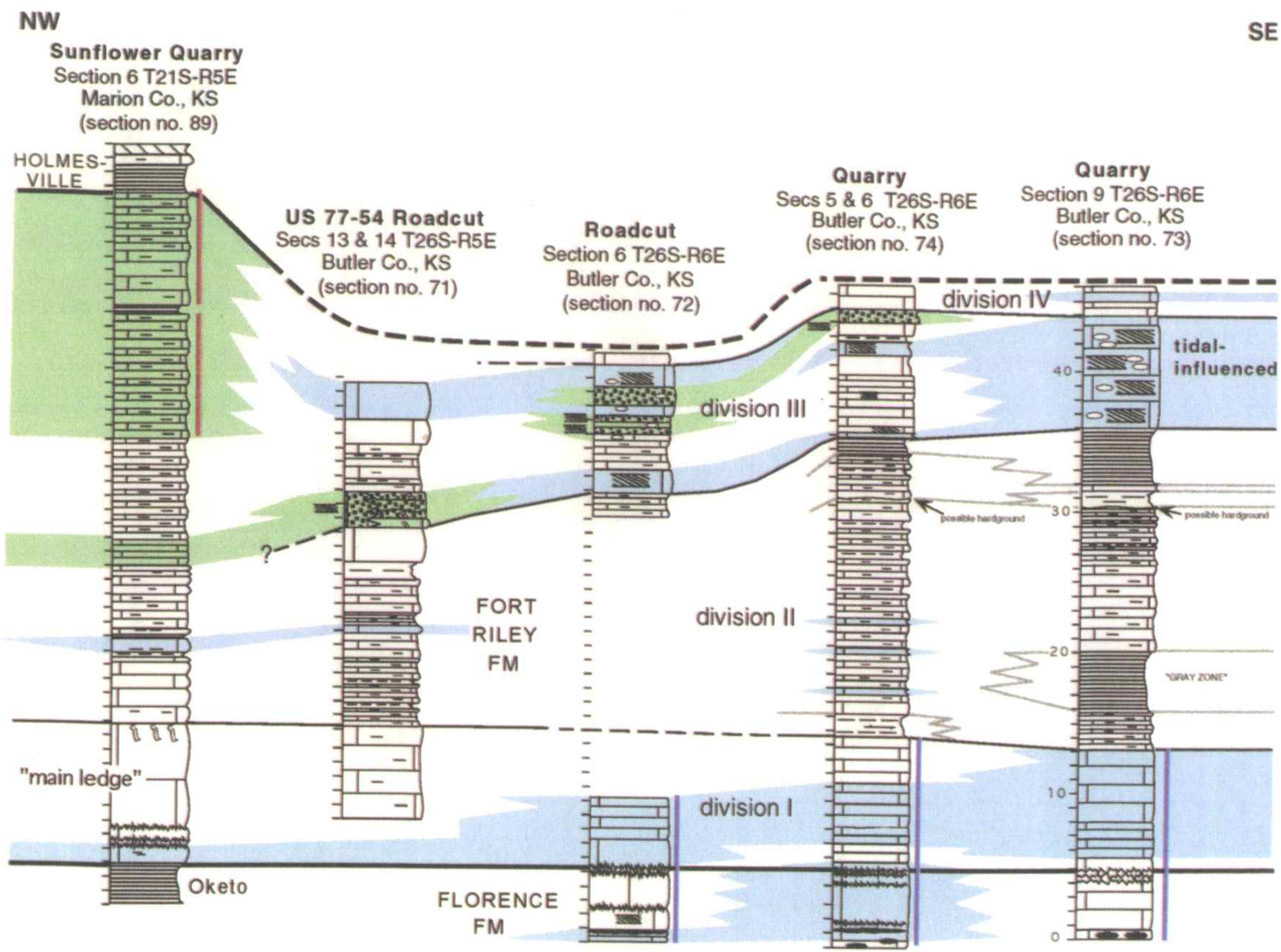


FIGURE 69—Dip section from Butler to Marion County showing facies transitions between carbonate sands and offshore, micritic lithologies in divisions I and III in the Fort Riley.

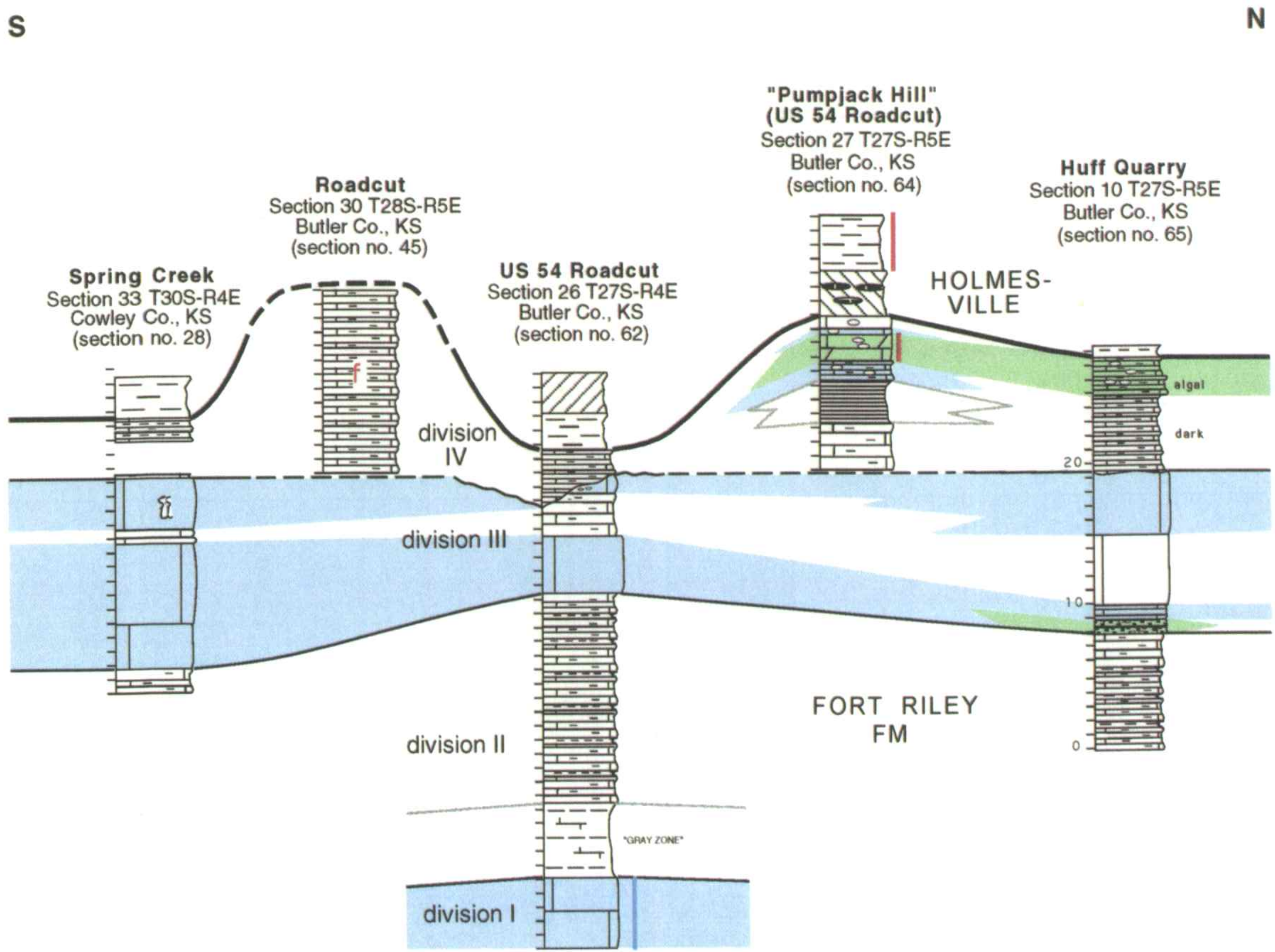


FIGURE 70—Section in south-central Kansas illustrating facies and thickness changes within Fort Riley division IV.

recognized at only one or two localities in Cowley County (within division II, fig. 67) and in Butler County (in division IV, fig. 68E). Thick sections of what we previously (1995) have interpreted to be subtidal but tidal-influenced, porous carbonate sands occur within division III strata at many localities in Butler and northern Cowley counties (e.g., measured section number 73, figs. 67, 68A). Thick cross stratified sets with bimodal-biopolar dips are prominent, and the rocks include tabular intraclasts of desiccated lime mudstone. Elsewhere in this area, these porous sands contain few to no intraclasts, they locally are extensively bioturbated, and although they consist of thick cross stratified sets, the dip directions of the cross strata are not bipolar (e.g., fig. 68B). In contrast, Fort Riley facies are dramatically different north of Butler County, where the formation becomes progressively more dolomitic, and thick sections of carbonate tidal flat facies compose a large part of the formation northward from Marion County (figs. 66, 68F). Together, these facies distributions define a northward-shallowing platform that included a relatively thin section of mainly nearshore-marine and tidal-flat facies in the northern part of the study area, which passed southward (and presumably westward) to a thicker section of more open-marine facies, at least during deposition of divisions I, III, and IV (figs. 65A, 66, 67, 69). The formation thickens into the Salina basin (fig. 69). Shaly division II thins to the west, into the Salina basin (fig. 69), and thins both to the north and south of its maximum thickness in Geary to Butler County (figs. 66, 67), suggesting a dominant source of siliciclastics to the east.

Oncolitic division I in south-central Kansas encompasses, in ascending order, continuation of the mLST that is inferred at the top of the Florence, and a rapidly ensuing TST and HST, the former with a relatively poorly recognized maximum flooding surface of either shale/mudrock or shaly limestone, depending on location (fig. 67). This same stratigraphy is recognized in central and northern Kansas, although a maximum flooding surface is not readily apparent (fig. 66). Uppermost beds of division I, and nearly all of division II strata in south-central Kansas appear to be an expanded mLST of mostly low-energy, nearshore, and marginal-marine mudrocks and shaly limestones (fig. 67). High-frequency cyclicity is present in this section (Mazzullo and Teal, 1994), although most of these cycles can not be traced for any distance laterally. We do not consider this section to be an RST because facies do not gradually shallow upward. In central and northern Kansas, this mLST appears to be very thin, and likewise, also includes some high-frequency cycles (fig. 66). Uppermost beds of division II, together with divisions III and IV in south-central Kansas are interpreted as an HST–RST couplet (fig. 67) because facies first deepen and then shallow-upward from high-energy carbonate sands to shallow-lagoonal and peritidal carbonate. The expanded RST in central and northern Kansas, which is composed of a thick section of carbonate peritidal facies (fig. 66), may be temporally equivalent to this HST–RST; compared to the underlying mLST, this section records relative highstand.

We have not found any evidence of an unconformity at the top of the Fort Riley anywhere in the study area. The sequence stratigraphy of the upper Fort Riley, together with the overlying basal Holmesville, define a normal regressive section (sensu Posamentier et al., 1992). This is the first appearance of such a stratigraphy in the Chase Group in that forced regressions were inferred at the tops of the underlying Schroyer, Kinney, and Bruno. Notwithstanding regional facies changes, the overall sequence stratigraphy of the Fort Riley, that is, relative HST–mLST–HST, is traced throughout the study area and may suggest dominant allogenic control on deposition of this formation. Superimposed on this motif, however, are the anomalously thick sections of apparently aggradational and progradational peritidal deposits in northern Kansas. Together with the lack of correlatability of the high-frequency cycles in the mLST, they suggest an overprint of autogenic control on deposition.

Doyle Shale

Regional Thicknesses

Thickness trends of the Doyle and its component members were difficult to map because of the many incomplete exposures of this formation in the study area. Several apparent discrepancies exist between our estimates of formation and member thicknesses (figs. 71, 72), especially concerning the Gage, and those of previous workers. By our estimates, for example, the Doyle is about 60–70 ft (18.3–21.4 m) thick in Cowley and Butler counties (fig. 71A). In contrast, Bass (1929) and Bayne (1962) estimated its thickness to be about 75–92 ft (22.9–28 m) in Cowley County, and Fath (1921) estimated it to be as much as 105 ft (32 m) thick in Butler County. However, these workers had included within the Doyle what we refer to as division IV of the Fort Riley, the Stovall or its equivalent (the Santa Fe Lake Member), and the Grant Member of the Winfield Limestone. Subtracting the combined average thickness of these units reduces the maximum thickness of the Doyle (by their estimates) to about 83 ft (25.3 m) in Cowley County and to about 91 ft (27.8 m) in Butler County, values that are still greater than our estimates. Although thicknesses of the Holmesville and Towanda are in general accord in these areas, Bayne (1962) estimated the Gage Member to be 55–65 ft (16.8–19.8 m) thick in Cowley County, whereas we measured a maximum of only 40 ft (12.2 m) at our section number 10 (fig. 74), at which upper and lower contacts of the member were exposed. Likewise, Fath (1921) estimated the Gage to be 50–60 ft (15.3–18.3 m) thick, whereas we described a maximum thickness of only about 35 ft (10.7 m) at several localities in Butler County at which upper and lower contacts of the member also were exposed (fig. 72B). Hence, using our measured thicknesses of the Gage further reduces previous thickness

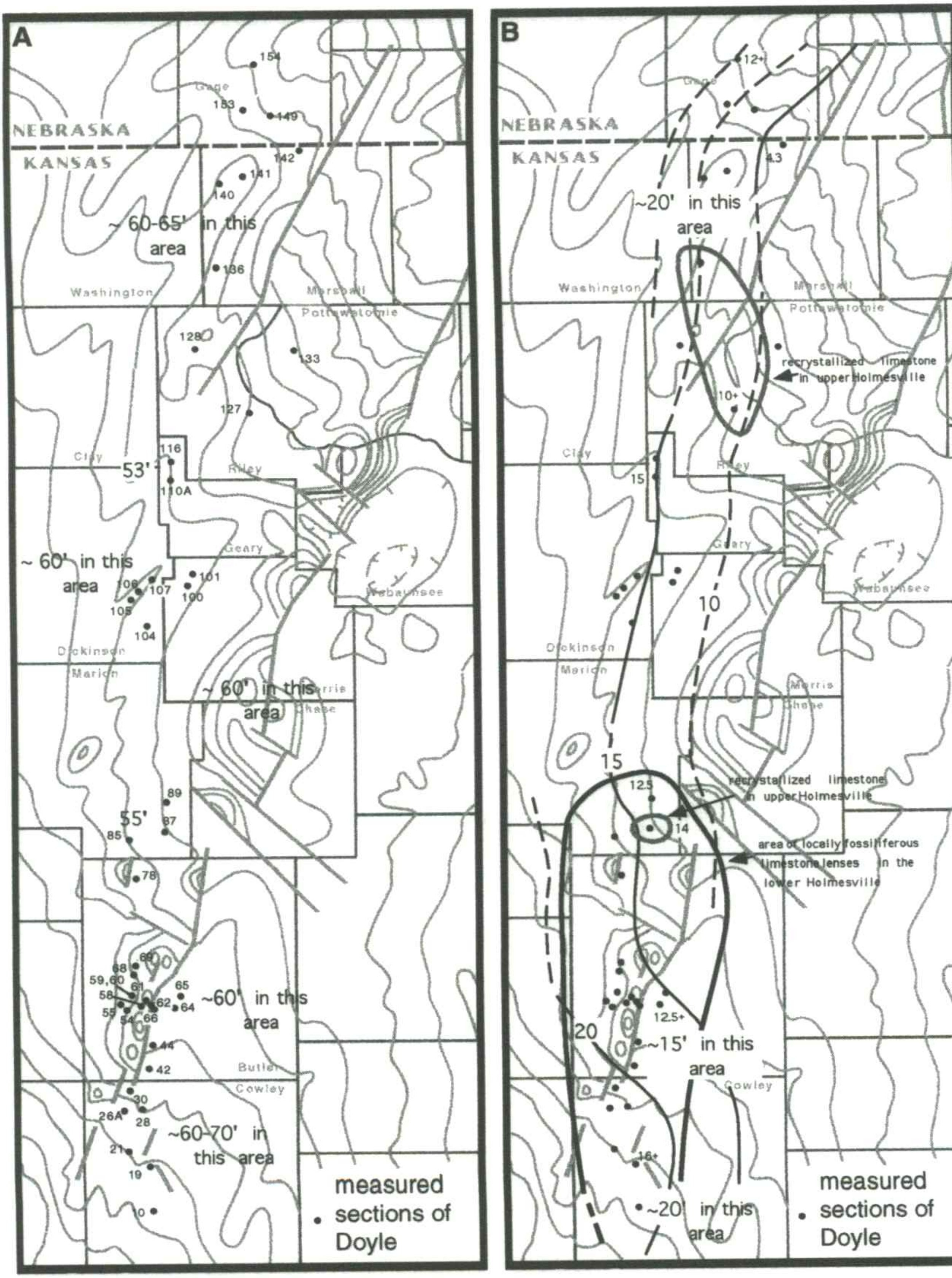


FIGURE 71—A) REGIONAL ESTIMATES OF THICKNESS OF THE DOYLE SHALE. B) Isopach of the Holmesville Member (CI = 5 ft [1.5 m]), and areal distribution of recrystallized limestone and locally fossiliferous limestone lenses in the member.

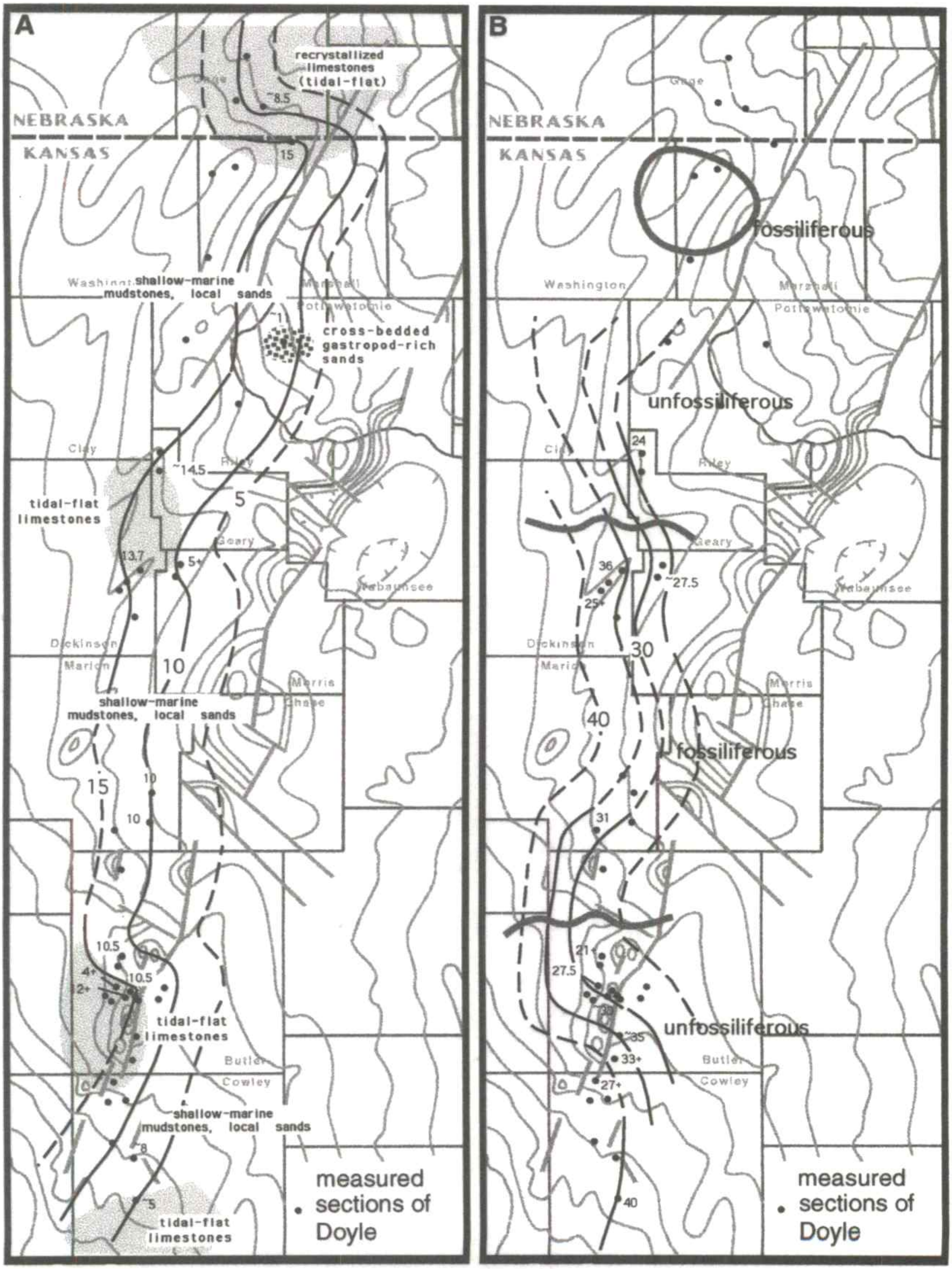


FIGURE 72—A) Isopach of the Towanda Member (CI = 5 ft [1.5 m]), and facies in the upper beds. B) Isopach of the Gage Member (CI = 5 ft [1.5 m]), showing the distribution of fossiliferous and unfossiliferous shales and/or mudrocks in the member.

estimates of the Doyle and results in general agreement between our data and previous workers in these counties.

Byrne et al. (1959) believed the Doyle was about 80 ft (24.4 m) thick in Marion County, whereas we have measured 55 ft (16.8 m) of thickness at, for example, our measured section numbers 85 and 87 (the latter which, surprisingly, is also the location of one of their own measured sections of the Doyle). The discrepancy in thickness arises from their estimate of 45 ft (13.7 m) for the Gage, whereas we have measured only 31 ft (9.5 m) of Gage strata at locality 85, where upper and lower contacts are exposed. Moore et al.'s (1951b) estimate of about 62 ft (18.9 m) for the Doyle in Chase County, and Mudge et al.'s (1958) estimate of about 67 ft (20.4 m) in Morris County, are in accord with our estimates in these areas. According to Jewett (1941), maximum thickness of the Doyle in Geary and Riley counties is 90 ft (27.5 m), with the thickness of the Gage here being about 50 ft (15.3 m). However, we have measured only about 53 ft (16.2 m) of Doyle, and about 24 ft (7.3 m) of Gage at our measured section numbers 110A and 116 (fig. 73), where upper and lower contacts are exposed. Walters and Bayne's (1959) estimate of the thickness of the Doyle in Clay County (65–70 ft [19.8–21.4 m]) is only slightly thicker than ours (53–65 ft [16.2–19.8 m]), and our estimate for Gage County, Nebraska, agrees with that of Condra and Upp (1931 [about 64 ft (19.5 m)]). However, we disagree with Walters (1954), who indicated that the Doyle was about 80 ft (24.4 m) thick in Marshall County; instead, we have estimated it to be only about 60–65 ft (18.3–19.8 m) thick here. Only part of the (lower) Doyle is exposed in Pottawatomie and Wabaunsee counties, and hence, we cannot determine total thickness here.

Based on these data, the thickness of the Doyle appears to be fairly uniform across the study area, and there is no indication of any significant local depocenters of increased accommodation during its deposition (fig. 71A).

Holmesville Member

By our data, minimum thickness of the Holmesville (4.3 ft [1.3 m]) occurs at measured section number 142 in northern Marshall County, and maximum thickness of about 20 ft (6.1 m) occurs to the west of this locality, into the Central Nebraska and Salina basins, and also in Cowley County, within the Walnut syncline (fig. 71B). However, the member generally appears to thicken from east to west within the study area. Fath (1921) believed the member was about 35 ft (10.7 m) thick in Butler County, which we consider to be excessive based on available outcrop control. Estimates of Holmesville thicknesses in Geary and Riley counties (Jewett, 1941 [20–25 ft or 6.1–7.6 m]), Pottawatomie County (Scott et al., 1959 [27–33 ft or 8.2–10.1 m]), and Marshall County (Walters, 1954 [20 ft or 6.1 m]) also are considerably thicker than the regional trend indicated by our data from the sparse number of outcrops and measured sections here. We could not rely on topographic relationships to estimate thickness of the member in these counties, as undoubtedly was done by these authors, because of structural complexity. Hence, we consider our map (fig. 71B) to be tentative. The member appears to be about 20 ft (6.1 m) thick in Gage County, Nebraska, a thickness that also was suggested by Condra and Upp (1931).

Throughout the study area most of the member is composed of unfossiliferous, dominantly tLST siliciclastics (figs. 73, 74). Thin limestones, separated by shale or mudrock, are recognized at approximately the same stratigraphic horizon in the lower part of the member (fig. 74) at several outcrops southward from Marion County into Cowley County, at localities that are atop the Nemaha Ridge, within the Walnut syncline, and along the eastern edge of the Salina basin (fig. 71B). They are shaly lime mudstones, locally with desiccation cracks, and are unfossiliferous except at measured section number 87 in Marion County, where they contain some crinoids and fragments of thin-shelled pelecypods. A few feet of recrystallized lime mudstone with evaporite relicts also occur in the upper Holmesville at locality 87 in Marion County (fig. 74), and similar limestones occur at approximately the same stratigraphic position in parts of Riley and Marshall counties (at measured sections 127 and 136, respectively); these localities are atop the Nemaha Ridge and the Salina basin (fig. 71B). These beds may be tidal-flat or nonmarine deposits. If all of these limestones are in fact marine (i.e., peritidal to nearshore), then their presence indicates as many as four high-frequency marine transgressions during Holmesville deposition (fig. 74). The erratic distribution of these carbonates could be the result of post-depositional erosion insofar as they are each overlain by apparently forced regressive, tLST deposits.

The contact of the Holmesville and marine beds of the overlying Towanda is abrupt at all localities at which it is exposed. At some localities uppermost Holmesville strata beneath the Towanda are light-colored, but unfossiliferous, mudrock which may be marginal-marine, initial TST deposits (figs. 73, 74). At other localities uppermost Holmesville strata are terrestrial red and/or green shale/mudrock, which may indicate either very rapid transgression, or the existence of local topographic highs on the Holmesville surface.

Towanda Member

The Towanda varies in thickness from about 5 to 15 ft (1.5-4.6 m), generally increasing in thickness from east to west across the study area (fig. 72A). These thickness values are in agreement with those of previous workers. No anomalous depocenters appear to have been in existence during deposition of this member.

Facies in Gage County, Nebraska, and Marshall County, Kansas, are dominantly porous, coarse-recrystallized limestones with secondary calcite veins, locally with

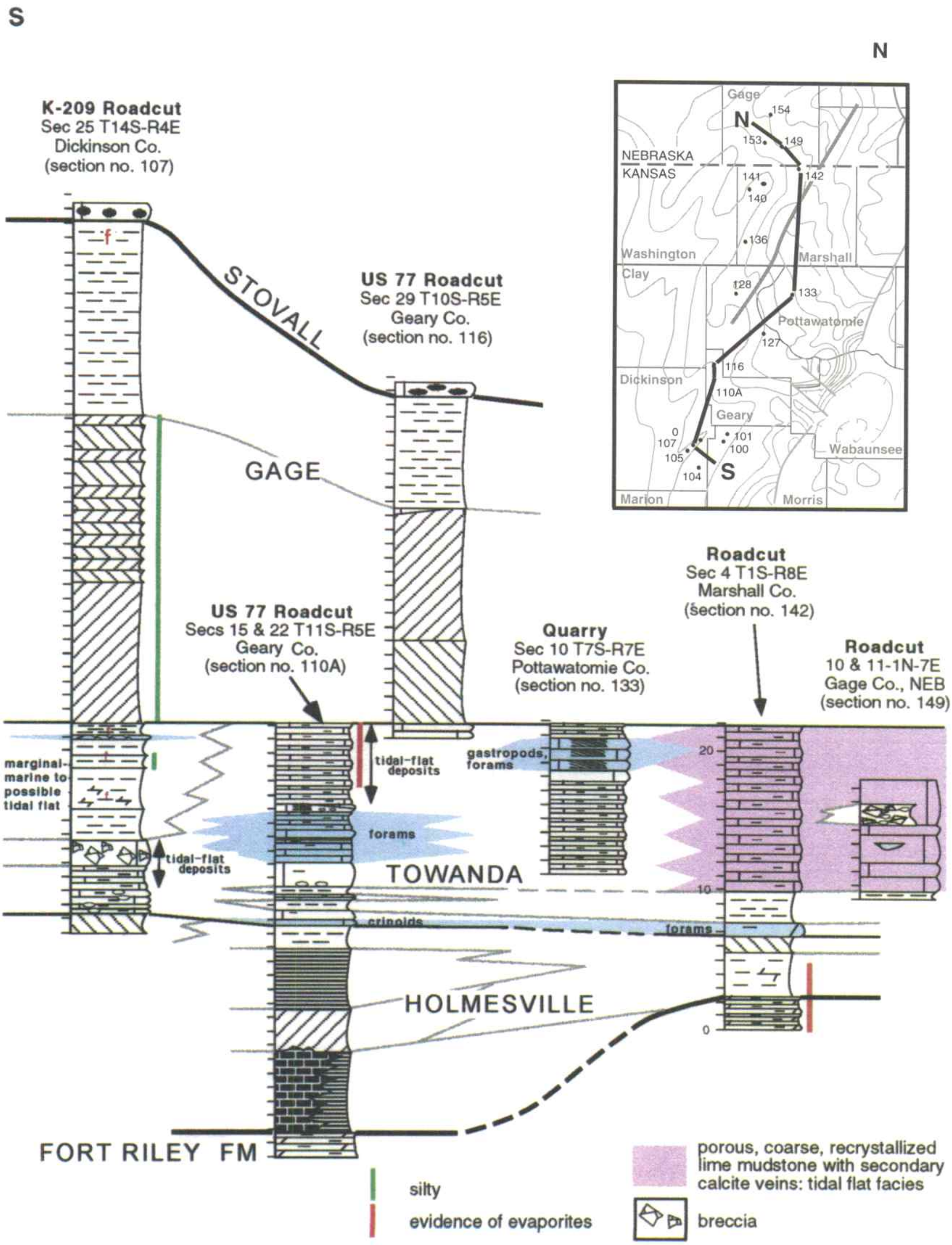


FIGURE 73—Section in northern Kansas and Nebraska showing stratigraphy, inferred facies, and correlation of units within the Doyle Shale. Note the gradational contact between the Towanda and Gage Members at measured section number 107 in Dickinson County.

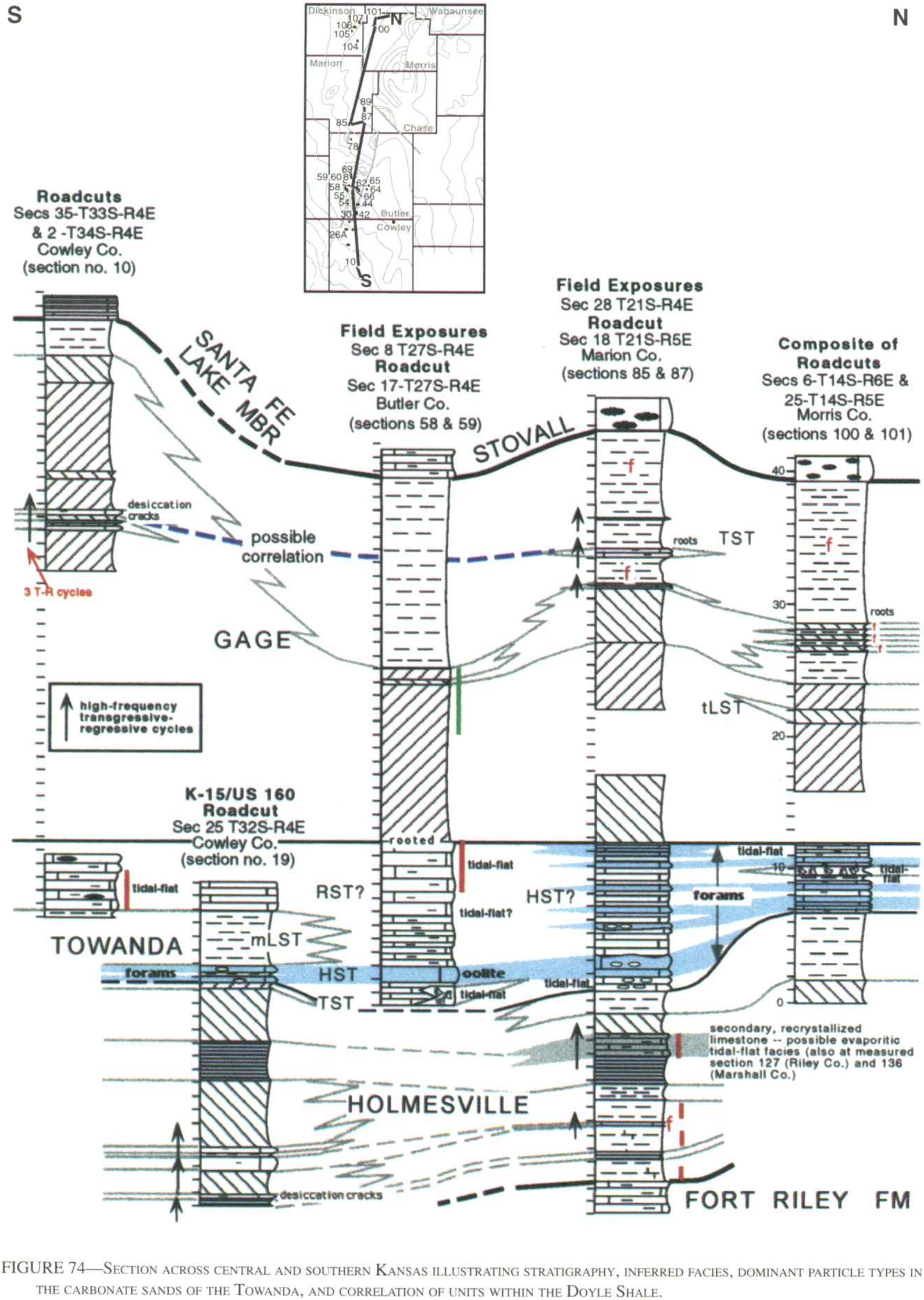


FIGURE 74—Section across central and southern Kansas illustrating stratigraphy, inferred facies, dominant particle types in the carbonate sands of the Towanda, and correlation of units within the Doyle Shale.

thin lenses of breccia (fig. 75A), shallow channel-fills of peloid and/or biograinstone, and lenses to thin layers of foraminiferal wackestones; these rocks are interpreted mainly as aggradational and progradational tidal-flat deposits (fig. 73). Breccias are interpreted as having resulted from dissolution of evaporites (Mazzullo and Teal, 1994; Mazzullo et al., 1995, 1996), for which there is ample evidence of their former presence in the rocks (e.g., fig. 75C) and also in the subsurface (Mazzullo and Teal, 1994). To the south, facies include nuclear areas of dominantly cyclic tidal-flat limestones (locally with breccias) amidst a broad facies tract of low-energy, subtidal micritic limestones interspersed with high-energy, carbonate sands (fig. 72A). The carbonate sands dominantly are foraminiferal, although oolite grainstones and prominently cross stratified, gastropod-rich (dominantly *Murchisonia* spp. and *Stegocoelia* spp.) packstones to grainstones occur locally in Butler and Pottawatomie counties, respectively (figs. 72A, 73, 74, 75B). Approximately the middle part of the Towanda changes from limestone to unfossiliferous, yellow mudrock and/or shale in Cowley County (fig. 74), although siliciclastics are also present in the lower part of the section northward from Geary County (fig. 73). The upper contact with the Gage is rarely exposed, although where it is, it mostly appears to be sharp and conformable, although locally rooted (e.g., at measured section number 58 in Butler County [figs. 74 and 75D]). A prominently expressed gradational contact between the Towanda and the overlying Gage, however, is well exposed at measured section number 107 in Dickinson County, Kansas (see Appendix).

The TST at measured sections 58–59 in Butler County, and also at measured sections 85–87 in Marion County (fig. 74), are represented by tidal-flat deposits overlain by oolitic and/or foraminiferal sands, the latter which represent a maximum flooding surface. At locality 58–59 the HST is overlain by what appears to be an apparently normal RST (sensu Posamentier et al., 1992) of presumed low-energy, shallow-subtidal limestones that grade upward to tidal-flat deposits that are rooted at the top but which do not otherwise include evidence of a pronounced unconformity at the top of the member. Individual, high-frequency, shallowing-upward cycles could not be identified in this section here, possibly because of amalgamation of facies (Mazzullo et al., 1995). In contrast, numerous shallowing-upward cycles of carbonate sand and subtidal micritic limestones are present above the maximum flooding surface at locality 85–87. This section appears to be an expanded HST that is not capped by peritidal facies or obviously truncated by an unconformity, although it is abruptly overlain by terrestrial siliciclastics. Cycles in this section likewise can not be correlated for any distance to the north or south (figs. 73, 74). At measured sections 19 in Cowley County and 142 in Marshall County (figs. 73, 74), for example, the maximum flooding surface is overlain by siliciclastics interpreted as mLST deposits, and in turn, these are overlain by relative HST deposits of subtidal to peritidal character, respectively. An even more complex lithostratigraphic scenario is present at measured sections 110A and 133 in Geary and Pottawatomie counties, respectively (fig. 73).

Considerable autogenic control on deposition during Towanda time clearly is suggested by: (1) the relatively thick sections of peritidal deposits, particularly in Nebraska and northern Kansas; (2) the patchwork mosaic of numerous centers of tidal-flat deposition (e.g., Ginsburg, 1971) amidst subtidal facies (fig. 72A); and (3) as discussed above, the complexity of the inferred sequence stratigraphy of the section. Relative to the dominantly tLST of the underlying Holmesville and the overlying Gage, however, the Towanda is an overall marine-dominated highstand phase of deposition that is recognized throughout the study area. We suggest that if this facies complexity were to be generalized, a "type" stratigraphy of the Towanda would be represented by the outcrops at, for example, measured sections 19 or 149 in Cowley and Gage counties, respectively (figs. 73, 74), where the stratigraphic motif is, in ascending order, a section composed of relative HST carbonate, mLST siliciclastic, and HST carbonate. Despite the difference in scale, this motif is similar to that in the Wreford, Kinney, and Fort Riley, and together with the regional persistence of the member, it suggests relative long-term allogenic control on deposition of the Towanda.

Gage Member

By our data, thickness of the Gage varies from about 24 to 40 ft (7.3–12.2 m) across the study area, generally increasing in an east to west direction (fig. 72B). Discrepancies between our data and estimates of member thickness in Butler and Cowley counties by Fath (1921), Bass (1929), and Bayne (1962), and in Geary and Riley counties by Jewett (1941), were discussed above. Moore et al. (1951b) and Mudge et al. (1958) indicated that the Gage is 38–44 ft (11.6–13.4 m) thick in Chase and Morris counties. Walters (1954) indicated a thickness of 45–50 ft (13.7–15.3 m) in Marshall County, and Condra and Upp (1931) suggested a thickness range of 34–46 ft (10.4–14.0 m) in Gage County, Nebraska. We have been unable to adequately determine the thickness of the member in these areas because of poor outcrops and/or structural complexity.

Facies in the Gage are red and green shales and mudrocks, representing a dominantly prolonged tLST, overlain by a thinner TST of light-colored shales and mudrocks (figs. 73, 74). These TST deposits are fossiliferous northward from northern Butler County into south-central Dickinson and southernmost Geary counties, and also in western Marshall County, but are unfossiliferous elsewhere (fig. 72B). Fossils in these beds include varying amounts of pectinid casts (including *Septimyalina* spp.), foraminifers, crinoids, bryozoans, echinoid fragments, and some *Derbyia* spp. and *Composita* spp. Several thin beds of limestone occur sporadically within the middle to upper part of the member, and near the base of the member, from Marshall County southward to Cowley County (fig. 76). Aphanitic and shaly, unfossiliferous lime mudstones, with desiccation cracks at the top, occur in central Butler to Cowley County, and they may be either marine or terrestrial deposits. To the north these limestones are mainly marine biowackestones to packstones with brachiopods (*Composita* spp., *Derbyia* spp., and some lingulids), crinoids, and bryozoans. The seeming erratic occurrence of at least the unequivocal marine limestones in such sections suggests several high-frequency, transgressive-regressive cycles which, by their apparent lack of correlatibility, are not convincingly of allogenic origin.

Winfield Limestone

Winfield strata normally vary in thickness from about 20 to 35 ft (6.1–10.7 m) across Kansas, generally increasing from east to west and north to south (figs. 77A and 79–81). The formation is anomalously thick, however, at and around measured section number 67 in Butler County (Peck quarry, fig. 81), where the approximate maximum thickness (based on exposures here and nearby outcrops) of 45 ft (13.7 m) defines a local depocenter to the immediate east of the Humboldt fault zone, within the Walnut syncline (fig. 77A). The formation likewise is about 42–43 ft (12.8–13.1 m) thick in northeastern Marion County, on the edge of the Salina basin (fig. 77A). At both localities the increased thickness of the Winfield is the result of expanded Luta sections (figs. 78B, 80, 81). A slightly positive feature existed during deposition of the Winfield as suggested by the east-west trend of relatively thin Winfield strata across Geary and northern Dickinson counties, which includes part of the Nemaha Ridge and the Salina basin (fig. 77A). This feature may have begun to form during deposition of the Doyle (e.g., fig. 71A). Another small, slightly positive feature occurs atop a locally high part of the Nemaha Ridge in southwestern Butler County (fig. 77A).

The westernmost exposure of the Winfield that we have located and examined is in northeastern Sumner County, Kansas, just north of the town of Oxford and along the bluffs of the Arkansas River within the Churchill oil field, in sec. 36, T. 31 S., R. 2 E. (our measured section number 155, shown in fig. 81). This outcrop was noted by Bass (1929, p. 92), who indicated that the Winfield, Enterprise shale (Luta and Odell of present usage), and Herington were exposed there. Although we found the Winfield (upper Grant to Luta) and the basal Odell in this

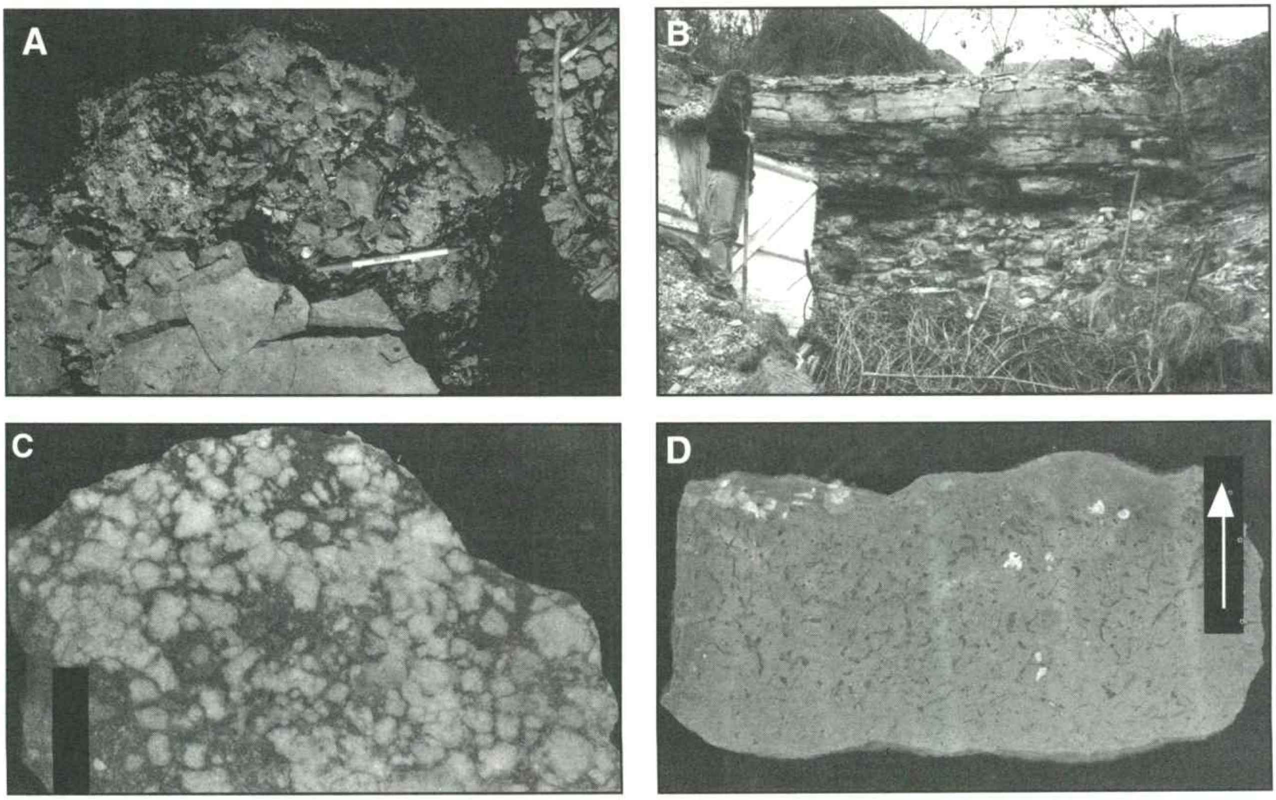


FIGURE 75—A) Outcrop of dissolution-collapse breccia in the Towanda, east side of Augusta Lake, measured section number 61, Butler County, Kansas (pen for scale). B) Quarry exposure of low-angle, cross stratified, gastropod-rich biopackstone to grainstone in upper Towanda, measured section number 133, Pottawatomie County, Kansas. C) Slab of calcite-replaced, nodular-mosaic evaporite nodules in Towanda (from measured section number 61, Butler County); length of scale 1 inch (2.5 cm). D) Slab of lime mudstone with fenestral fabric and inferred vertical rootcasts, top of the Towanda at measured section number 58, Butler County, Kansas); length of scale 1 inch (2.5 cm), arrow points to stratigraphic top.

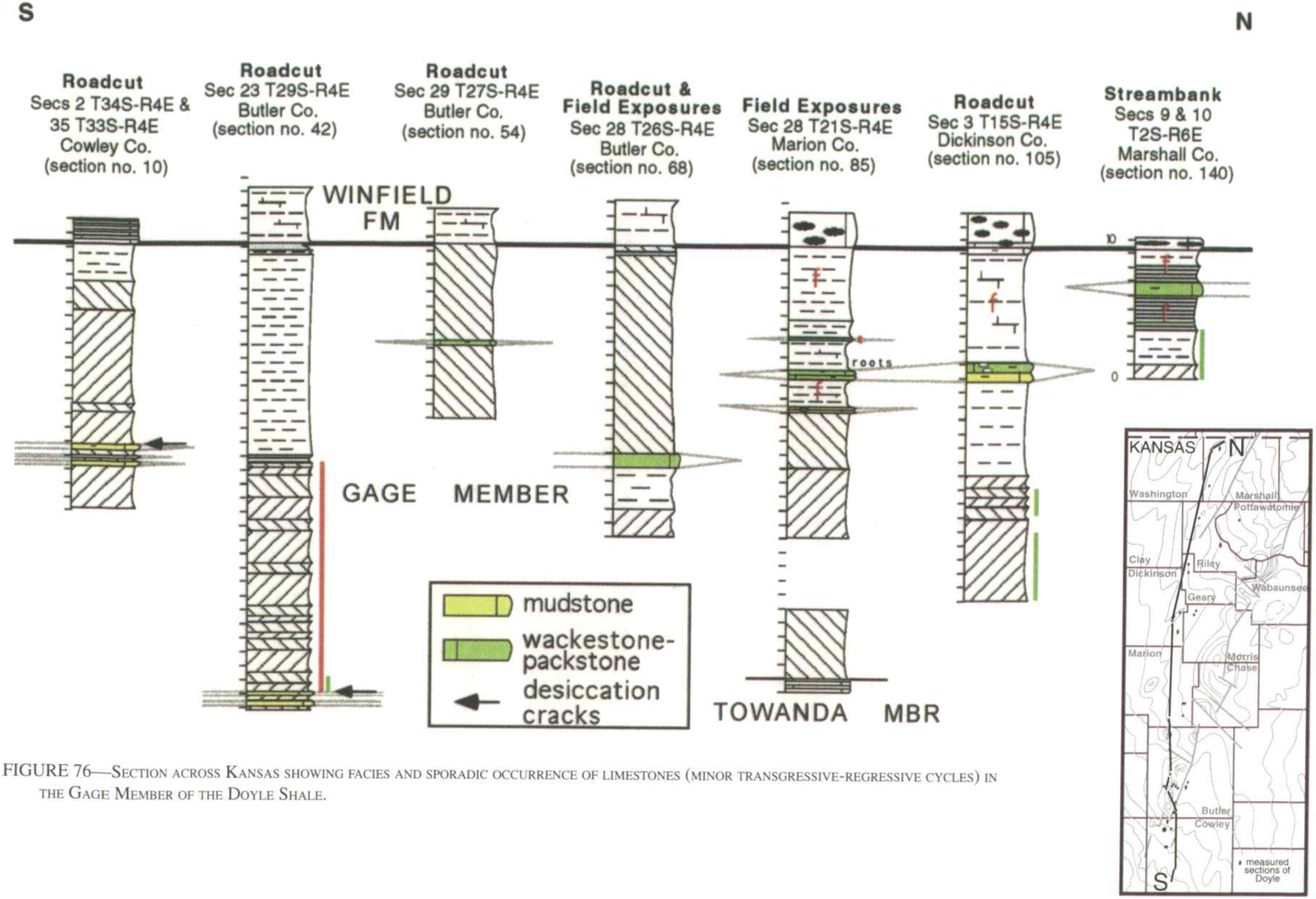


FIGURE 76—Section across Kansas showing facies and sporadic occurrence of limestones (minor transgressive-regressive cycles) in the Gage Member of the Doyle Shale.

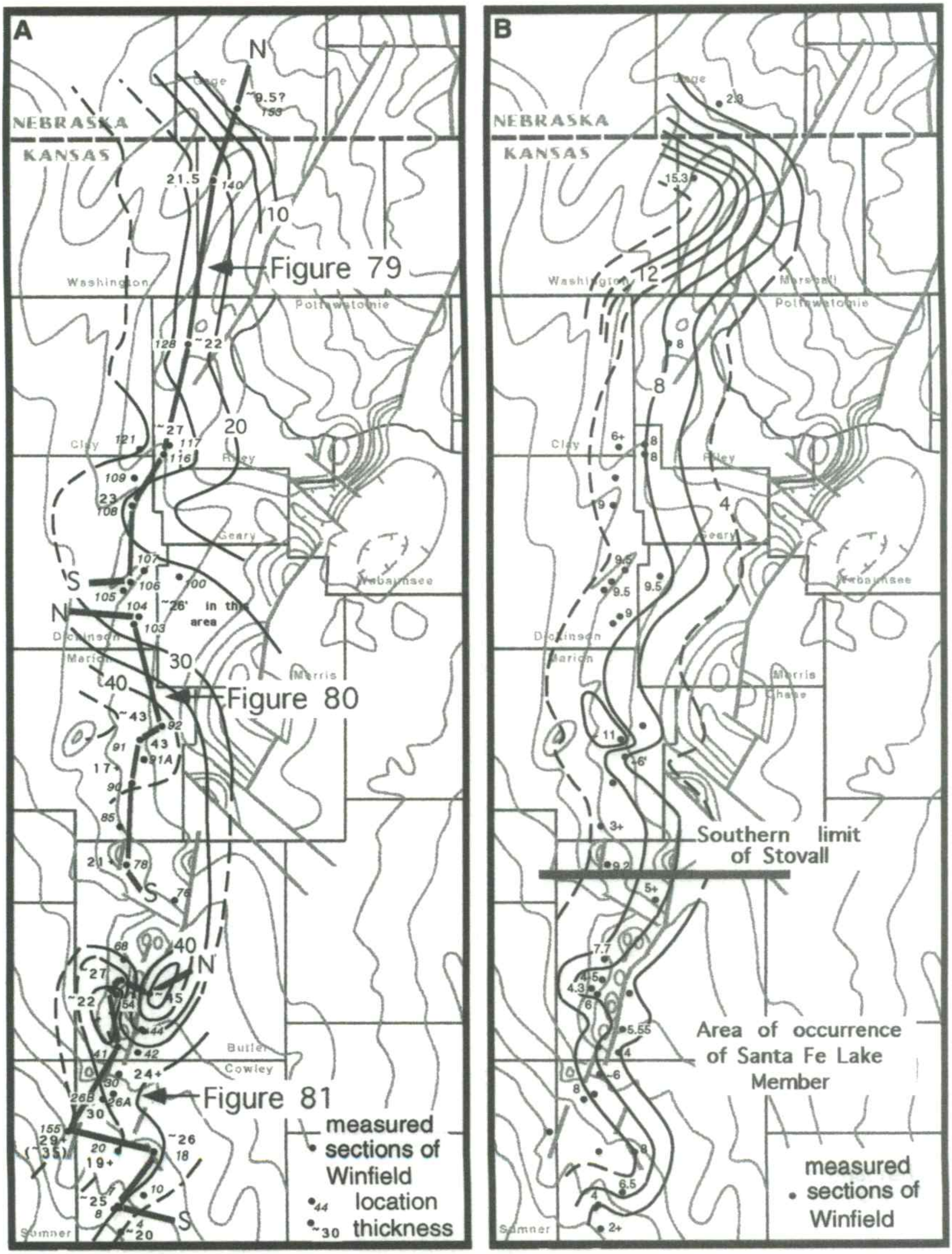


FIGURE 77—A) Isoapch of the Winfield Limestone (CI = 5 ft [1.5 m]), and locations of cross section figs. 79–81. B) Isopach of the Grant Member (CI = 2 ft [0.6 m]), and areal distribution of the Stovall and Santa Fe Lake Members.

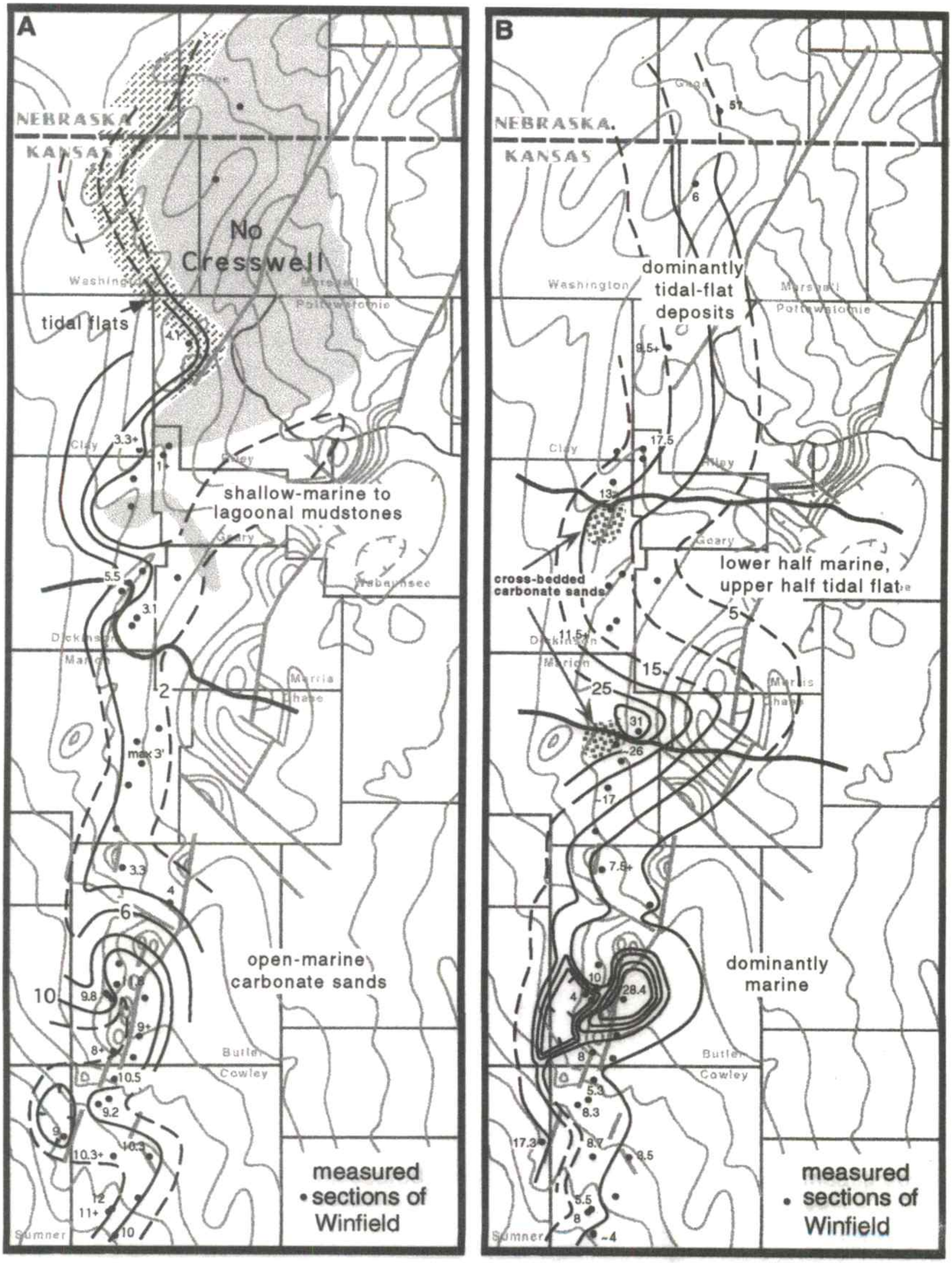


FIGURE 78—A) Isopach of the Cresswell Member (CI = 2 ft [0.6 m]) and distribution of inferred facies. B) Isopach of the Luta (CI = 5 ft [1.5 m]), and dominant facies.

area, detailed search disclosed that stratigraphically higher units in fact are not present. Estimated thickness of the Winfield is about 35 ft (10.7 m) at this locality (figs. 77A, 81). Perhaps because of the narrowness of the outcrop belt, this exposure of Chase Group strata is not included on the current geologic map of Kansas.

Correlation of the Winfield Limestone across Kansas is fairly straightforward, notwithstanding facies and thickness changes in its component members (figs. 79–81). The Winfield is very poorly exposed, however, in Nebraska. What we believe may be about 9.5 ft (2.9 m) of exposed Winfield, as suggested by field relations, is an outcrop along the streambank at measured section number 153 in Gage County (fig. 79). The Winfield–Odell contact is sharp to locally gradational, and there is no evidence of an unconformity at the top of, or anywhere within, the formation where we have seen it in Kansas and Nebraska.

Relative to the dominantly tLST of the Gage and the overlying Odell, the Winfield represents a major marine HST that is recognized throughout the study area. At a finer scale of resolution, the tripartite subdivision of the Winfield, which is also recognized regionally, is interpreted to represent, in ascending order, relative highstand (Stovall–Santa Fe Lake Members), mLST (Grant Member), and ensuing dominant highstand (Cresswell and Luta Members) phases of deposition. This stratigraphic mosaic is therefore similar to that in the Wreford, Kinney, Fort Riley, and Towanda, and suggests long-term allogenic control on deposition of the formation.

Stovall–Santa Fe Lake Members

The Stovall Member, that is, cherty limestone, is clearly recognized from northernmost Butler County to Marshall County, Kansas (figs. 77B, 79, 80). The member varies in thickness in this area from about 1 to 3.3 ft (0.3–1.0 m) and generally thins to the north. Maximum thickness of 3.3 ft (1.0 m) occurs at measured section number 91A in northeastern Marion County (e.g., shown in fig. 80). These thickness values agree with those of previous workers. The Stovall consists mainly of fossiliferous, nonporous lime mudstones to biowackestones, and local biopackstones, with relatively abundant *Derbyia*, *Reticulatia*, and bryozoans. At measured section number 153 in Gage County, Nebraska (fig. 79), the presumed Stovall-equivalent section is a little over 2 ft (0.6 m) of interbedded, shaly, intraclastic dolomudstones, biowackestones, and fossiliferous, light-gray mudrocks with foraminifera, *Permophorus* spp., *Aviculopecten* spp., *Septimyalina* spp., and some high-spired gastropods. If indeed this section is Stovall, then these facies suggest proximity to its northern paleoshoreline. The Santa Fe Lake Member is sporadically developed throughout Butler and Cowley counties (fig. 77B), where it is about 3–4 ft (0.9–1.2 m) thick and composed mainly of thin-bedded, shaly, and poorly fossiliferous (e.g., some pelecypods) lime mudstones (fig. 81). A thin bed of oncolitic carbonate sand occurs at the base of the member at measured section number 7 in Cowley County (fig. 81).

Regional lithologic and biotic relationships suggest that the Stovall represents open-marine facies, whereas the Santa Fe Lake is composed of marginal-marine, and locally, tidal-flat deposits. We believe that the Stovall is the deepest-water of facies within the Winfield Limestone (Mazzullo et al., 1995, 1996). The initial TST and the HST of the Winfield cycle are therefore represented by the upper Gage and Stovall–Santa Fe Lake Members; a maximum flooding surface is not readily apparent within the former members (fig. 80).

Grant Member

The minimum thickness of this member is about 4 ft (1.2 m) in southernmost Cowley County, although it is as much as 8 ft (2.4 m) thick at some other localities in the county (fig. 77B). The Grant previously was thought not to be present in most of Cowley County (e.g., Bass, 1929; Bayne, 1962; Zeller, 1968), although it is clearly identified here, as well as in Sumner County (at measured section 155), as fossiliferous mudrocks and shaly limestones above the Santa Fe Lake Member (where present) and/or the unfossiliferous Gage (fig. 81) as was demonstrated by Mazzullo and Teal (1994). The thickness of the member increases to the north, to a maximum of about 15.3 ft (4.7 m) at measured section number 140 in Marshall County, on the edge of the Salina basin (figs. 77B, 79, 80). These thickness values agree with those of previous workers. Local thickening of the member occurs at measured section number 91 in Marion County, within the Salina basin (fig. 77A). The presumed Grant at measured section number 153 in Gage County, Nebraska, is 2 ft 4 inches (0.7 m) of unfossiliferous, black shale interpreted to be lagoonal deposits (fig. 79). Regional thickness of the Gage suggests a dominant source of siliciclastics from the north-northeast.

The Grant consists largely of fossiliferous (*Derbyia* spp., *Reticulatia* spp., crinoids, bryozoans), marginal-marine mudrocks with some lenses of shaly limestone. Inferred evaporitic tidal-flat facies (mainly siliciclastic) occur at the top of the member at several localities in northern Kansas (figs. 79–81). Presumed paleosols occur immediately above the Santa Fe Lake Member, at the base of the Grant, at several localities in Butler County (e.g., at measured sections 44 and 55, shown in fig. 33). Small nodules of black chert occur locally in the section in Geary and Marshall counties (fig. 79).

A prominent and readily mappable, oncolitic limestone section about 3 ft (0.9 m) thick, with red oncolites, occurs just below the top of the member throughout most of Cowley County (figs. 81, 82A, B), and we traced this unit into Sumner County (measured section 155)(fig. 81). This bed was referred to as the "concretionary zone" by Bass (1929) and Bayne (1962), and as the "pebble zone" by Condra and Upp (1931). Bass and Bayne, however, had

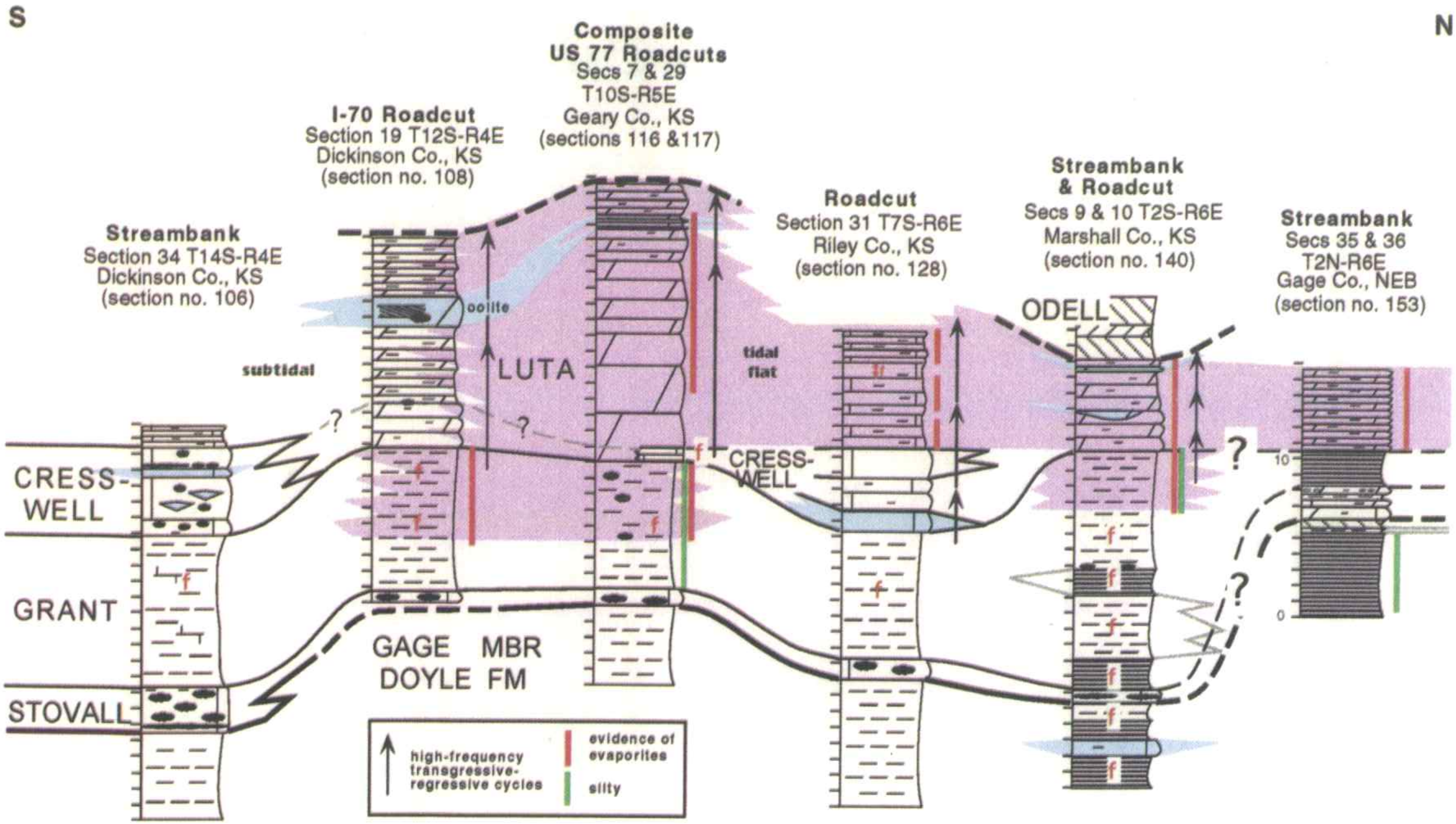


FIGURE 79—SECTION FROM DICKINSON COUNTY, KANSAS, NORTHWARD TO GAGE COUNTY, NEBRASKA, SHOWING STRATIGRAPHY AND INFERRED FACIES IN THE WINFIELD LIMESTONE. Dashed gray lines with arrows refer to possible facies correlation where the Cresswell is not recognized.

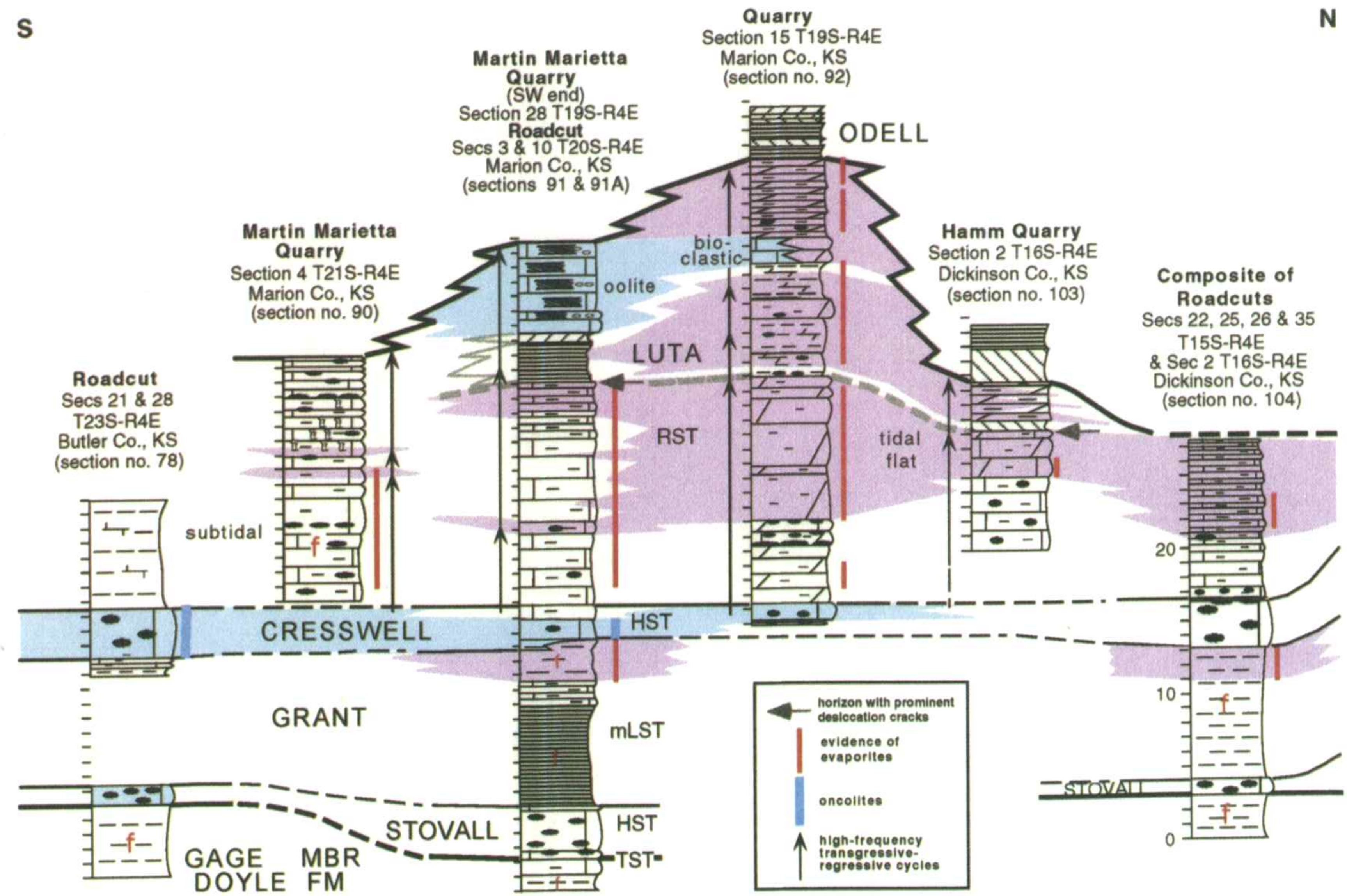


FIGURE 80—SECTION THROUGH CENTRAL KANSAS SHOWING STRATIGRAPHY AND INFERRED FACIES WITHIN THE WINFIELD LIMESTONE. Bold arrows connecting dashed gray line show correlation of prominent desiccated cryptalgal lime mudstones within the Luta. Note presumed facies relationship between Luta and Odell.

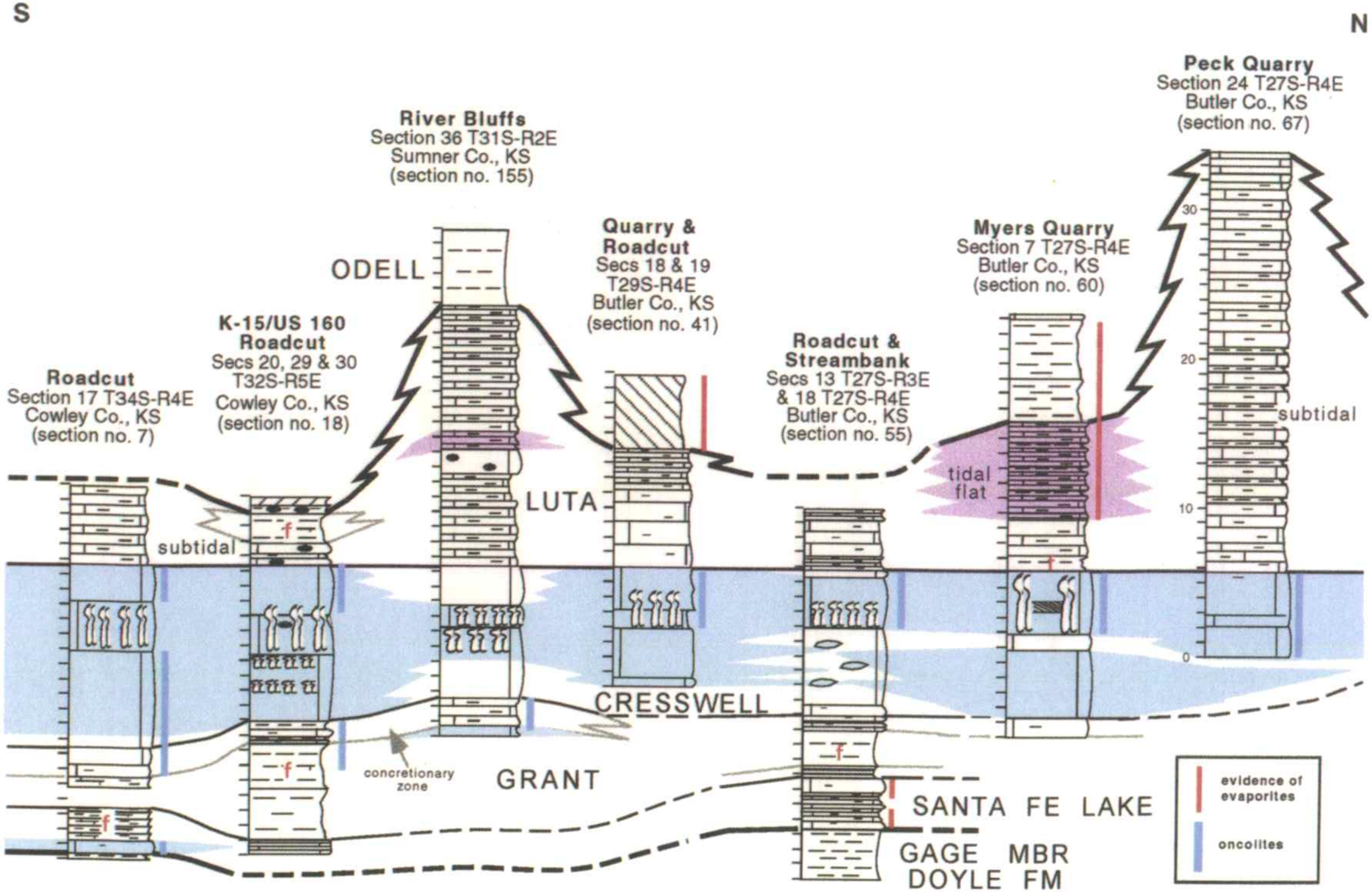


FIGURE 81—SECTION THROUGH BUTLER AND COWLEY COUNTIES, ILLUSTRATING STRATIGRAPHY AND INFERRED FACIES WITHIN THE WINFIELD LIMESTONE. Note presumed facies relationships between Luta and Odell.

erroneously included this unit within the Gage Member of the Doyle Shale. In south-central Kansas the uppermost foot or so of the member is variously fossiliferous mudrock or a recessive-weathering, shaly, bioturbated limestone; to the north, the contact is placed between the underlying mudrock and the massive, commonly cherty limestone of the overlying Cresswell (figs. 79–81).

Cresswell Member

The Cresswell Member is recognized lithologically on the basis of its light color, local content of chert nodules, massive bedding, and "rough" weathering appearance due to the presence of silicified fossils (Prosser, 1897; Condra and Upp, 1931). The upper contact with the Luta is conformable but locally gradational (fig. 83A). As so recognized, the Cresswell is readily traced from Riley and Clay counties southward to Cowley County, where it increases in thickness from about 3 ft to a maximum of about 12 ft 2 inches (0.9–3.7 m)(figs. 78A, 79–81). The thickness of the member drastically increases south of the latitude of El Dorado in Butler County, both within the Walnut syncline and on the Nemaha Ridge (fig. 78A). These thickness values are consistent with those of other workers and, considering the relatively uniform thickness of the underlying Grant Member, suggest increased accommodation toward the south during deposition of the Cresswell. At measured section 155 in Sumner County the Cresswell is only 9 ft (2.7 m) thick, and defines a local high atop the transition from the Nemaha Ridge into the Sedgwick basin (fig. 78A). The relatively thin Cresswell section to the immediate east of this locality suggests that this high is part of an east-west-trending arch that extended into the Walnut syncline (fig. 78B).

In Sumner, Cowley, Butler, and southern Marion counties, the member is dominantly very porous, oncolitic carbonate sand, deposited on a shallow, high-energy, open-marine shelf (figs. 78A, 80, 81). This section typically includes one or more beds with prominent vertical burrows (locally with the pelecypods *Aviculopinna*, *Septimyalina*, and *Allorisma* spp.), and it locally is cross stratified (figs. 81, 82C and D). Foraminifers are abundant in many beds, and accessory fossils include bryozoans, *Derbyia* spp., crinoids, and echinoid fragments. At measured section number 92 in Marion County, the Cresswell is 1.7 ft to, perhaps, a maximum of 3 ft thick (0.5–0.9 m), and facies likewise are porous, bioclastic carbonate sands (with fossils as above), but without oncolites. These sands pass into more micritic, probably lagoonal lithologies farther to the north, in Dickinson County (figs. 78A, 79, 80). On the basis of lithology, the Cresswell is not recognized in parts of northeastern Dickinson and adjoining Geary and Morris counties, and in most areas to the north as far as Nebraska (figs. 78A, 79), where instead, the Luta sits directly on the Grant (figs. 82E, F). Interbedded Cresswell-type and Luta-type lithologies are exposed at measured section number 128 in central Riley County, just north of the town of Walsburg (figs. 79, 83A). The upper part of the thickened section of Grant at measured section 140 in Marshall County, which includes a few feet of tidal-flat siliciclastics at the top, may be the facies equivalent of the Cresswell (fig. 79).

Field observations and correlations suggest that the Cresswell is absent by nondeposition rather than by erosion in the northern part of the study area, and is a facies of the Luta, and locally perhaps, also of the upper Grant. This area was not emergent during deposition of the underlying fossiliferous Grant, although shallowing during this time is suggested by peritidal facies in the upper Grant (e.g., at measured section 140, fig. 79). The Grant is not anomalously thick where the Cressswell is absent (figs. 77B and 78A). The overlying Luta is present as a section of peritidal carbonate facies where the Cresswell is absent (fig. 78B). These observations lead us to conclude that the area where the Cresswell changes facies to the Luta may have been a somewhat positive area that may have resulted from a pulse of tectonic uplift. Compensating for this uplift was increased subsidence toward the south, where the Cresswell is thick.

Although they were unsure of stratigraphic relationships, Condra and Upp (1931) believed that the Cresswell could be traced from Kansas into Nebraska, whereas the Luta was absent in northern Kansas and Nebraska. This same contention was reiterated by Zeller (1968). As shown in figs. 78A and 79, however, it is our contention that it is the Cresswell that pinches out long before reaching southeastern Nebraska, whereas the Luta alone is present in northern Kansas and Nebraska (fig. 82E, F). In fact, even Moore and Elias (no date, open-file report) had earlier questioned Condra and Upp's (1931) conclusions regarding these members, and in doing so, precognitively lended support to our conclusions when they stated (p. 133) "... and that it is the Luta that persists through Marshall and Washington counties and into Nebraska." By our correlations (e.g., fig. 79), the Cresswell likely is a facies of the lower Luta (and locally, possibly also the upper Grant) in northern Kansas. Insofar as the Luta in northern Kansas is mainly tidal-flat facies, the line of depositional pinchout of the Cresswell (fig. 78A) represents its paleoshoreline. Figure 84 illustrates the lithofacies nature of this pinchout where it occurs, for example, across part of Dickinson, Geary, and Morris counties. The Cresswell is dominantly open-marine, carbonate sands southward from Marion County, and becomes more micritic marginal-marine facies, and locally, peritidal facies farther to the north (e.g., figs. 78A, 84) before it pinches out.

Luta Member

As discussed above, the Luta is traced from Marshall County southward to Cowley and Sumner counties, Kansas, where its thickness generally varies from about 3.5 to 20 ft (1.1–6.1 m), generally increasing in an east to west direction and decreasing to the south (fig. 78B). The member is anomalously thick in south-central Butler County (28.4 ft [8.7 m]), within the Walnut syncline immediately east of the Humboldt fault, and in northeastern Marion County (31 ft [9.5 m]) essentially on the Nemaha Ridge (fig. 78B). Two east-west-trending areas of relatively thin Luta section, in adjoining parts of northern Morris, southern Geary, and western Dickinson counties, and in northern Butler County, are interpreted to be slightly positive areas that separated depocenters where the Luta is anomalously thick (fig. 78B). A local, but prominently thin Luta section (4 ft [1.2 m]) defines a slightly

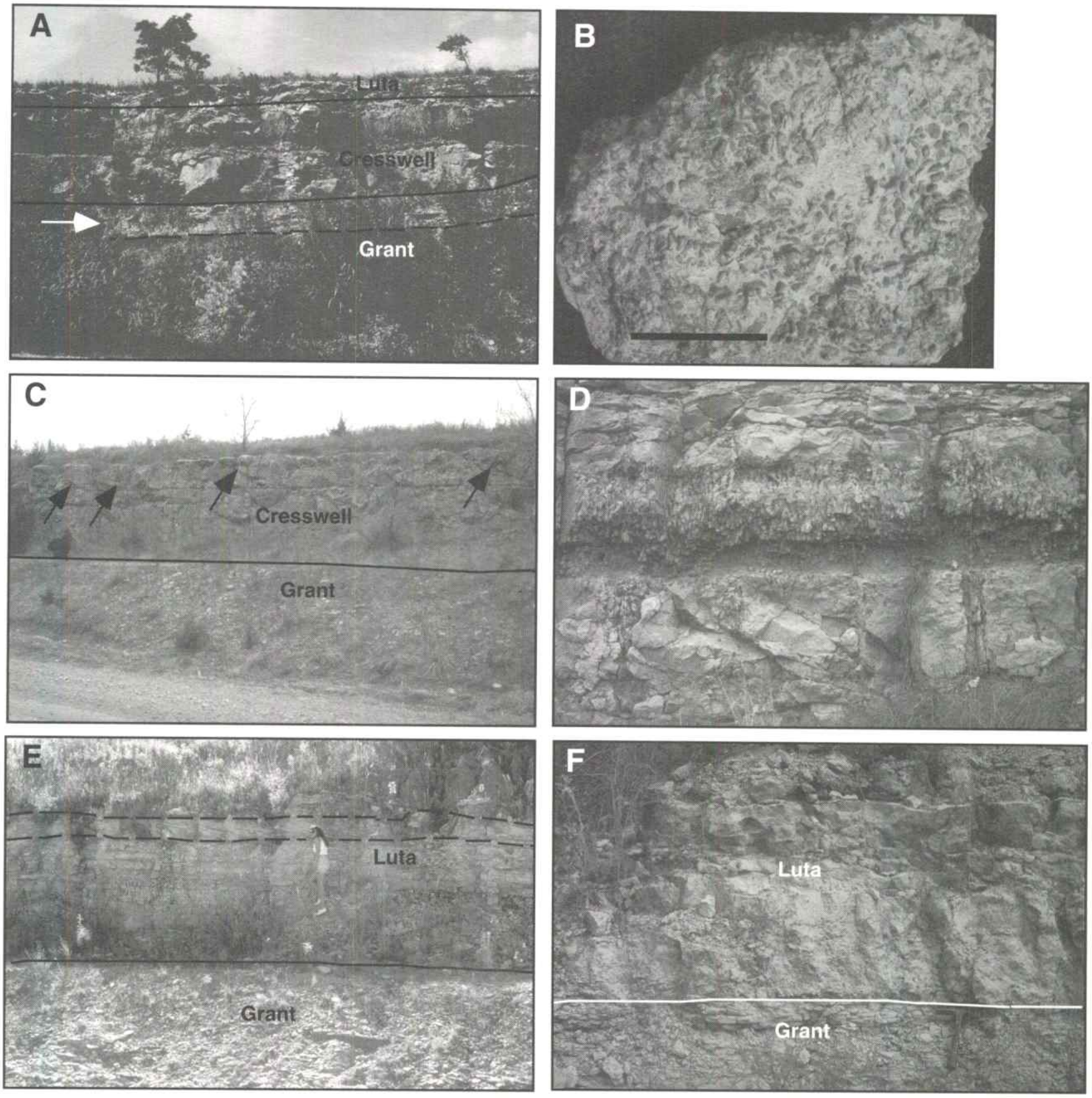


FIGURE 82—A) Roadcut along K–15 east of Udall, showing Winfield section, and particularly, the 3-ft (0.9-m)-thick oncolitic ("concretionary") zone in the upper part of the Grant Member (indicated by the white arrow); measured section number 26A, Cowley County, Kansas). B) Slab of oncolites from the "concretionary zone" at this locality; length of scale 2 inches (5.1 cm). C) Roadcut along Hopkins Switch Road, west side, showing apparent large-scale foresets (arrows) in the upper part of the Cresswell; measured section number 66, Butler County, Kansas. D) Roadcut along US–77 just north of Rock, east side, showing prominent porous, vertically burrowed zone in the Cresswell (hammer for scale); measured section number 30, Cowley County, Kansas. Nearly the entire thickness of the Cresswell is shown. E) Luta directly overlying the Grant; note 2-ft (0.6-m)-thick, crossbedded, dolomitized oolite grainstone (between dashed lines); measured section number 108, Dickinson County, Kansas, along I–70, south side. The Stovall is exposed to the immediate left (east) of this photo. F) Luta directly overlying the Grant (hammer for scale); roadcut adjoining Roemer Creek, measured section number 140, Marshall County, Kansas.

elongate arch in southwesternmost Butler County, atop the Nemaha Ridge (fig. 78B). The Luta is 17.3 ft (5.3 m) thick at measured section number 155 in Sumner County, along the eastern edge of the Sedgwick basin (figs. 78B, 81). Bass (1929, p. 94) erroneously reported the Luta to be 25 ft (7.6 m) thick at this locality. Presumed Luta strata exposed at measured section number 153 in Gage County (fig. 79) are 5 ft (1.5 m) of shaly dolomudstones with evidence of former evaporites (tidal-flat facies).

Throughout Butler, Cowley, and Sumner counties, the Luta consists mainly of non-porous, shallow, nearshore-marine, micritic and fossiliferous limestones (locally dominated by *Composita* spp.) that grade upward into the Odell (fig. 81). A relatively thick section of tidal-flat limestones occurs in the upper half of the member at measured section number 60 in Butler County (fig. 81). Northward from Marion County, the Luta becomes dolomitic and porous (from the dissolution of evaporite nodules), and evaporitic tidal-flat deposits compose progressively more of the member (figs. 78B, 79, 80). In general, these lithostratigraphic attributes suggest that the Luta dominantly is a normal RST (sensu Posamentier et al., 1992). Some higher-frequency cycles are evident in these sections, and some of them appear to be persistent over large areas (figs. 79, 80), and hence, may be of allogenic origin. Lenses of relative highstand carbonate sand (variously oolitic or bioclastic) compose at least one of these cycles in the upper part of the Luta at measured sections 91 and 92 in Marion County, 108 in Dickinson County, 116–117 in Geary County, and 140 in Marshall County (figs. 79, 80, 82E, 83C). The anomalously thick peritidal deposits in central and northern Kansas likely reflect autogenic, Ginsburg (1971)-type cycles superimposed on long-term allogenically controlled deposition.

The thick Luta section at Peck quarry in Butler County (figs. 81, 83B) is entirely subtidal, fossiliferous marine limestones and mudrocks. The overlying Odell section here is not exposed, but detailed mapping in the vicinity of this quarry suggests it is only about 7 ft (2.1 m) thick (fig. 85A). The thick Luta at the type-locality quarry in Marion County (measured section number 92, fig. 80) is nearly entirely tidal-flat facies and likewise is overlain by a relatively thin (11 ft [3.4 m]) Odell section (fig. 85A). The upper 6 ft (1.8 m) of the Luta at the Martin Marietta quarry in sec. 28, T. 19 S., R. 4 E. in Marion County (measured section nunmber 91, fig. 80) is a locally developed lens of cross stratified, porous, oolite grainstone (fig. 78B) directly overlying a few feet of dark shale which, in turn, is underlain by interbedded tidal flat and shallow-subtidal limestones (fig. 83C); these dark shales are typical lower Odell-type facies (e.g., refer to the lower Odell at measured section number 103, fig. 80). We correlate the oolite here with a thin section of porous, fossiliferous carbonate sands at the Luta-type locality quarry (fig. 80). A similar lens of cross stratified, porous, oolitic dolograinstone occurs in the upper Luta at measured section number 108 in northern Dickinson County (figs. 78B, 79, 82E). Most importantly, we have traced a prominently expressed bed of desiccated, presumed cyanobacterial laminites (fig. 83D) between the exposures in these quarries and those in the Hamm quarry (measured section number 103) in Dickinson County (fig. 80). We believe this exposure horizon, which is developed only locally, resulted from aggradational and/or progradational deposition rather than from a forced regression. By these correlations, and by available thickness data for the Odell as discussed above, it appears that the expanded Luta sections in Butler and Marion counties occur at the expense of the overlying Odell. That is, not only is the Luta locally interbedded with the underlying Cresswell (e.g., measured section number 128, fig. 79), but it also locally appears to be a facies of the Odell as well (as shown in figs. 80, 81).

Odell Shale

The Odell is recognized throughout the study area (fig. 85A). Two areas of maximum thickness of from about 29 to 40 ft (8.8–12.2 m) occur in northern Marshall, northeastern Washington, and southern Gage counties, on the edge of the Salina and Central Nebraska basins, and in southernmost Cowley County within the Walnut syncline. In between, its thickness ranges from about 7 ft (2.1 m) in central Butler County (above the thickened Luta at measured section number 67) to from 11 to 27 ft (3.4–8.2 m), generally increasing in an east to west direction. This thickness distribution suggests two sources of siliciclastics, one to the north and the other to the south. Approximately 5 ft (1.5 m) of basal Odell strata are exposed at measured section number 155 in Sumner County (fig. 81).

Throughout most of the study area the Odell is composed of a tLST of unfossiliferous, mostly red and green terrestrial siliciclastics, and with some lighter-colored shales/mudrocks and abundant paleosols locally in some sections (fig. 86). A few feet of light-colored, unfossiliferous shales occur at the top of the formation in northernmost Kansas and Nebraska, and they may be incipient TST marginal-marine to possible peritidal facies that were deposited in a topographic low on the edge of the Salina and Central Nebraska basins. Elsewhere there is an abrupt contact between marine TST facies of the basal Nolans Formation and the terrestrial red and green shales/mudrocks and paleosols (tLST facies) in the upper Odell from Washington County southward to central Cowley County (fig. 86). At measured sections 4, 8, and 9 in southernmost Cowley County, the upper few feet of the Odell consist of unfossiliferous, laminated black shales (fig. 86) that may be tidal laminites, and hence, the TST of the overlying marine cycle of deposition.

Nolans Limestone

The Nolans Limestone is relatively poorly exposed in the study area, where it varies in thickness from about 18 to 37 ft (5.5–11.3 m), generally increasing in a northeast-to-southwest direction (fig. 85B). Relative to the dominantly tLST of the underlying Odell and the overlying Wellington Formation, the Nolans is a marine-dominated section that defines a long-lived highstand. At a finer scale of resolution, however, the Nolans is a tripartite section of two relative HST carbonates (Krider and Herington Members) separated by mLST siliciclastics (Paddock Member) within which there is no evidence of regional subaerial exposure (fig. 86). Such a stratigraphy, which is similar to that of the Wreford, Kinney, Fort Riley, Towanda, and Winfield, implies fundamental long-term allogenic control on deposition of this formation.

Krider Member

The Krider Member varies in thickness across the study area from about 2.4 to 9.3 ft (0.7–2.8 m), with maximum thickness in southernmost Cowley County (fig. 87A). The upper contact with the Paddock Shale Member is mostly gradational within a few inches, and a possible unconformity is present at the top of the Krider at only one locality in the study area (measured section number 109 in Dickinson County, fig. 86) as indicated by the presence of vertical rootcasts and intraclasts. Except in southernmost Cowley County, the member is nearly everywhere a tripartite section of two thin carbonates (HST) separated by marginal-marine (mLST) mudrocks and/or shales (e.g., figs. 38B, 86), a stratigraphy that because of its regional occurrence may represent allogenic cyclicity. Despite the difference in scale, this cyclicity mimics that of the relatively lower-frequency cyclicity in the Wreford, Kinney, Fort Riley, Towanda, and Winfield. Mudrocks occur in place of the lower carbonate and are interbedded with the upper carbonate at some localities (fig. 86). The TST of the Nolans cycle is inferred to include the basal bed in the Krider, and locally, some strata in the uppermost Odell; the maximum flooding surface of this cycle is obscure, but may occur within the basal carbonate. The middle section of mudrock/shale within the Krider generally is sparsely fossiliferous (pelecypods), and variously light-colored to black and/or variegated black and gray/green.

A thickened section of Krider, composed instead of three beds of carbonate separated by fossiliferous mudrocks, occurs in southernmost Cowley County at measured sections 4, 8, and 9 (fig. 86). We believe that the

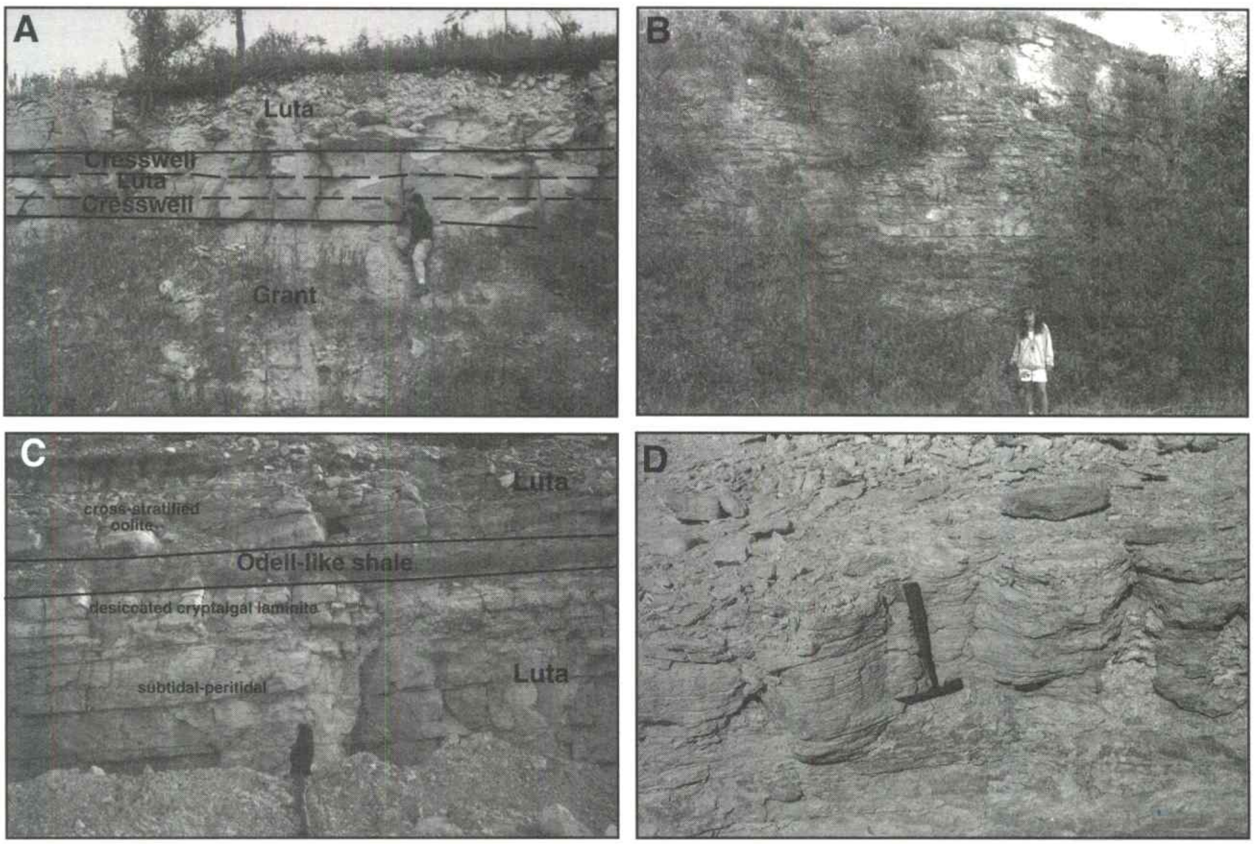


FIGURE 83—A) Interbedded Cresswell and Luta lithologies at roadcut along Union Road north of Walsburg, measured section number 128, Riley County, Kansas. The Stovall is also exposed at this locality. B) Thick section of marine facies in the Luta at Peck quarry, measured section number 67, Butler County, Kansas. C) Luta and interbedded Odell-like shale at Martin Marietta North Marion quarry, measured section number 91, Marion County, Kansas. The zone of desiccated cryptalgal laminites below the shale is correlated to nearby outcrops (see next figure). D) Deep desiccation cracks in bed of cryptalgal laminites in the upper Luta at Hamm quarry, measured section number 103, Dickinson County, Kansas.

uppermost of these carbonate beds, which is dolomitic, is an "extra" cycle within the dominant HST of the Krider. Toomey and Mitchell (1986) similarly recognized this tripartite Krider section here and in northern Oklahoma. Biotic diversity decreases upward within the Krider, but increases upward within both the lower and middle limestones in the section. The basal limestone is generally a coarsening-upward section of lime mudstone and biowackestone, with crinoids and high-spired gastropods, to biopackstone with abundant *Derbyia*, crinoids, fenestrate and ramose bryozoans, *Myalina*, and large discoidal oncolites. This limestone is prominently exposed at the most westerly outcrop along the bluff at the base of the Spring Hill Golf Course in Arkansas City (measured section number 8 [see fig. 89A]). At the next outcrop a few hundred feet to the east, this bed weathers so recessively that the overlying middle limestone and overlying dolomitic bed can easily be confused for only a bipartite Krider section (i.e., two limestones separated by a shale). The middle limestone also coarsens upward from lime mudstone and biowackestone with crinoids, echinoid fragments, and some *Derbyia*, to biowackestone and packstone with relatively abundant *Derbyia* and accessory *Composita*, echinoid fragments, crinoids, ramose and fenestrate bryozoans and vertical burrows, some of which are occupied by *Aviculopinna*. The uppermost bed is porous, dolomitic biowackestone with abundant biomolds and ramose bryozoans. This bed is poorly exposed at the most westerly outcrop at the Spring Hill Golf Course (fig. 89A), but well exposed a few hundred feet to the east and at nearby measured sections 4 and 9 (e.g., fig. 89B). Each of the intervening sections of mudrock between the carbonate beds generally include abundant large, discoidal oncolites in the lower half, and very abundant *Composita* in the upper half.

Carbonate facies in the Krider northward from northern Butler County are mostly shaly dolomudstones with micro-intercrystalline porosity which, together with the intervening mudrocks, carry a sparse and impoverished biota dominated by pectinids. These rocks are interpreted as low-energy, shallow-marine deposits. A thin lens of high-energy, pelecypod-gastropod sand occurs within the upper carbonate at measured section number 109 in Dickinson County (fig. 86). In contrast, carbonate facies in the Krider in Cowley County are more open-marine limestones (non-porous biowackestones and some

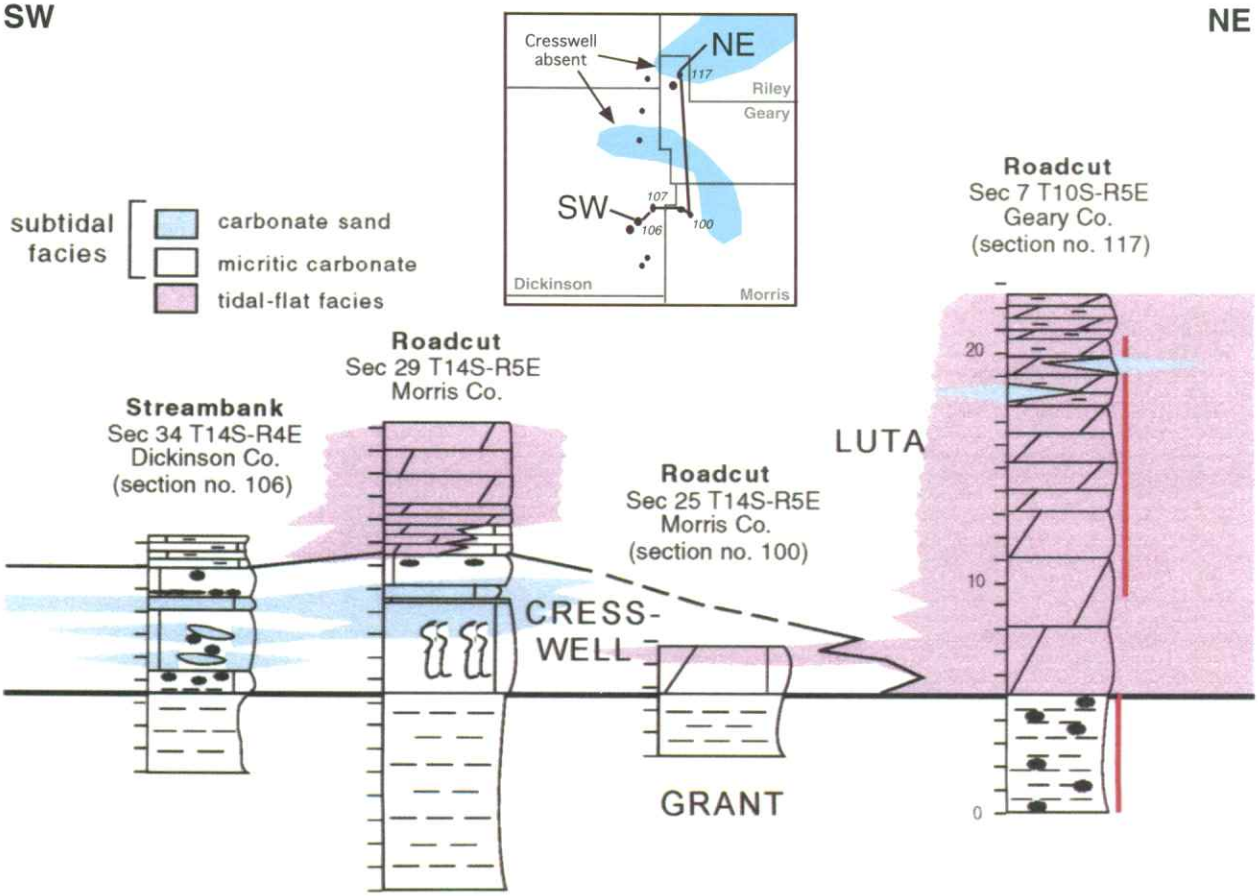


FIGURE 84—Section across part of central-northern Kansas showing nature of the Cresswell-to-Luta transition. Note the change from open-marine Cresswell limestone facies, with abundant brachiopods, crinoids, foraminifers and bryozoans (section number 106); to marginal-marine and peritidal (at top), silty, poorly fossiliferous, evaporitic, dolomitic Cresswell (section number 100); to tidal-flat dolomites in the Luta (section number 117).

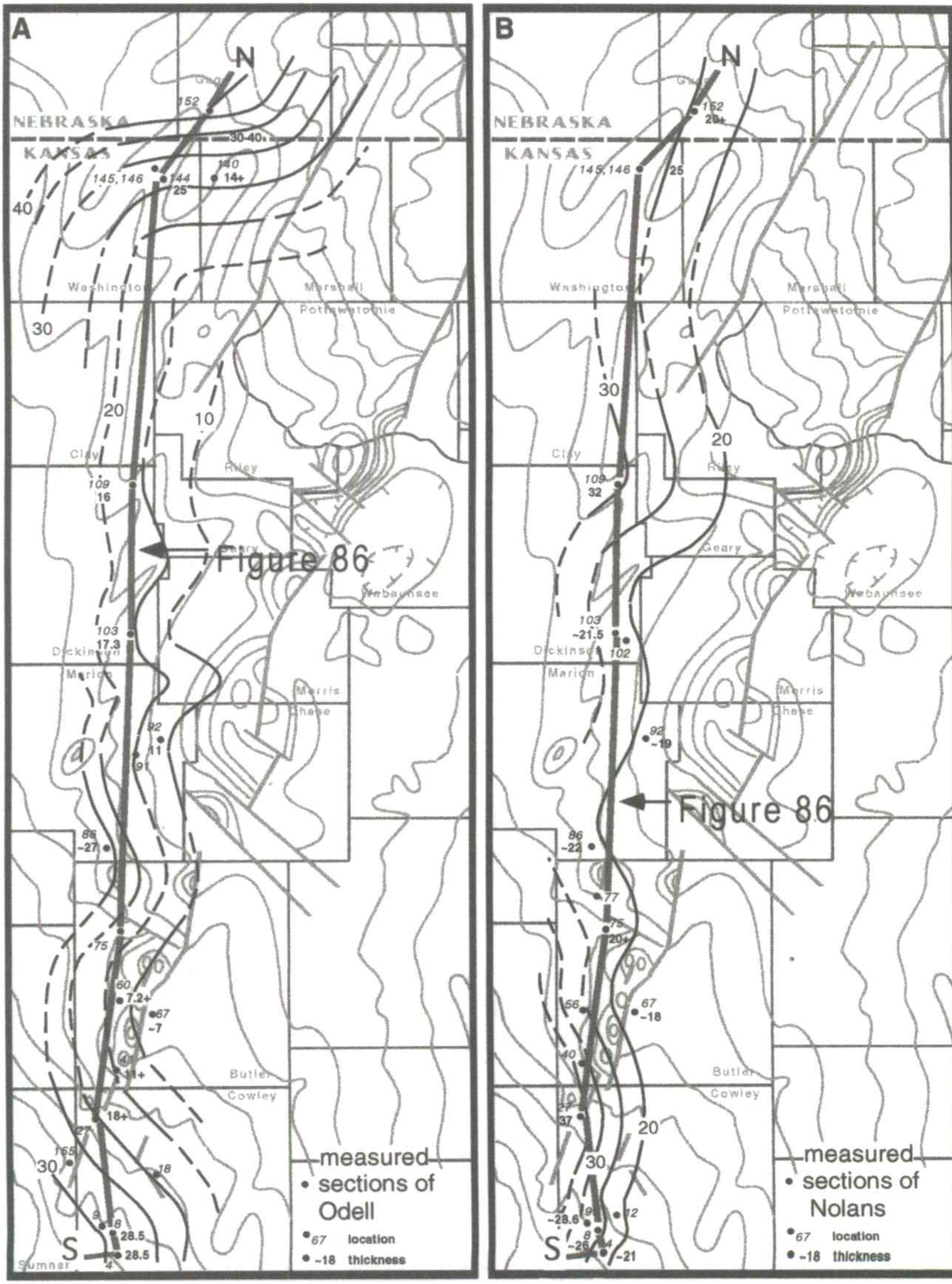


FIGURE 85—A) Isopach of the Odell Shale (CI = 5 ft [1.5 m]), and location of cross section fig. 86. B) Isopach of the Nolans Limestone (CI = 5 ft [1.5 m]), and location of cross section fig. 86.

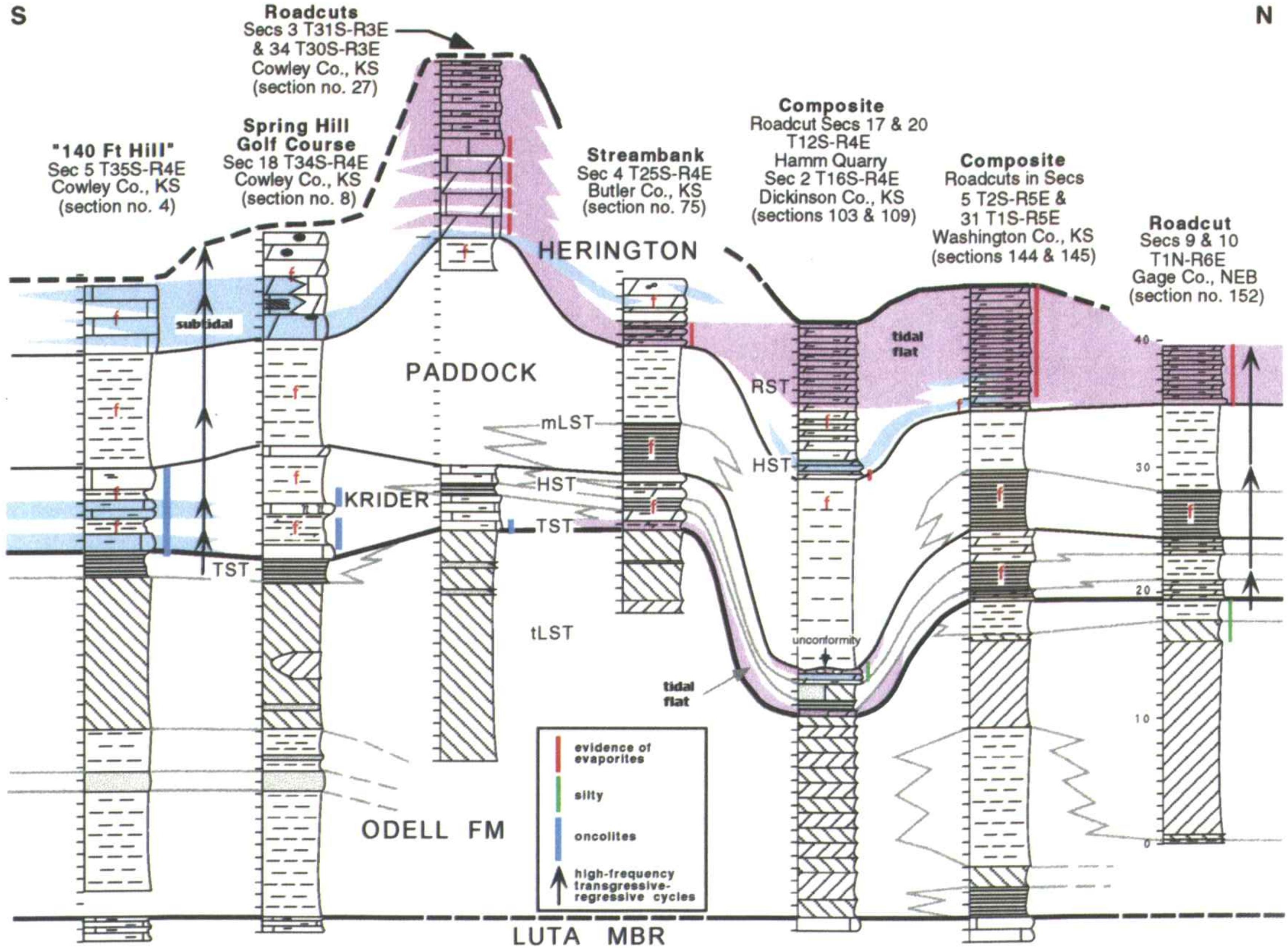


FIGURE 86—Section from Gage County, Nebraska, to Cowley County, Kansas, showing stratigraphy, inferred facies, and correlation of units within the Nolans Limestone.

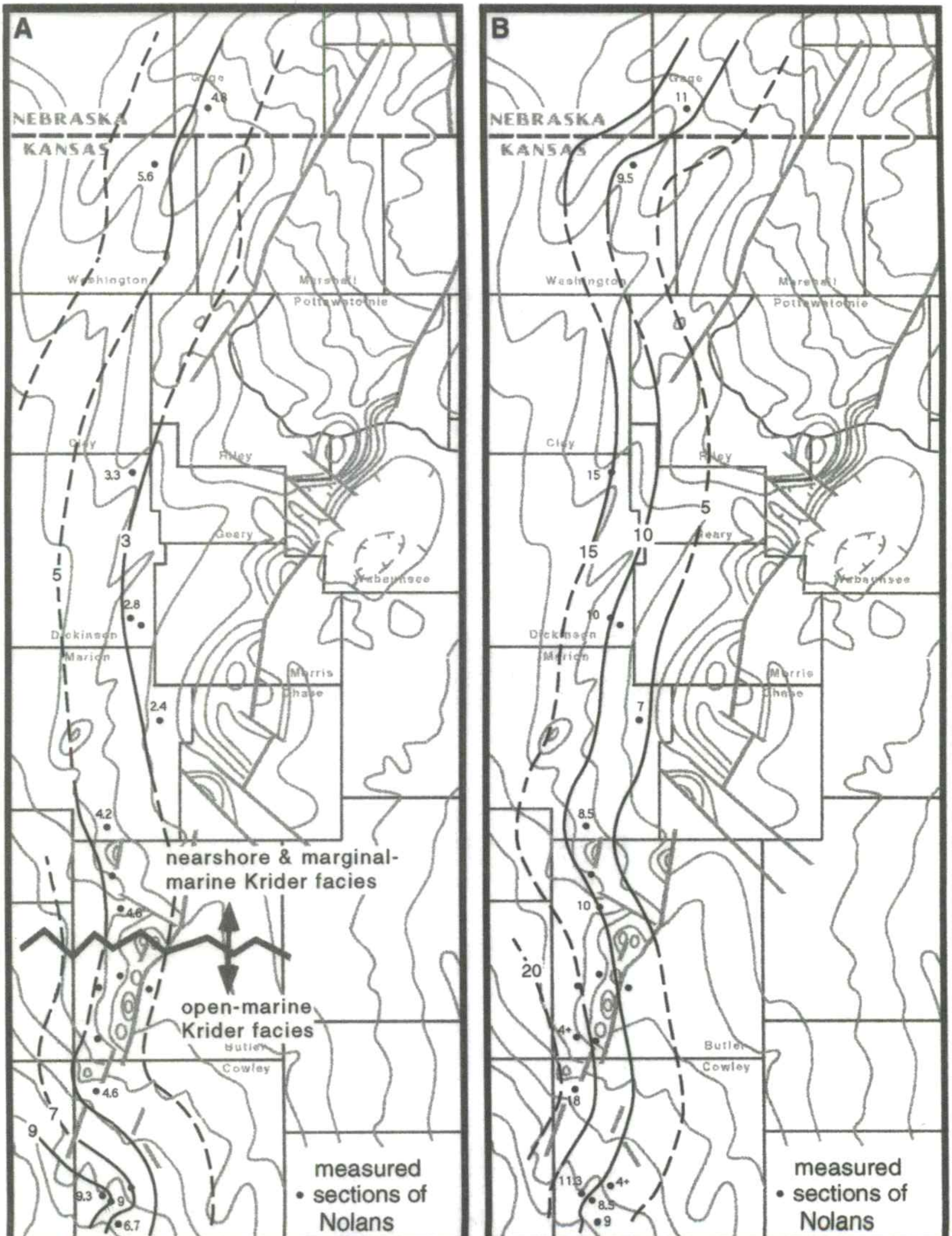


FIGURE 87—A) Isopach of the Krider Member (CI = 2 ft [0.6 m]), and distribution of dominant facies. B) Isopach of the Paddock Member (CI = 5 ft [1.5 m]).

packstones) which, together with the intervening mudrocks, contain a more diverse biota.

Paddock Member

The Paddock also is recognized throughout the study area and varies in thickness from 7 to 18 ft (2.1–5.5 m); maximum thickness is in northwestern Cowley County, on the edge of the Walnut syncline (fig. 87B). Facies generally are sparsely fossiliferous, light-colored shales and mudrocks from Cowley County northward to Dickinson County. In northern Kansas and Nebraska, and at one locality in northern Butler County, the member consists of sparsely fossiliferous, dark shale and mudrock overlain by unfossiliferous, light-colored mudrock (fig. 86). Pectinids, and locally, bryozoans, are the most common fossils in the Paddock. The member is interpreted to represent an mLST within which there is no definitive evidence of subaerial exposure. The Paddock generally weathers to form gentle slopes. At several localities around Arkansas City in southern Cowley County, however, the member becomes slightly more calcitic than elsewhere, and locally, weathers to form prominent vertical faces (e.g., at and around measured sections 4 and 9 [fig. 89C]).

Herington Member

Exposures of the Herington, where it is in contact with the overlying Wellington Formation (Sumner Group) are uncommon in the study area because of the recessive weathering nature of both units. Hence, it was difficult to precisely determine the thickness of this member. Where such exposures are present, the top of the Herington is sharp to locally gradational into the Wellington. Its thickness generally increases from east to west within the study area, from about 6 to 13.8 ft (1.8–4.2 m); a minor embayment of slightly increased thickness occurs in southern Cowley County (fig. 88). The member is nearly entirely dolomite except in southernmost Cowley County, where it is limestone (fig. 86).

From northern Cowley County into Nebraska, the Herington is dominantly unfossiliferous, thin-bedded tidal-flat facies, locally silty, and with evidence of former evaporites at most localities (figs. 86, 89D). These rocks are very porous (micro-intercrystalline porosity). A relatively thick section of porous, cross stratified, dolomitized bioclastic sands occurs in the lower part of the member at measured section number 8 in southern Cowley County (fig. 89E), and a few miles south this section changes facies to interbedded nearshore-marine lime mudstones and lime sands (fig. 86). Fossils in the carbonate sands include mainly foraminifers with accessory crinoids, bryozoans, high-spired gastropods, *Bellerophon* spp., pectinid fragments, *Allorisma* spp., and *Composita* spp. We have been able to trace porous, bioclastic sands near the base of the member from southernmost Cowley

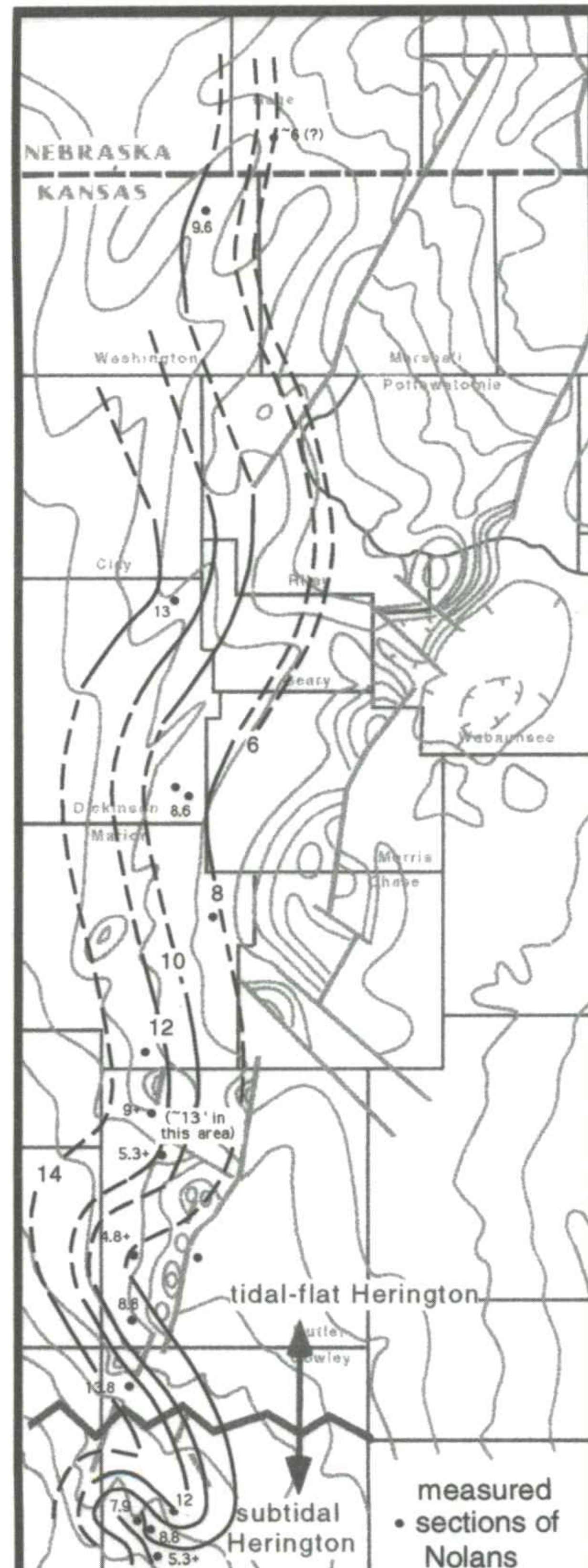


FIGURE 88—Isopach of the Herington Member (CI = 2 ft [0.6 m]), and distribution of dominant facies.

County north into Washington County (fig. 86), and generally, these beds contain abundant molds of foraminifers, pelecypods, and gastropods. We interpret this zone as the HST, including the maximum flooding surface, of the Herington cycle; and the overlying, dominantly tidal-flat deposits, and correlative subtidal facies in Cowley County, are interpreted as normal RST deposits (sensu Posamentier et al., 1992). The thick sections of peritidal facies in the Herington may suggest dominant autogenic control on deposition.

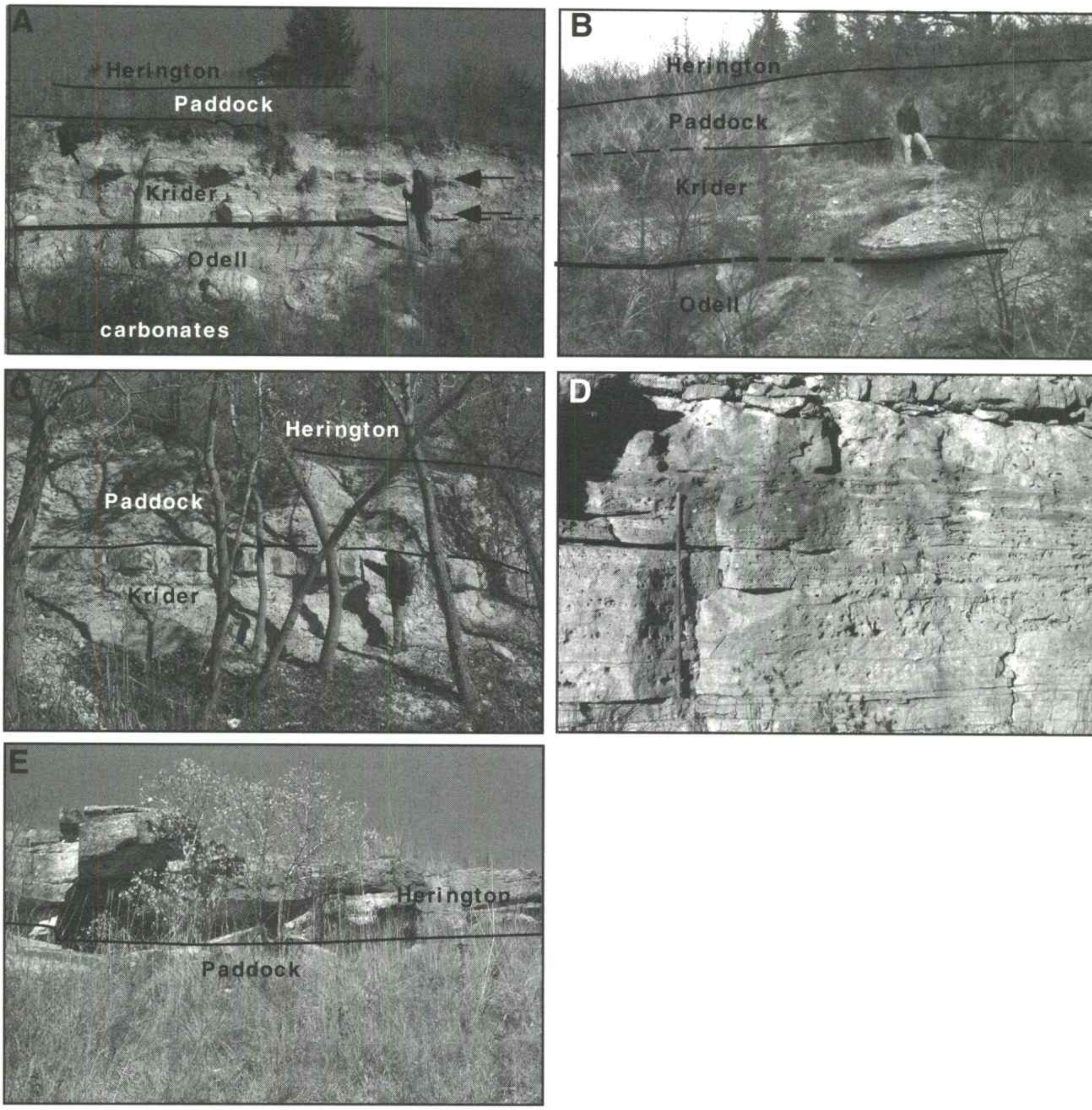


FIGURE 89—A) Odell to Herington section at the Spring Hill golf course in Arkansas City, measured section number 8, Cowley County, Kansas. Note the three carbonates in the Krider. B) Roadcut of Odell to Herington section at "140 Foot Hill," measured section number 4, Cowley County, Kansas. Note the three limestones in the Krider. C) Massive, cliff-forming character of the Paddock Shale at measured section number 9, Cowley County, Kansas. Only the upper two limestones in the Krider appear in this view. D) Typical view of Herington with abundant vugs believed to be dissolved evaporite nodules; rod divided into 20-cm segments. Measured section number 40, Butler County, Kansas. E) Exposure of cross stratified dolobiopackstone to grainstone in the basal Herington, Arkansas City golf course, measured section number 8. The thickness of the Herington shown is about 5.5 ft (1.7 m).

Summary

Revised Stratigraphy and Regional Thickness

Figure 90 illustrates the stratigraphy and thickness of the Chase Group following our proposed revisions in terminology and assignments. Compilation of measured sections to produce the four composite sections of the group shown in this figure purposely did not include outcrops at which units were anomalously thick. Rather, the sections included are located mostly along the axis of the Nemaha Ridge so as to provide data on average thickness of the group. A composite section of the group in Nebraska was not constructed because of incompleteness of exposures. Average thickness of the Chase Group varies very little along depositional strike within the study area, from about 270 to 285 ft (84–87 m), and thins somewhat to the south. This range in average thickness is less than that reported previously in Kansas by Mazzullo et al. (1995). Compilation of measured sections from areas where units are anomalously thick, however (table 1), indicates that maximum thickness of the Chase Group is, as was suggested previously by Mazzullo et al. (1995), about 416 ft (127 m).

As discussed earlier, regional westward thickening into the Central Nebraska and Salina basins and toward the Sedgwick basin is indicated on the outcrop. Tyler Sanders had prepared a regional subsurface cross section of Chase Group strata that runs north-to-south from Marion County, through Wichita, and into northern Oklahoma. This section (included in the Kansas Geological Society 1994 field-trip guidebook) is within the Salina and Sedgwick basins, and is about 15 mi (24 km) to the west of the outcrop belt. The thickness of many of the formations and members within the Chase Group increases relative to their average thickness on outcrop in most of the wells along this section; a representative well along this cross section is included in table 1 for comparison. Such regional westward thickening suggests that the Central Nebraska, Salina, and Sedgwick basins were subsiding more rapidly than the area atop the Nemaha Ridge during deposition of the Chase Group.

Cyclicity in Chase Group Strata

The hierarchy of inferred cyclicity in Chase Group strata is illustrated in fig. 91, in which the thicknesses of formations and members of the group are shown at true relative scale. Lack of well-constrained radiometric ages in this part of the section precludes estimation of the durations of the Chase Group and of the various cycles therein. However, seven intermediate-frequency cycles can be readily recognized in this section, and they are labeled DS–1 through DS–7 in fig. 91. Mazzullo et al. (1995) had earlier recognized only six such cycles in the section. These cycles are defined as phases of dominantly highstand marine deposition (including both carbonates and siliciclastics) separated by thick sections of dominantly terrestrial lowstand, typically silty shales, mudrocks, and paleosols (tLST). These cycles compose the upper Speiser to the top of the Schroyer (DS–1), the Wymore to the top of the Kinney (DS–2), the lower Blue Springs and the Bruno (DS–3 [this cycle was not recognized previously by Mazzullo et al., 1995]), the upper Blue Springs to the basal Holmesville (DS–4), the middle Holmesville to the basal Gage (DS–5), the middle Gage to the lower Odell (DS–6), and the middle Odell to the basal Wellington (DS–7). The boundaries between cycles DS–1, DS–2, and DS–3 are the prominent unconformities that are recognized throughout most of the study area at the tops of the Schroyer, Kinney, and Bruno limestone; boundaries between cycles DS–4 through DS–7 are placed at the base of thick sections of terrestrial red shales and mudrocks (fig. 91). Nearly the same cycles were defined by Elias (1937), who similarly recognized these natural lithostratigraphic subdivisions of the Chase Group at a scale greater than that of cyclothems as defined by, for example, Heckel (1977, 1994).

These seven cycles are interpreted as depositional sequences sensu Mitchum et al. (1977). Three lower-frequency cycles are recognized on the basis of the general upward decrease in thickness of stacked depositional sequences 1–7. These cycles, shown in blue on the right side of fig. 91, are referred to as cycle A (includes DS–1, 2, and 3), cycle B (includes DS–4 and 5), and cycle C (includes DS–6 and 7). These cycles appear to be third-order depositional sequences because, in turn, they define a long-term, even lower-frequency relative sea-level curve (shown by the bold black line on the right side of fig. 91) that is consistent with deposition of the Chase Group during overall decreasing accommodation concurrent with the second-order cycle of sea-level fall in the Early Permian (Vail et al., 1977). Presumed third-order cycle B is anomalously thick, and accordingly, rather than being a gradually sloping line this second-order curve inflects at the top of cycle A. Its resulting shape is therefore similar to that illustrated by Ross and Ross (1988). We therefore consider the seven depositional sequences (DS–1 to DS–7) to be either third or fourth-order cycles following the terminology of Goldhammer et al. (1991).

Higher-frequency, fourth- or fifth-order cycles are superimposed on these depositional sequences (fig. 91), and they are regionally correlative. Depositional sequences 1, 2, and 4–7 each are clearly of tripartite architecture in that they are composed of two highstand phases of dominantly marine carbonate deposition separated by an intervening lowstand phase of dominantly marginal-

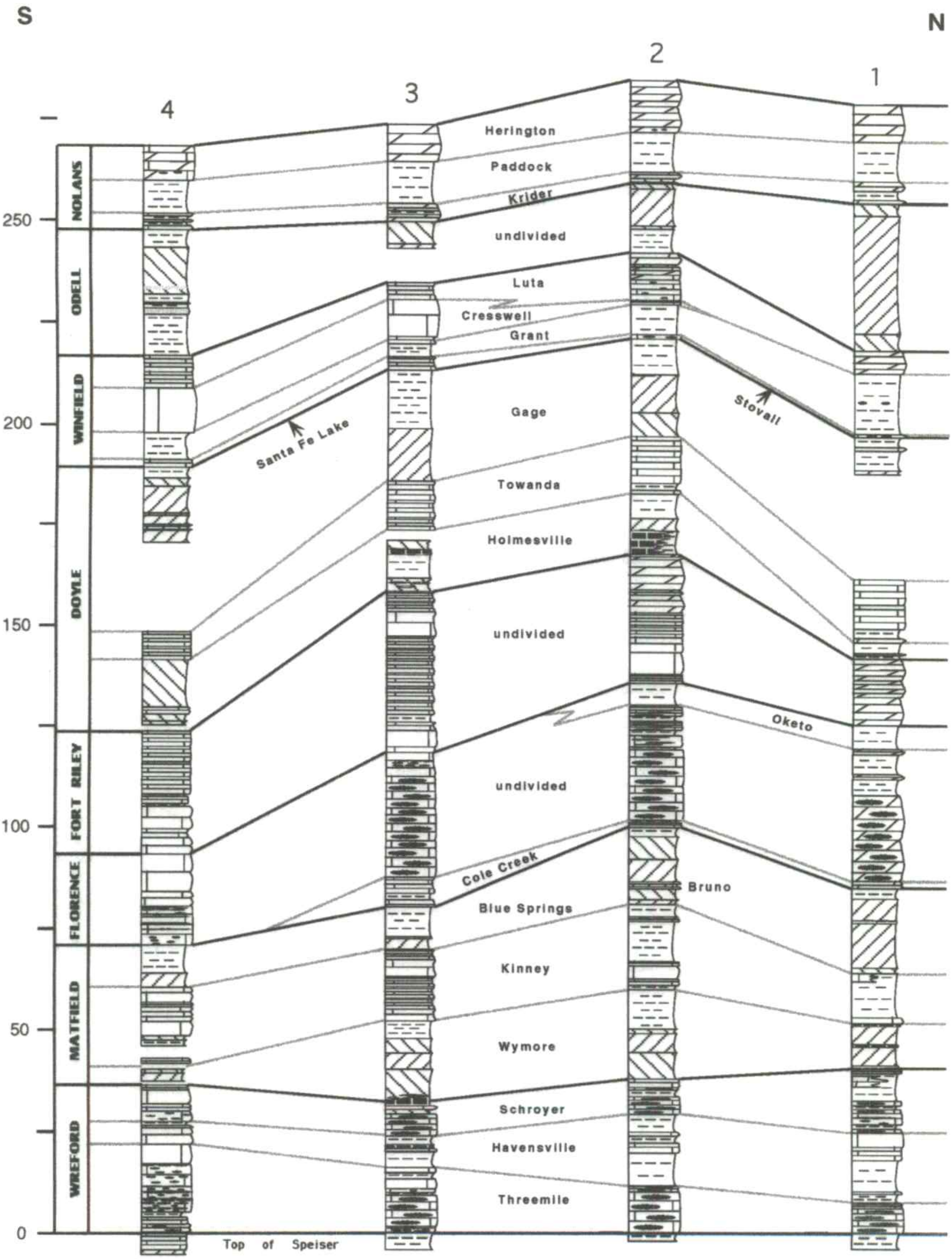


FIGURE 90—LITHOSTRATIGRAPHIC SECTION ACROSS KANSAS SHOWING THICKNESS VARIATION OF THE CHASE GROUP, BASED ON THE FOLLOWING MEASURED SECTIONS: column 1—numbers 136, 137, 138, 140, and 142 in Marshall County, and 145 and 146 in Washington County; column 2—numbers 110A and B, 113 and 116 in Geary County, and 103 and 109 in Dickinson County; column 3—numbers 39, 40, 46, 50, 53, 55, 58, 59, 64. and 75 in Butler County; and column 4—numbers 1, 6, 8, 10, and 19 in Cowley County. Lithologic sequence is somewhat generalized because of limitations of scale. Vertical scale in feet.

marine siliciclastics and minor carbonates (the mLST described in previous sections) with no evidence of regional subaerial exposure. These fourth- or fifth-order cycles are present at both the member and intra-member scale. For example, the cycles in DS–1 (Wreford Limestone) are represented by the Threemile (HST)-Havensville (mLST)-Schroyer (HST) package of members, whereas those in DS–2 are represented by the upper and lower limestones (HST) and intervening siliciclastics (mLST) solely within the Kinney Member (fig. 91). These fourth- or fifth-order cycles are clearly distinct from the presumed third- or fourth-order depositional sequences which are thicker and are separated by thick sections of terrestrial deposits, including red shales and mudrocks. DS–3 encompasses the Bruno limestone, and two fourth- or fifth-order cycles are present at those localities where the Bruno consists of two thin beds of carbonate separated by shale and/or mudrock. Erosion may have removed part of this section at those localities where only one bed of carbonate is present; alternatively, such areas may have been updip of the maximum extent of either of the two transgressive phases represented by the fourth- or fifth-order cycles.

Each fourth- or fifth-order cycle within the Chase Group is a mesoscale, transgressive-regressive package of strata that would best correspond to typical midcontinent

TABLE 1—Regional thicknesses of formations and members within the Chase Group (in ft).

Formation/Member	Outcrop	Subsurface[1]
Nolans Ls.	18–37	40
Herington	6–13.8	20
Paddock	7–18	12
Krider	2.4–9.3	8
Odell Sh.	7–40	23[2]
Winfield Ls.	9.5(?)–45	50
Luta	3.5–31	23
Cresswell	0–12.1	11
Grant	2.3(?)–15.3	12
Stovall-Santa Fe Lake	0–4	4
Doyle Sh.	53–70	79
Gage	24–40	29
Towanda	5–15	28
Holmesville	4.3–20	22
Fort Riley Fm.	16.5–47.5	53
Florence Fm.	15.5–44	40
Oketo	3–8	not present[3]
Cole Creek	1.8–8.2	13
Matfield Sh.	25–66	50
Blue Springs	5–28.4	16
Bruno limestone	0.67–4	?
Kinney	5–27.5	26
Wymore	5–24.5+	7
Wreford Ls.	28–41	36
Schroyer	5–16	8
Havensville	3.5-23.5	8
Threemile	5.5-26.5	20
Average	270–285	
Maximum	416	

[1]From the Kewanee Booker No. 8 well, sec. 30, T. 28 S., R. 1 E., Sedgwick County, Kansas.
[2]Maximum thickness 50 ft in the Forney Carothers No. 1–21 well, sec. 21, T. 33 S., R. 1 E., Sumner County, Kansas.
[3]This unit is not present in south-central Kansas, but it is about 6 ft thick in the Allen Drilling No. 1–3 Suderman well, sec. 3, T. 21 S., R. 2 E., Marion County, Kansas.

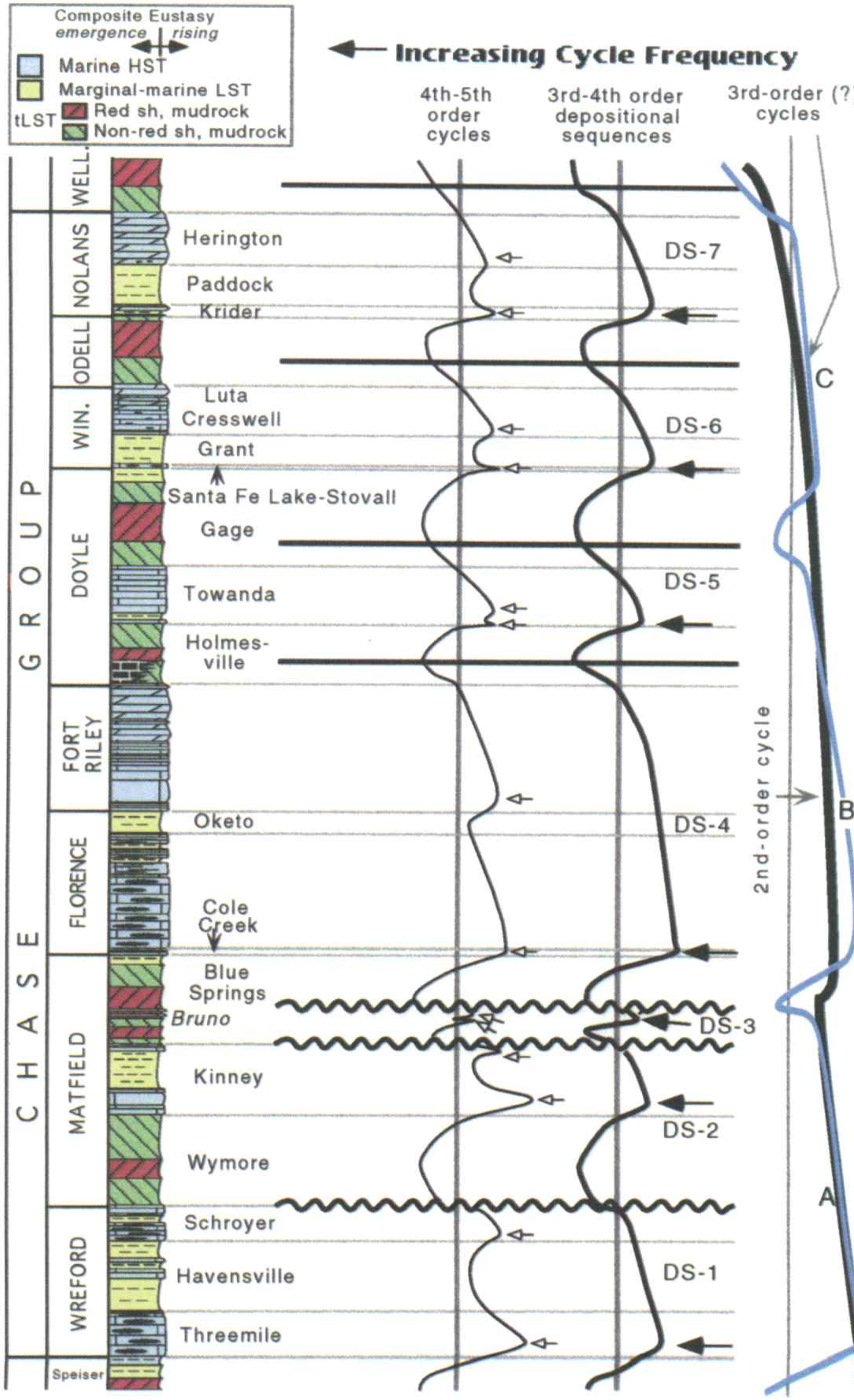


FIGURE 91—Inferred hierarchy of cyclicity in the Chase Group (modified from Mazzullo et al., 1995). Composite lithostratigraphic section on the left is from fig. 90, column 2. Bold, wavy lines at the tops of sequences 1, 2, and 3 are prominent unconformities traced throughout most of the study area. Open arrows point to major transgressive surfaces of fourth- or fifth-order cycles, whereas the bold arrows point to the one such flooding surface that is regarded to be the maximum flooding surface within each of the depositional sequences (DS–1 through DS–7) within the section. The second-order sea-level curve is modified from Vail et al. (1977).

Pennsylvanian cyclothems in terms of scale and depositional response to eustasy (e.g., Heckel, 1994). However, typical Pennsylvanian cyclothems, and these presumably analogous fourth- or fifth-order cycles in the Chase Group, are significantly different in several respects (e.g., Watney et al., 1995), the descriptions of which are beyond the scope of this study. Even higher-frequency, shallowing-upward cycles are present within the fourth- or fifth-order cycles in the Chase Group (Mazzullo et al., 1995), and they may equate to the meter-scale cycles that are common in many other ancient carbonates (e.g., Elrick, 1995).

Inferred Controls on Deposition

Several attributes of the hierarchal cyclic stratigraphy in the Chase Group (fig. 91) are significant in terms of the inferred origin of the cycles and controls on their deposition. These attributes are (a) thinning upward from cycle B to cycle C superimposed on overall declining accommodation through time indicated by the second-order sea-level curve; (b) thinning upward of component DS–1, 2, and 3 within cycle A, and of DS–4 and 5 within cycle B; (c) thinning upward of the component fourth- or fifth-order cycles within DS–1 and, in the area of the composite stratigraphic column shown in fig. 91 (from northern Kansas), also of DS–2; (d) coincident with this trend is the general shallowing upward of lithofacies within successive fourth- or fifth-order cycles within DS–1 and 2, and the interpretation that the maximum flooding surfaces of these sequences, and hence, maximum inferred paleowater depths, consistently occur within the lower of the two fourth- or fifth-order cycles. These same attributes also characterize DS–4, 5, 6, and 7; (e) the pronounced asymmetry of the relative sea-level curves of all of the fourth- or fifth-order cycles, all of the depositional sequences within which they occur, and of lower-frequency cycles A, B, and C. Such shapes imply relatively rapid transgression and slow, prolonged regression similar to that of midcontinent Pennsylvanian cyclothems (Heckel, 1994); and (f) the overall gradual shallowing of the depositional sequences through time as specifically suggested by progressively more abundant, and thicker, sections of peritidal deposits in DS–4 through 7, beginning in the upper Fort Riley; no significant peritidal deposits are recognized within DS–1 through 3. Furthermore, not only are all of the third- to fifth-order cycles in the Chase Group present throughout the study area, but according to Ross and Ross (1988) and Boardman and Nestell (1993), they may even be correlated to similar cycles as far away as Texas. In this regard, however, we point out that we do not agree with the identification of depositional sequences in the Chase Group as illustrated by Ross and Ross (1988, their figs. 4 and 6) because whereas they recognized only three such sequences, we recognize seven.

Together, these aforementioned attributes appear to suggest fundamental stratigraphic forcing (sensu Goldhammer et al., 1993) via eustatic control. Insofar as the Early Permian was a time of (waning) glaciation (Crowell, 1978; Veevers and Powell, 1987; Crowley, 1994), glacio-eustatic forcing is suggested. Sea-level fluctuations may have been tied to climatic fluctuations which affected the nature of carbonate-siliciclastic sedimentation and the vertical succession of different types of paleosols in terrestrial lowstand deposits in the lower Chase Group (Miller and West, 1993; Miller et al., 1996). Yet, there are some important aspects of the cyclostratigraphy of Chase Group strata that are inconsistent with such allogenically controlled deposition, and for the purpose of direct comparison, these are discussed under the same order of sub-headings as above. For example: (a) the anomalous thickness of third-order cycle B relative to thinner cycle A is somewhat perplexing considering overall deposition of Chase Group strata during second-order accommodation decrease; (b) there is no significant thinning upward of stacked DS–6 and 7 within cycle C; rather, these sequences appear to be of nearly equal thickness; (c) component stacked fourth- or fifth-order cycles within DS–4, 5, 6, and 7 thicken upward rather than thin upward as they do in DS–1. Except for in northern Kansas (mainly because of facies change to marginal-marine siliciclastics) as shown in fig. 91, the upper limestone in the Kinney always is the thicker of the two component fourth- or fifth-order cycles within DS–2; and (d) shallowing upward of lithofacies in the component fourth- or fifth-order cycles within DS–3, 4, 5, 6, and 7 occurs despite the fact that these cycles thicken upward rather than thin upward as in DS–1. Furthermore, the very thick sections of peritidal facies that are major components of these fourth- or fifth-order cycles in the Fort Riley, Towanda, Luta, and Herington, as well as the only local occurrence of highest-frequency (meter-scale?) shallowing-upward cycles throughout the section, argue for autogenically controlled deposition (e.g., Ginsburg, 1971) rather than for allogenic control. Last, although forced regression, assumed to have been caused by eustasy, is inferred during deposition of DS–1, 2, and 3 (on the basis of the regionally correlative unconformities at their tops), it is not evident in overlying depositional sequences that likewise appear to have been stratigraphically forced to a large extent.

Based on these stratal characteristics, we contend that whereas overall deposition of the Chase Group may have been fundamentally controlled by glacio-eustasy, it must also have been affected to a large extent by tectono-eustasy acting on a regional as well as local scale. Regional tectonic control on deposition of midcontinent Pennsylvanian cyclothems similarly has been proposed (e.g., Klein and Kupperman, 1992; Klein, 1994). That regional tectonism affected deposition of the Chase Group is based on the following lines of evidence. First, Chase Group strata thicken to the west into the Central Nebraska, Salina, and Sedgwick basins, and there is no evidence (at least on the outcrop) of increasing paleowater depths in this direction. These observations suggest regionally differential rates of subsidence, possibly related to periodic uplift of the Nemaha Ridge (a conclusion also reached by Heckel, 1994). Regional differential subsidence in Kansas during deposition of Pennsylvanian cyclothems was most recently discussed by Watney et al. (1995). Second, regardless of location with respect to the Nemaha Ridge or surrounding basins, cycle B and component DS–4 (the Florence and Fort Riley Formations) are anomalously thick and counter the trend of decreasing accommodation through time as suggested by the second-order sea-level curve. In contrast, Ross and Ross (1988) show the Wreford (= DS–1 of the present study) rather than the Florence–Fort Riley to be the thickest cycle in the Chase Group. Fort Riley strata are all of very shallow water aspect, and the underlying Florence is considered to have been deposited in paleowater depths less than those of the Schroyer and Threemile Members of the Wreford Limestone (Mazzullo et al., 1995). Hence, one can not reasonably argue for a high-magnitude eustatic rise with resulting increased accommodation as a cause for the anomalous thickness of this cycle. Rather, we suggest that it is more reasonable to infer that deposition of this cycle occurred during a time of abnormally high rates of subsidence within the study area. Likewise, the observation that DS–6 and DS–7 within cycle C do not thin upward also argues for a tectonic overprint on allogenically controlled deposition.

Perhaps the best evidence for local tectonism affecting deposition of the Chase Group is the existence of numerous small depocenters and positive features (arches) that appear at different places and at different times during deposition. Although the formation of these features conceivably could have been related to differential compaction of underlying strata, it is difficult to explain their erratic temporal and spatial development by compaction alone, especially considering the lithologic uniformity of strata across the study area. The facts are that (1) many depocenters are located atop grabens on the Precambrian and along or to the immediate west and east of the Humboldt fault zone; (2) likewise, many positive areas are located along upthrown fault blocks and/or structural noses on the Precambrian; and (3) both depocenters and arches occur within the Walnut syncline and on the Nemaha Ridge. There is considerable evidence that the Nemaha Ridge with its bounding faults, as well as similar structures throughout the midcontinent, have remained tectonically active throughout the Phanerozoic (Nelson and Lumm, 1984; Burchett, 1988; Carlson, 1989a, b; Stander, 1989; Steeples, 1989; Heckel, 1994; Marshak and Paulsen, 1996). We therefore contend that periodic tectonic reactivation along the Nemaha Ridge and its bounding faults offers the most likely explanation for the origin of the sporadically occurring, local depocenters and arches that developed during deposition of the Chase Group. Such reactivation likely was a response to temporal and spatial variations in laterally directed stress fields associated with deformation in adjoining orogenic areas (e.g., Kluth and Coney, 1981; Kluth, 1986).

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Appendix: Measured Sections in Kansas and Southeastern Nebraska

Vertical thickness of units was measured in feet and inches. The weathered color of nearly all carbonate rocks in the study area varies from yellow gray to various shades of gray; colors in the descriptions of measured sections are those of fresh surfaces. The weathered colors of the siliciclastic rocks (which are mostly all silty shales and silty mudrocks) are mostly the same as their fresh colors. Lithologic descriptions are field descriptions combined with laboratory examination of prepared rock slabs; carbonate lithologies are described according to the terminology of Dunham (1962). The most commonly occurring fossils within each unit are listed in order of decreasing relative abundance; the rocks are apparently unfossiliferous in units where no fossils are listed. Cherts in the Wreford and Florence Formations are dark gray to light gray, and variously weather gray, yellow, orange, or white; the color of cherts in other units is specifically described.

Measured Section Number: 1

Location: Roadcuts, both sides of Cowley County Highway 1, and on dirt road into, and inside Camp Ko–Ha–Me: in secs. 8 and 17, T. 35 S., R. 5 E., Cowley County, Kansas

Comment: Part of the Threemile Member of the Wreford Limestone is exposed along the bank of Grouse Creek at the northern end of this outcrop, but a direct tie-in to the roadcut is not possible because of cover

FORT RILEY FORMATION
(probable top of the formation)

7 ft 9 inches	Medium-bedded, relatively coarse-grained limestone, biowackestone-packstone, bioturbated, yellow; crinoids
5 ft 0 inches	Thin-bedded, relatively coarse-grained limestone, biowackestone, bioturbated, yellow; crinoids
3 ft 0 inches	Medium-bedded limestone, biowackestone, yellow; crinoids
3 ft 2 inches	Basal 8 inches mudrock to shaly limestone, biowackestone, light-gray. Overlain by 1 ft 8 inches thin-bedded limestone, biowackestone, light-gray. Overlain by 10 inches mudrock to shaly limestone, biowackestone, light-gray. All rocks contain crinoids
5 ft 4 inches	Thick-bedded: basal 2 ft 4 inches relatively coarse-grained limestone, bioturbated oncolite biopackstone, uneven hard ground at top, yellow. Overlying bed finer-grained limestone, oncolite biopackstone, yellow, with orange oncolites. Rocks contain foraminifers, bivalve fragments, crinoids
2 ft 3 inches–2 ft 8 inches	Thin-bedded, coarse-grained limestone, oncolite biopackstone, yellow, with orange oncolites; foraminifers, bivalve fragments, crinoids
4 ft 2 inches	Thick-bedded: basal 1 ft 9 inches, coarsening-upward bed of limestone, oncolite biopackstone with an uneven hard ground at top, light-yellow, with abundant Composita, crinoids, foraminifers, bivalve fragments. Upper bed is coarse-grained limestone, oncolite biopackstone, light-yellow, the bed thins along the length of the outcrop; contains ramose bryozoans, crinoids. All oncolites are orange in this 4 ft 2 inches unit

FLORENCE FORMATION

4 ft 6 inches	Bed of highly jointed limestone, biowackestone, "ridge-and-furrow" horizontal weathering in top 8 inches, light-yellow to white; abundant Composita, ramose bryozoans
4 ft 8 inches	Thick-bedded, highly jointed limestone, fines upward from biowackestone-packstone to biowackestone, light-orange-yellow in basal 2 ft 2 inches, light-yellow above that; ramose bryozoans, brachiopod fragments
1 ft 6 inches	Bed of limestone, mudstone, brownish-gray; ramose bryozoans, crinoids, brachiopod fragments
1 ft 10 inches	Bed of limestone, mudstone, light-gray; ramose bryozoans
1 ft 2 inches	Thin bedded limestone, mudstone, yellow, three layers of discontinuous chert nodules
1 ft 4 inches	Bed of limestone, sparse biowackestone, gold-yellow, small chert nodules; fenestrate bryozoans, ramose bryozoans, brachiopod fragments, spicules
1 ft 5 inches	Bed of limestone, mudstone, light-yellow-brown, 1-inch-thick chert layer at top; foraminifers
1 ft 3 inches	Bed of limestone, sparse biowackestone, light-brownish-yellow, 2-inch-thick chert layer at top; fusulinids, ramose bryozoans, brachiopod fragments, foraminifers
1 ft 0 inches	Bed of limestone, sparse biowackestone, light-yellow, 3-inch-thick fusulinid-bearing chert layer at top; fusulinids, ramose bryozoans, brachiopod fragments, foraminifers
0 ft 4 inches	Bed of limestone, mudstone to sparse biowackestone, white, chert layer in middle
1 ft 0 inches	Bed of limestone, mudstone, light-yellow, chert nodules

1 ft 4 inches	Basal 4 inches and top 2 inches of shaly limestone, biowackestone-packstone, yellow; middle 10 inches yellow mudrock, abundant chert nodules with fusulinids

MATFIELD SHALE

Blue Springs Shale Member

3 ft 3 inches	Sparsely fossiliferous, yellow-brown mudrock; pectinid and other pelecypod fragments
0 ft 4 inches	Bruno limestone bed: limestone, shaly biowackestone, light-brownish-yellow; pelecypod fragments
3 ft 4 inches	Unfossiliferous, grayish-yellow shale; small, white nodules of paleocaliche in lower 1 ft 0 inches
3 ft 4 inches	Unfossiliferous, red shale to mudrock

Kinney Limestone Member

3 ft 8 inches	Thick-bedded limestone to platy-bedded limestone at top, all light-yellow-gray: fines upward from porous, fine-grained biopackstone-grainstone to biopackstone, the basal 2 ft 4 inches bed with faint cross strata, the top few inches with streaks of red shale; foraminifers, crinoids, brachiopod fragments, scattered Bellerophon
0 ft 10 inches– 1 ft 2 inches	Thin-bedded, porous limestone, fine-grained biopackstone to grainstone, light-grayish-yellow with orange-stained vugs; foraminifers, crinoids, brachiopod fragments, including Composita, echinoid fragments, scattered Bellerophon
3 ft 6 inches	Medium-bedded, porous, fine-grained limestone, biopackstone-grainstone, light-grayish-yellow, graded layers about 4 inches thick in lower half, current-laminated and cross stratified above that, vertical burrows or dissolution pipes(?) in top 2 inches; foraminifers, crinoids, brachiopod fragments
3 ft 6 inches	Thick-bedded limestone, coarsens upward from mudstone to biopackstone, bioturbated, light-yellow with pinpoint dark spots; crinoids, foraminifers, brachiopod fragments, bryozoans
1 ft 0 inches	Unfossiliferous, gray-green shale to mudrock with a 0.5-inch-thick layer of shaly lime mudstone in the middle
1 ft 7 inches	Unfossiliferous, green to medium-gray shale to mudrock, top 1 inch of gray, shaly lime mudstone
3 ft 0 inches	Concealed
1 ft 4 inches	Thin-bedded limestone, medium-gray, fines upward from coarse-grained, oncolite biowackestone-packstone with lenses of foraminiferal biopackstone-grainstone, to Derbyia-rich, fine-grained biopackstone-grainstone; Derbyia, Composita, foraminifers, crinoids, ramose bryozoans

Wymore Shale Member

1 ft 6 inches	Concealed
1 ft 0 inches	Unfossiliferous, yellow-green shale
2 ft 0 inches	Unfossiliferous, red mudrock with abundant calcite nodules (paleocaliche)

WREFORD LIMESTONE

Schroyer Limestone Member

4 ft 0 inches	Thick-bedded limestone, light-gray, fines upward from oncolite biowackestone-packstone in lower 1 ft 4 inches, to oncolite biowackestone above that; brachiopod fragments, crinoids, echinoid spines

Measured Section Number: 2

Location: Small, old quarry along now-removed railroad tracks and in adjoining gully, SW sec. 3, T. 35 S., R. 5 E., Cowley County, Kansas

FLORENCE FORMATION

1 ft 0 inches	Bed of limestone, biowackestone, light-yellow, chert nodules; ramose and fenestrate bryozoans, crinoids, brachiopod fragments
2 ft 0 inches	Sparsely fossiliferous, calcitic, yellow-brown mudrock, some chert nodules with fusulinids

MATFIELD SHALE

Blue Springs Shale Member

2 ft 0 inches	Unfossiliferous, yellow-brown mudrock
6 ft 8 inches	Unfossiliferous, red shale and mudrock

Kinney Limestone Member

3 ft 0 inches	Medium- to thick-bedded limestone, biopackstone, current- layered and some cross strata, light-gray to reddish-gray, red shale-filled veins, fissures and rootcasts; foraminifers
3 ft 4 inches	Thin-bedded: lower 1 ft 0 inches shaly biowackestone to calcitic mudrock, yellow. Overlain by 1 ft 4 inches thin-bedded, reddish-gray lime mudstone with red shale streaks and red shale-filled rootcasts. Overlain by 1 ft 0 inches limestone, intraclastic biopackstone-grainstone with red and green shale streaks, red shale-filled rootcasts and dissolution channels. The limestones contain foraminifers, bivalve fragments
3 ft 7 inches	Basal 1 ft 0 inches knobby-weathering lime mudstone, light-gray. Top 2 ft 7 inches thin-bedded limestone, biopackstone-grainstone,

	graded layers 2–4 inches thick, yellow. Limestone contains foraminifers, crinoids, encrusting bryozoans, pelecypod and brachiopod fragments
8 ft 0 inches	Light-gray, calcitic mudrock with sporadic lenses of very shaly limestone (mudstone to biowackestone). The basal 4 ft of section contain abundant fossils, in order of decreasing abundance: Derbyia, Composita, Juresania, Allorisma, Septimyalina, and are bioturbated; the upper 4 ft locally have a greenish tinge and are relatively sparsely fossiliferous (Derbyia, Juresania)
1 ft 5 inches	Three beds of shaly limestone, fine-grained biowackestone, light-yellow, with a thin parting of light-yellow shale at the base; limestones are bioturbated (with Thalassinoides-type burrows), and contain Derbyia, accessory crinoids, echinoid fragments, Composita, Juresania, oncolitically coated bioclasts; shales with finely comminuted skeletal fragments
0 ft 10 inches	Thin-bedded, shaly limestone, biowackestone-packstone, light-yellow-gray, bioturbated (with Thalassinoides-type burrows); Derbyia, Composita, oncolitically coated bioclasts, fenestrate bryozoans, crinoids, echinoid fragments
0 ft 6 inches	Sparsely fossiliferous, yellow, calcitic mudrock; brachiopod fragments
0 ft 10 inches	Two beds of slightly shaly limestone, fine-grained biopackstone, light-yellow-gray, bioturbated (with Thalassinoides-type burrows); basal bed oncolitic, upper bed with abundant Derbyia and accessory crinoids, bryozoan fragments, echinoid fragments
0 ft 11 inches	Section grades upward from limestone to mudrock, then grades upward to limestone. Limestones are medium-gray, shaly mudstones to biowackestones with Derbyia, Composita, and accessory crinoids, echinoid fragments, Juresania, bryozoan fragments. Mudrocks are yellowish-brown, sparsely fossiliferous, with brachiopod fragments, crinoids
2 ft 4 inches	Three beds of shaly limestone, biopackstone, splotchy light-gray and grayish-yellow, bioturbated (with Thalassinoides-type burrows); abundant Derbyia and Composita, accessory crinoids, echinoid fragments, Juresania, bryozoan fragments, Myalina

Wymore Shale Member

3 ft 0 inches	Unfossiliferous, light-gray to greenish-gray/yellow-gray mudrock with slicken sides (paleosol)
4 ft 6 inches	Unfossiliferous, red shale and mudrock, soil anticlines at the top (paleosol)

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 0 inches	Bed of prominently vertically burrowed limestone, biopackstone to grainstone, the top ~6 inches finer-grained and not bioturbated, light-yellow-gray; crinoids, brachiopod fragments, fragments of large pelecypods—Aviculopinna?
1 ft 8 inches	Medium-bedded limestone, biowackestone, the basal and top 2 inches of biopackstone; limestone is highly dissolution-pitted, light-yellow, and contains calcitized chert nodules. Crinoids, and bryozoan and brachiopod fragments

Measured Section Number: 3

Location: Roadcut along old railroad right-of-way (now a small dirt road into a pasture) in the SE NE sec. 4, T. 35 S., R. 5 E. (very close to measured section number 2), Cowley County, Kansas

Comment: The remainder of the overlying Blue Springs is concealed in the slope, and the lower Florence is exposed at the crest of the hill just off the road

MATFIELD SHALE

Blue Springs Shale Member

3 ft 0 inches	Unfossiliferous, red shale and mudrock
0–8 inches	Bruno limestone bed: very hard limestone, mudstone, with conchoidal fracture, possible rootmolds; pelecypod fragments
2 ft 2 inches	Unfossiliferous, calcite-impregnated, red mudrock, rootcasts

Kinney Limestone Member

1 ft 0 inches	Basal 6 inches unfossiliferous red shale. Overlying 6-inch bed of limestone, biopackstone, red shale matrix (with foraminifers), that pinches out laterally to red shale. This section is a gradational contact between the Kinney and Blue Springs
3 ft 8 inches	Thick-bedded: basal two beds of limestone, biopackstone-grainstone, white, red shale matrix in upper bed (foraminifers, crinoids, brachiopod fragments). Upper bed biopackstone, red shale matrix and thin partings of red shale (foraminifers, crinoids, brachiopod fragments). All beds are cross stratified, with bimodal-bipolar dips ("herringbone"). Along the length of the outcrop this unit thickens to 5 ft 8 inches
1 ft 10 inches	Medium-bedded, knobby-weathering limestone, coarsens upward from mudstone to biopackstone, light-gray, thin partings of red shale with 3-inch-thick layer of red shale at top. This unit thickens along the length of the outcrop to 2 ft 6 inches

Measured Section Number: 4

Location: "140-Foot Hill": roadcuts in SE sec. 5, T. 35 S., R. 4 E., adjoining Camp Quaker Haven, Cowley County, Kansas

NOLANS LIMESTONE

Herington Member
(probable top of the member)

5 ft 4 inches	Medium-bedded, fine-grained limestone, biowackestone-packstone, porous, light-yellow; foraminifers, bivalve fragments, crinoids

Paddock Shale Member

9 ft 0 inches	Fossiliferous, yellow mudrock; crinoids, ramose bryozoans, bivalve hash

Krider Member

1 ft 8 inches	Bed of limestone, shaly oncolite biowackestone, gradational top, sharp base, yellow-brown; crinoids, brachiopod fragments, foraminifers
0 ft 10 inches	Calcitic mudrock and lenses of coarse-grained, oncolite biopackstone, yellow; Derbyia, crinoids, ramose bryozoans
1 ft 5 inches	Thin-bedded limestone: coarsening-upward section from biowackestone-packstone to oncolite biopackstone, light-gray, gradational top and sharp base; Derbyia and Composita, foraminifers, ramose bryozoans
1 ft 3 inches	Calcitic mudrock to shaly limestone, oncolite biowackestone-packstone, yellow, with large discoidal oncolites; Composita in upper half of section
1 ft 4 inches	Bed of shaly limestone, oncolite biowackestone-packstone, gradational top and sharp base, yellow; crinoids, brachiopod fragments, foraminifers, bryozoans

ODELL SHALE

~28.5 ft	Unfossiliferous shale, relatively poorly exposed: see detailed description at nearby measured section number 8

WINFIELD LIMESTONE

Luta Member

4 ft 0 inches	Poorly exposed, thin-bedded limestone, shaly mudstone, light-gray; some Composita, crinoids

Cresswell Limestone Member

10 ft 0 inches	Bed of porous limestone, biopackstone, light-yellow, lichen-covered; oncolites, foraminifers, crinoids, Derbyia, bryozoans

Grant Shale Member

2 ft 0 inches	Thin-bedded limestone, shaly biowackestone, bioturbated, yellow-gray; crinoids, brachiopod fragments

Measured Section Number: 5

Location: Roadcut along Cowley County Highway 1 and in creek bed, in the W/2 sec. 28, T. 34 S., R. 5 E., Cowley County, Kansas

Comment: These outcrops directly adjoin the old "Silverdale quarry" to the immediate west of the road, which is now a housing development

FLORENCE FORMATION

1 ft 2 inches	Bed of limestone, mudstone, white, with fusulinid-bearing chert layer at top
0 ft 10 inches	Interbedded fossiliferous, calcitic mudrock and shaly limestone, biowackestone-packstone, light-yellow-gray, chert nodules; Reticulatia, Derbyia, ramose bryozoans, crinoids, fusulinids

Cole Creek Member

0 ft 10 inches	Interbedded fossiliferous, calcitic mudrock and shaly limestone, biowackestone-packstone, light-yellow-gray; Reticulatia, Derbyia, ramose bryozoans, crinoids
1 ft 5 inches	Fossiliferous, calcitic mudrock and lenses of limestone, shaly mudstone to biowackestone, light-yellow-gray; Derbyia, crinoids
1 ft 5 inches	Medium-bedded limestone, sparse biowackestone, shaly, bioturbated, yellow-gray; Reticulatia, Composita, crinoids, ramose bryozoans

MATFIELD SHALE

Blue Springs Shale Member

2 ft 0 inches	Thin-bedded, unfossiliferous, calcitic mudrock, light-gray
~9 ft	Concealed

Kinney Limestone Member

3 ft 6 inches	Medium-bedded limestone, biopackstone, light-gray; Derbyia
4 ft 0 inches	Interbedded limestone, shaly mudstone, dark-gray, with Derbyia, Juresania; and unfossiliferous, yellow-reddish-gray shale. The top 1 ft 4 inches of this unit is highly bioturbated
3 ft 0 inches	Thin-bedded limestone, shaly mudstone, weathers into brick-shaped blocks, dark-gray; Derbyia, crinoids

Measured Section Number: 6

Location: Roadcut along newly-designed course of US–166, in the E/2 sec. 13, T. 34 S., R. 5 E., Cowley County, Kansas

Comment: This roadcut was freshly blasted when we examined it in 1995

WREFORD LIMESTONE

Schroyer Limestone Member

4 ft 0 inches	Bed of limestone that fines upward from biopackstone to biowackestone-packstone, porous, prominent vertical burrows, light-yellow; crinoids, foraminifers, ramose bryozoans, brachiopod fragments. Close to the top of the member if not the top
0 ft 11 inches	Thin-bedded limestone, coarse-grained biopackstone, some chert nodules, yellow; crinoids, foraminifers, ramose bryozoans, brachiopod fragments
2 ft 4 inches	Bed of limestone that coarsens upward from fine- to coarse-grained biopackstone, orange-yellow, with angular chert nodules that appear brecciated; crinoids, Reticulatia, ramose bryozoans, spicules

Havensville Shale Member

1 ft 0 inches	Calcitic mudrock with lenses of coarse-grained limestone, oncolite biopackstone, light-yellow-gray; Aviculopecten, echinoid fragments, bryozoans, high-spired gastropods
3 ft 1 inches	Fining-upward and then coarsening-upward section from oncolite biopackstone to nononcolitic biopackstone, to oncolite biopackstone, light-yellow-gray; crinoids, foraminifers, ramose bryozoans; some echinoid fragments, high-spired gastropods, and Aviculopecten at top
0 ft 4 inches	Fossiliferous, calcitic mudrock, orange to medium-gray; brachiopod fragments
1 ft 6 inches	Bed of shaly limestone, mudstone, yellow to medium-gray; brachiopod fragments

Threemile Limestone Member

4 ft 8 inches	Bed of coarse-grained limestone, oncolite biopackstone, porous, prominent vertical burrows in basal 1 ft 4 inches, light-yellow; crinoids, Bellerophon, Allorisma, Reticulatia, Aviculopecten, Composita
5 ft 2 inches	Medium-bedded limestone, biowacke-stone, very light gray, small chert nodules throughout, and the top of the unit is a prominent, 3-inch-thick, discontinuous layer of oval chert nodules. Shaly seams about 0.5 inches thick at 1 ft 4 inches, 2 ft 1 inch and 4 ft 3 inches above the base. Lower bed with pelecypod fragments, overlying section with crinoids, ramose bryozoans, and brachiopod fragments
4 ft 0 inches	Bed of very light gray limestone that coarsens and then fines upward from biowackestone to fine-grained biopack-stone to biowackestone; oval, laminated chert nodules toward the base of the unit; a 9-inch-thick layer of laminated chert 2 ft 2 inches above the base. Overlain by a 10-inch-thick section with scattered chert nodules; and a discontinuous, 2–3-inches-thick chert layer at the top. Rocks contain crinoids, brachiopod fragments, ramose bryozoans
2 ft 4 inches	Bed of light-gray limestone, biowacke-stone-packstone; chert nodules in basal 1 ft, prominent discontinuous layers of chert nodules 1 ft above the base and at the top of the unit, with angular and brecciated-appearing chert nodules in-between. Rocks contain crinoids, brachiopod fragments, ramose bryozoans
1 ft 4 inches	Shaly limestone, biowackestone, in the lower half, light-yellow-gray; and fossiliferous, calcitic, yellow-gray mudrock in upper half. Composita, Derbyia, and crinoids throughout; plus fenestrate bryozoans in upper half
1 ft 8 inches	Thin-bedded, shaly limestone, mudstone, bioturbated, abundant silicified Composita, light- to mottled-dark-gray, bedding decreases upsection; accessory crinoids, brachiopod fragments
2 ft 0 inches	Medium-bedded, shaly limestone, biowackestone, abundant silicified Composita, calcitized chert nodules following burrows, and a 0.5-inch-thick discontinuous chert layer at top; rocks are dark- to light-gray; Composita, Derbyia, crinoids, ramose bryozoans

SPEISER FORMATION

4 ft 0 inches	Thin- to medium-bedded, shaly limestone, mudstone, dark-gray and yellow-gray (with time, will probably weather to interbedded shaly lime mudstones and calcitic shales)
1 ft 5 inches	Unfossiliferous, red mudrock

Measured Section Number: 7

Location: Roadcut along unnamed paved road in NW sec. 17, T. 34 S., R. 4 E., Cowley County, Kansas

Comment: This section exposes nearly all of the Winfield Limestone and is very close to the type locality of the Cresswell Limestone Member (Condra and Upp, 1931), which is measured section number 8.

WINFIELD LIMESTONE

Luta Member

5 ft 4 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, bioturbated, yellow-gray, minor replacement of fossils by chert; crinoids, Composita

Cresswell Limestone Member

2 ft 6 inches	Bed of limestone, slightly porous oncolite biopackstone, locally bioturbated, yellow; crinoids, ramose bryozoans, brachiopod fragments
3 ft 4 inches	Bed of porous limestone, biograinstone, prominent vertical burrows, yellow; Derbyia, crinoids, pelecypod fragments
6 ft 4 inches	A single bed of orange-yellow, porous limestone that consists, in ascending order of: (a) 1 ft of biowackestone with some oncolites, bioturbated; (b) 3 ft of oncolite biopackstone-grainstone, locally bioturbated; and (c) 2 ft 4 inches oncolite biopackstone, locally bioturbated. Fossils in this unit include Derbyia, crinoids, and ramose bryozoans

Grant Shale Member

1 ft 2 inches	Bed of bioturbated limestone, biowackestone, with conspicuous large oncolites, very light gray; brachiopod fragments, foraminifers, crinoids, high-spired gastropods
0 ft 10 inches	Bed of oncolite biowackestone-packstone, bioturbated, gray ("concretionary zone"); ramose bryozoans, brachiopod fragments
0 ft 8 inches	Unfossiliferous, orange-yellow mudrock and shaly lime mudstone
1 ft 4 inches	Concealed

Santa Fe Lake Member

3 ft 0 inches	Thin-bedded section: basal 10 inches is oncolite biopackstone, gray-orange, with foraminifers and pelecypod fragments; top 2 ft 2 inches is laminated lime mudstone and calcitic shale, some laminae of foraminiferal calcisiltite

DOYLE SHALE

Gage Shale Member

0 ft 4 inches	Unfossiliferous, yellow shale

Measured Section Number: 8

Location: Outcrops along the bluffs on the grounds of the Spring Hill Golf Course in Arkansas City, which include the type locality of the Cresswell Limestone Member of the Winfield Limestone (Condra and Upp, 1931): in the center of sec. 18, T. 34 S., R. 4 E., Cowley County, Kansas

NOLANS LIMESTONE

Herington Member
(probable top of the member)

3 ft 6 inches	Medium-bedded dolomudstone, light-yellow: top 7 inches laminated, and a 4-inch-thick layer of burrowed and laminated dolowackestone-packstone 4 inches above the base, with large intraclasts of dolomudstone. Small, light-gray chert nodules in upper half of the unit; foraminifers, fenestrate bryozoans, high-spired gastropods, pelecypod molds
3 ft 4 inches	Thick-bedded, porous, cross stratified dolopackstone-grainstone with bimodal-bipolar dips ("herringbone"); this unit passes laterally (westward) along the outcrop to porous dolomudstone-pack-stones, and then, again to a bed of cross stratified dolopackstone to grainstone that is only 2 ft 4 inches thick; (foraminifers, gastropods, pelecypod molds, crinoids, fenestrate bryozoans); at the farthest west outcrop, only about 1 ft 4 inches of section is exposed that represents the basal part of this unit, and it consists of very fine grained limestone, biowackestone. Top of this 3 ft 4 inch-thick unit locally has thin lenses of white chert that has replaced fine-grained biopackstone
1 ft 11inches	Bed of porous dolomite: basal 6 inches fines upward from biopackstone to sparse biowackestone, with Composita and Bellerophon. Overlying section coarsens upward from biowackestone in the lower half, to biopackstone in the upper half with large biomolds, Composita, Bellerophon, Allorisma, and fenestrate bryozoans. Thin, erratic lenses of white chert at the top are replaced, fine-grained biopackstones; the chert follows burrows. Accessory fossils in this 1 ft 11 inches-thick unit include pectinid molds, crinoids, abundant foraminifers, some planispiral and high-spired gastropods. This unit passes laterally, to the west, to a similar thickness of limestone that coarsens upward from fine-grained to coarse-grained biopackstone, light-yellow, cross stratified at the base

Paddock Shale Member

8 ft 0 inches	Thin-bedded, fossiliferous, calcitic mudrock with some lenses of shaly limestone, sparse biowackestone, light-yellow-gray; pectinids, crinoids

Krider Member

0 ft 8 inches	Bed of dolomitic limestone, biowackestone, light-yellow to tan, abundant biomolds; ramose bryozoans, bivalves
2 ft 6 inches	Coarse-blocky, calcitic mudrock, sparsely fossiliferous, light-tannish-yellow, some orange streaks; orange-stained casts and molds of pelecypods in upper 10 inches, scattered Composita, crinoids, ramose bryozoans
1 ft 4 inches	Fossiliferous, calcitic mudrock, orange-yellow, number of fossils decreases upsection; crinoids, Derbyia, ramose bryozoans, echinoid fragments, small oncolites

0 ft 7 inches– 0 ft 10 inches	Bed of limestone, coarsens upward from mudstone-biowackestone to wackestone-sparse biopackstone, locally prominent Aviculopinna in vertical burrows, granular texture, brownish-yellow up to light-gray; Derbyia, and some Composita, echinoid fragments, crinoids, fenestrate and ramose bryozoans, Aviculopinna
2 ft 6 inches	Calcitic mudrock, yellow: basal 1 ft 3 inches weathers yellow, and contains large, discoidal oncolites and accessory crinoids, Derbyia, and Myalina; middle 6 inches weathers orange-yellow, and contains scattered crinoids, Composita, Derbyia, small oncolites; top 9 inches weathers yellow, and contains abundant Composita and accessory crinoids
1 ft 2 inches	Bed of shaly limestone, coarsens upward from mudstone-biowackestone to sparse biopackstone, and biotic diversity increases upsection, sharp base and gradational top, bioturbated, light-yellow-gray; laterally along the outcrop, to the east, this bed weathers very shaly and recessive. Basal part with crinoids, high-spired gastropods; from just above the middle to the top of the bed, abundant Derbyia, and locally, Aviculopinna, large discoidal oncolites, large crinoid fragments, fenestrate bryozoans, echinoid fragments, oncolitically coated Myalina)

ODELL SHALE

1 ft 4 inches– 1 ft 11 inches	Unfossiliferous, dark-gray to greenish-gray shale, fissile and laminated; passes laterally along the outcrop (to the west) to brownish-green, blocky mudrock
3 ft 0 inches	Unfossiliferous, green mudrock, laminated
4 ft 6 inches	Unfossiliferous, green mudrock with reddish tint in lower 2 ft
4 ft 0 inches	Unfossiliferous, green mudrock; a 6-inch-thick, white-gray paleosol just below the middle, with orange breccia at its top
2 ft 0 inches	Unfossiliferous, light-gray mudrock
1 ft 2 inches	Unfossiliferous, gray mudrock, with a thin paleosol at the top, capped by orange breccia
1 ft 7 inches	White-gray paleosol, orange breccia at its top
6 ft 9 inches	Unfossiliferous, light-gray mudrock, silty to slightly sandy
3 ft 0 inches	Unfossiliferous, fissile, light-yellow, calcitic shale with orange streaks, light-gray in the upper half (appears to be a thin-bedded, shaly limestone)

WINFIELD LIMESTONE

Luta Member

8 ft 0 inches	Poorly exposed, thin-bedded to fissile, fining-upward section of limestone, from shaly biowackestone to shaly mudstone, bioturbated, light-gray; Composita, ramose bryozoans, crinoids

Cresswell Limestone Member

11 ft 0 inches	Bed of relatively coarse-grained limestone, mostly oncolite biopackstone, porous, yellow-orange; ramose bryozoans, brachio-pod fragments, crinoids, foraminifers

Measured Section Number: 9

Location: Cliff behind Dopp's Chiropractic Clinic and Orscheln Tires on US–77, just north of Radio Lane in Arkansas City, in the SE sec. 13, T. 34 S., R. 3 E., Cowley County, Kansas

NOLANS LIMESTONE

Herington Member
(probable top of the member)

5 ft 0 inches	Thin-bedded dolomudstone to dolosiltite, yellow-brown, with small, dark-gray chert nodules in middle, top 6 inches are laminated
0 ft 8 inches	Unfossiliferous, yellow-brown shale, 0.25-inch-thick layer of lime mudstone in middle
1 ft 0 inches	Basal 3 inches unfossiliferous, yellow mudrock; overlain by 9 inches yellow-brown dolomudstone
1 ft 3 inches	A 1-inch-thick bed of dolomudstone at base, overlain by 6 inches unfossiliferous, yellow mudrock, and then, 8 inches dolomudstone, brown-yellow

Paddock Shale Member

3 ft 2 inches	Poorly exposed calcitic shale, unfossiliferous, light-yellow
4 ft 10 inches	Massive appearing mudrock, yellow, but with large nodular-shaped areas where it is dark-gray, scattered large calcite nodules (paleocaliche), sparsely fossiliferous (crinoids)
3 ft 4 inches	Mudrock, sparsely fossiliferous (crinoids): yellow in basal 1 ft 4 inches, overlying 1 ft 1 inch variously dark-gray or yellow, with a 1-ft-thick zone of calcite nodules in the middle; top 8 inches yellow

Krider Member

1 ft 2 inches	Bed of porous limestone, biopackstone, small light-gray chert nodules in middle, orange, sharp base and gradational top; brachiopod fragments, crinoids, ramose bryozoans, foraminifers
2 ft 8 inches	Fossiliferous, yellow mudrock, local calcite nodules; lower half with abundant pelecypod molds, upper half with abundant Composita. The entire unit also contains fenestrate and ramose bryozoans
1 ft 10 inches	Bed of limestone that coarsens upward from biowackestone to oncolite biowackestone to packstone (oncolites are orange), with sharp base and gradational top; brachiopod fragments, crinoids, ramose bryozoans

2 ft 6 inches	Calcitic, yellow mudrock, large, discoidal oncolites in the lower half, abundant Composita in the upper half
1 ft 2 inches	Bed of shaly limestone, coarsens upward from mudstone-biowackestone to biowackestone-sparse packstone, bioturbated, light-yellow-gray; crinoids, echinoid fragments, Derbyia, high-spired gastropods, fenestrate bryozoans

ODELL SHALE

1 ft 0 inches	Dark-gray-green, unfossiliferous, fissile and laminated shale

Measured Section Number: 10

Location: Roadcut along boundary between sec. 35, T. 33 S., R. 4 E. and sec. 2, T. 34 S., R. 4 E. (for the Towanda), and in SW sec. 35, T. 33 S., R. 4 E. (for Gage and Winfield)

WINFIELD LIMESTONE

Cresswell Limestone Member

3 ft 3 inches	Bed of porous limestone, biopackstone-wackestone, light-yellow; foraminifers, scattered oncolites, ramose bryozoans

Grant Shale Member

6 ft 8 inches	Bioturbated, calcitic mudrock with lenses of shaly limestone, biowackestone, oncolitic in top 3 ft, yellow; crinoids, ramose bryozoans, pelecypod casts

Santa Fe Lake Member

1 ft 8 inches	Thin-bedded, shaly limestone, mudstone, gray

DOYLE SHALE

Gage Shale Member

2 ft 8 inches	Unfossiliferous, yellow-brown mudrock
2 ft 0 inches	Unfossiliferous, green shale
4 ft 8 inches	Unfossiliferous, red shale and mudrock, with a 3-inches-thick layer of green shale 1 ft 9 inches below the top
0 ft 7 inches	Unfossiliferous, green shale to mudrock
2 ft 4 inches	Unfossiliferous, red mudrock
1 ft 4 inches	Three thin interbeds of light-gray, shaly lime mudstone, with desiccation cracks in the top bed, and unfossiliferous, green shale
~20 ft	Concealed

Towanda Limestone Member

1 ft 4 inches	Thin-bedded limestone, shaly mudstone, yellow-brown
2 ft 8 inches	Thin-bedded limestone, shaly mudstone, laminated in lower 2 ft; secondary calcite veins and laminae of palisades calcite crystals, scattered small white chert nodules; yellow-brown
0 ft 6 inches	Unfossiliferous, yellow-brown mudrock

Measured Section Number: 11

Location: Roadcut in center of W/2 sec. 24, T. 33 S., R. 4 E., along bluffs of Walnut River

Comment: Estimated concealed thickness of the Doyle Shale from here to the top of the hill, where the basal Winfield Limestone is exposed, is about 60 ft

FORT RILEY FORMATION
(top of the formation)

4 ft 0 inches	Medium-bedded limestone, fines upward from biowackestone-packstone to biowackestone, yellow; foraminifers, crinoids, bivalve fragments
2 ft 9 inches	Medium-bedded limestone, coarsens upward from biowackestone to biograinstone, light-tan; crinoids, bivalve fragments, Derbyia, foraminifers
2 ft 4 inches	Thin-bedded shaly limestone, mudstone, and a 4-inch-thick layer of mudrock in the middle, brownish-yellow
4 ft 8 inches	Medium-bedded, porous limestone, fines upward from biopackstone-grainstone to, in the top 8 inches, biopackstone; low-angle cross stratification, graded layers, yellow. Rocks contain Derbyia, foraminifers, accessory crinoids
3 ft 2 inches	Medium-bedded, porous limestone, mostly fine-grained lime mudstone, thin-layered to laminated, with wavy-bedded lenses of biowackestone-packstone; and a 1-inch-thick channel at the top, filled with biopackstone-grainstone, light-yellow. Rocks contain crinoids, Composita, foraminifers
2 ft 7 inches	Medium-bedded shaly limestone, mudstone, and thin interbeds of shale, light-tan, surface-dissolution pits
0 ft 9 inches	Laminated shaly limestone, mudstone, light-yellow
3 ft 0 inches	Medium-bedded limestone, sparse biowackestone, light-tan; pelecypod fragments, crinoids

Measured Section Number: 12

Location: Roadcuts, both sides, along boundary between sec. 33, T. 33 S., R. 4 E. and sec. 4, T. 34 S., R. 4 E., Cowley County, Kansas

NOLANS LIMESTONE

Herington Member
(probable top of the member)

4 ft 1 inches	Lower and upper part of the section medium-bedded, middle part is thin-bedded: slightly shaly dolomudstone with about 1 ft of lime mudstone at the top, light-gray
5 ft 5 inches	Medium- up to thin-bedded dolomudstone, slightly shaly, yellow-gray
2 ft 6 inches	Interbedded unfossiliferous mudrock and lime mudstone, yellow, with calcite geodes and thin laminae of gypsum

Paddock Shale Member

4 ft 0 inches	Mostly unfossiliferous, yellow-brown mudrock and shale; with lenses of shaly lime mudstone at base (6 inches thick), and 1 ft 4 inches above base (1.5 inches thick), 1 ft 8 inches above base (1 inch thick), 2 ft 5 inches above base (1 inch thick), and 2 ft 8 inches above base (1 inch thick)

Measured Section Number: 13

Location: Roadcuts along bluffs of Walnut River, in NE sec. 23, T. 33 S., R. 4 E., and gully into the river

Comment: Estimated concealed thickness of the Doyle Shale on the overlying slope, to the base of the exposed Winfield Limestone, is about 50 ft

FORT RILEY FORMATION
(probable top of the formation)

1 ft 7 inches	Bed of limestone, fine-grained biograinstone, yellow-brown; foraminifers, crinoids, bivalve fragments
4 ft 0 inches	Concealed: float of shaly mudstone to sparse biowackestone
1 ft 4 inches	Medium-bedded limestone, mudstone, chocolate-brown
3 ft 0 inches	Concealed: float of shaly lime mudstone
2 ft 6 inches	Bed of limestone, mudstone, yellow; crinoids, brachiopod fragments
0 ft 10 inches	Thin-bedded limestone, biowackestone, yellow; crinoids
4 ft 4 inches	Thin-bedded limestone, shaly mudstone, light-gray
2 ft 6 inches	Thin-bedded, shaly limestone, mudstone to biowackestone, gray; crinoids
4 ft 4 inches	Progressively thinner-bedded shaly limestone, mudstone, light-gray
1 ft 4 inches	Thin-bedded, shaly limestone, fine-grained, oncolite biopackstone, less shaly toward top, medium- to dark-brownish-yellow-gray; crinoids, brachiopod fragments
1 ft 3 inches	Bed of limestone, oncolite biowackestone, light-yellow-gray; crinoids
1 ft 0 inches	Thin-bedded limestone, oncolite biowackestone, medium-yellow-brown; crinoids
6 ft 6 inches	Thick-bedded limestone, coarsens upward from fine-grained to coarser-grained oncolite biopackstone, yellow-brown; crinoids, ramose bryozoans, bivalve fragments
1 ft 3 inches	Medium-bedded limestone, oncolite biowackestone, what appear to be white intraclasts in upper half are actually fenestrate bryozoan-encrusted grains, light-yellow; base is a prominent stylolite

FLORENCE FORMATION

3 ft 4 inches	Bed of limestone, oncolite biowackestone-packstone, light-yellow; crinoids, bivalve fragments
1 ft 8 inches	Medium-bedded limestone, mudstone-sparse biowackestone, light-yellow; crinoids, bryozoan fragments

Measured Section Number: 14

Location: Roadcuts and small quarry at intersection of K–38 and K–15, in SE sec. 24, T. 32 S., R. 6 E., SW sec. 19 and NW sec. 30, T. 32 S., R. 7 E., west of the BJN Ranch; the top few feet of the Florence section is measured at the roadcut along K–15 in adjoining secs. 24 and 25, T. 32 S., R. 6 E.; all outcrops in Cowley County, Kansas

FLORENCE FORMATION

1 ft 5 inches	Medium-bedded limestone, biowackestone, light-yellow-gray; chert nodules follow burrows, a 2-inch-thick chert layer in the middle. Rocks contain fusulinids, ramose and fenestrate bryozoans, crinoids
3 ft 4 inches	Progressively thinner-bedded limestone, porous, fine-grained biowackestones, light-yellow-gray, chert nodules; fusulinids, fenestrate and ramose bryozoans, crinoids
3 ft 4 inches	Seven beds of limestone, with chert nodules, that thin upward from about 7 inches thick to 4–5 inches thick, separated by 2–3-inches-thick chert layers: mudstone to sparse biowackestone,

	light-gray; fenestrate and ramose bryozoans, crinoids
1 ft 7 inches	Bed of limestone, sparse biowackestone, light-yellow, chert nodules and 3-inches-thick layers of chert at top and base; fusulinids, ramose and fenestrate bryozoans, crinoids
1 ft 4 inches	Bed of limestone, porous biowackestone, yellow, small chert nodules; fusulinids, ramose and fenestrate bryozoans, crinoids
1 ft 4 inches	Thin-bedded limestone, sparse biowackestone, light-yellow, 3 ft 4 inches-thick chert layer in middle, 1-inch-thick chert layer at top; fenestrate and ramose bryozoans, crinoids
2 ft 2 inches	Platy-bedded shaly limestone, biowackestone, bioturbated, more shaly at top, yellow, chert nodules; crinoids, spicules, ramose bryozoans, Reticulatia, Derbyia

Cole Creek Member

2 ft 4 inches	Basal 4 inches limestone, biowackestone, yellow, overlain by 8 inches yellow shale, then 4 inches yellow biowackestone, then 1 ft yellow-orange shale; crinoids, fenestrates bryozoans, Reticulatia
1 ft 10 inches	Basal 3 inches calcitic mudrock to shaly lime mudstone. Overlying 1 ft 7 inch-thick bed of limestone, biopackstone-grainstone, pelecypod-rich, bioturbated, gray. Other fossils in the unit are crinoids, Derbyia, planispiral and high-spired gastropods
1 ft 6 inches	Thin-bedded, upper and lower limestones (pelecypod-rich biopackstones) separated by thin, yellow shale; planispiral and high-spired gastropods, Composita

MATFIELD SHALE

Blue Springs Shale Member

5 ft 3 inches	Yellow-brown mudrock, unfossiliferous except for the top 6 inches, which contains pelecypod fragments
1 ft 3 inches	Basal 8 inches unfossiliferous, reddish-green mudrock; top 7 inches unfossiliferous, reddish-green to yellow-brown mudrock
11 ft 0 inches	Unfossiliferous, red mudrock, occasional streaks of green and yellow-green shale; top 2 inches is green shale
0 ft 4 inches	Unfossiliferous, green shale

Kinney Limestone Member

1 ft 4 inches	Thin-bedded, but coarsening-upward section of limestone, reddish-gray: biowackestone to sparse packstone at base, to oncolite biopackstone-grainstone at top, both with streaks of green shale. Rocks contain foraminifers, crinoids, bivalve fragments

Measured Section Number: 15

Location: Roadcuts on K–38, and adjoining field to north of road on BJN Ranch, in secs. 19 and 30, T. 32 S., R. 7 E., Butler County, Kansas

Comment: There is about 7 inches of concealed section between the top of the red shale in the Blue Springs, and outcrops of cherty Florence limestones in the fields north of the road

MATFIELD SHALE

Blue Springs Shale Member

3 ft 0 inches	Unfossiliferous, red mudrock
3 ft 0 inches	Unfossiliferous, yellow-brown mudrock
3 ft 0 inches	Concealed

Kinney Limestone Member

1 ft 0 inches	Top few inches is a ledge of bioturbated, dark-gray, shaly lime mudstone
0 ft 10 inches	Concealed
4 ft 0 inches	Poorly exposed, medium-bedded limestone, fines upward from biopackstone to biowackestone-packstone, bioturbated, medium-yellow-gray; Composita, Derbyia, oncolites, foraminifers, crinoids, planispiral gastropods

Wymore Shale Member

5 ft 6 inches	Poorly exposed, unfossiliferous, red mudrock
0 ft 10 inches	Unfossiliferous, green mudrock

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 2 inches	Medium-bedded limestone, coarsens upward from biopackstone to biograinstone, yellow-gray; foraminifers, crinoids, brachiopod fragments
0 ft 10 inches	Bed of limestone, porous, coarse-grained biopackstone, conspicuous vertical burrows, yellow, some chert nodules; echinoid spines, crinoids, Reticulatia, Composita, fenestrate bryozoans
3 ft 4 inches	Bed of limestone, coarsens upward from biopackstone to biograinstone, then fines upward to biowackestone-packstone, yellow-gray, scattered chert nodules and a 2–3-inches-thick chert layer at the top; foraminifers, crinoids, ramose bryozoans, brachiopod fragments, echinoid spines, Reticulatia
0 ft 8 inches	Fossiliferous, calcitic, yellow mudrock; Composita
2 ft 1 inches	Medium-bedded limestone, coarsens upward from fine-grained biopackstone to coarse-

	grained biopackstone-grainstone, some vertical burrows, porous, yellow; foraminifers, crinoids, brachiopod fragments

Havensville Shale Member

3 ft 4 inches	Bed of yellow-gray limestone: basal 1 ft 4 inches biopackstone-grainstone, vertical burrows. Overlain by 1 ft 2 inches very coarse grained biopackstone-wackestone with large brachiopod fragments. Then 10 inches fine-grained biopackstone with vertical burrows. Rocks contain foraminifers, crinoids, pelecypod and echinoid fragments, Composita, bryozoans
2 ft 4 inches	Basal 10–14 inches unfossiliferous, yellow mudrock; upper 14–18 inches fissile, very dark gray, laminated, sparsely fossiliferous shale. Rocks contain high-spired gastropods, Aviculopecten

Threemile Limestone Member

2 ft 0 inches	Bed of porous limestone, fines upward from biopackstone-grainstone to biopackstone, vertical burrows in lower half, yellow; foraminifers, crinoids, some oncolites
4 ft 0 inches	Thick-bedded limestone, light-yellow: basal 9 inches coarsens upward from biowackestone to oncolite biopackstone, with a 2–3-inches-thick layer of oval chert nodules just below the top. Overlain by 1 ft 4 inches oncolite biopackstone-grainstone, very coarse grained at the top, vertical burrows. Top 1 ft 11 inches fines upward from biopackstone-grainstone to biopackstone. Rocks contain foraminifers, crinoids, pelecypod fragments; lower beds also with spicules, bryozoans, Allorisma, Aviculopecten
3 ft 8 inches	Medium-bedded limestone, medium-yellow: basal 1 ft 3 inches porous biowackestone, shaly at top. Overlain by 4 inches shaly biowackestone, then 5 inches porous biowackestone, then a 3-inches-thick chert layer, then 1 ft 5 inches porous biowackestone. Scattered chert nodules in the limestones, which contain Reticulatia, gastropods, spicules, bryozoans, brachiopod fragments
2 ft 9 inches	Bed of limestone that fines upward from biowackestone-packstone to biowackestone, porous, light-yellow-tan, small angular chert nodules and an 11-inches-thick layer of laminated chert 6 ft 7 inches below the top; spicules, bryozoans, brachiopod fragments
2 ft 9 inches	Medium-bedded limestone, coarsens upward from fine-grained biowackestone to biopackstone, yellow to brownish-gray, angular chert nodules that appear brecciated; spicules, bryozoans, brachiopod fragments
0 ft 11 inches	Basal 6 inches limestone, fine-grained biowackestone-packstone, yellow, angular chert nodules; upper 5 inches yellow calcitic shale to shaly lime mudstone. Unit contains spicules, bryozoans, brachiopod fragments
2 ft 9 inches	Top 1 inch and basal 2 inches are fossiliferous, yellow mudrock to shaly lime mudstone; middle is a bed of limestone, fine-grained biowackestone-packstone, bioturbated, light-yellow-tan, small oval chert nodules in middle. Unit contains Composita, ramose and fenestrate bryozoans, crinoids, spicules, Juresania, Derbyia
0 ft 7 inches	Glauconitic limestone, biopackstone, abundant silicified Composita, tan-gray; crinoids, ramose bryozoans, Juresania, Derbyia

SPEISER FORMATION

6 ft 0 inches	Interbedded gray, fossiliferous mudrocks and shaly limestones (biowackestones); 10 inches below top is 5 inches of very dark gray, calcitic shale to shaly biowackestone; crinoids, spicules, brachiopods, with Orbiculoides at the top

Measured Section Number: 16

Location: Roadcut, north side of K–15/US–160, and gully into Silver Creek on south side of the road, in adjoining parts of secs. 19, 20, and 30, T. 32 S., R. 6 E., Cowley County, Kansas

FORT RILEY FORMATION

2 ft 2 inches	Thick-bedded limestone, biograinstone-packstone, yellow-gray; foraminifers, pelecypod fragments
1 ft 0 inches	Interbedded shaly lime mudstone and mudrock, yellow-gray, bioturbated, fossiliferous; crinoids, bivalve fragments
3 ft 0 inches	Bed of porous limestone, coarsens upward from biopackstone to biopackstone-grainstone, bioturbated, yellow; foraminifers, some crinoids and bivalve fragments
0 ft 10 inches	Bed of limestone, mudstone, yellow-gray, upper half greenish; bivalve fragments
2 ft 0 inches	Thin-bedded limestone, mudstone, yellow-gray
3 ft 4 inches	Limestone, yellow: basal 2 ft porous, cross stratified biograinstone, scattered intraclasts of lime mudstone. Overlying 1 ft 4 inches interbedded mudstone and porous biograinstone in the lower half, cross stratified, and mudstone in the upper half. Rocks contain foraminifers, bivalve fragments
0 ft 6 inches–1 ft 4 inches	Basal few inches of fossiliferous, yellow, calcitic mudrock overlain by thin-bedded, yellow, shaly lime mudstone, erosional top; bivalve fragments
2 ft 6 inches	Thin-bedded limestone, mudstone with lenses of biowackestone-packstone, light-yellow; crinoids
3 ft 1 inches	Thick-bedded limestone, prominent surface-dissolution vugs, yellow to light-gray. The unit consists of layers of lime mudstone with

	desiccation cracks and porous biowackestone-packstone with clasts of desiccated mudstone; contains foraminifers, crinoids, bivalve fragments, including gastropods
2 ft 3 inches	Basal 1 inch yellow shale overlain by a bed of limestone, biowackestone, top 10 inches laminated, light-yellow; pelecypod fragments, crinoids
3 ft 9 inches	Medium-bedded limestone, coarsens upward from biowackestone to porous biopackstone, some vertical to sub-vertical burrows, prominent surface-dissolution vugs, locally thick-bedded along the outcrop; crinoids, bivalve fragments, and at the top, also high-spired gastropods
1 ft 4 inches	Thin interbeds of biowackestone and mudrock, both fossiliferous, light-yellow-gray; crinoids, bivalve fragments
2 ft 0 inches	Calcitic, fossiliferous, yellow mudrock to shaly limestone, mudstone; crinoids, bivalve fragments
1 ft 8 inches	Thin-bedded, shaly limestone, biowackestone, bioturbated, yellow-brown; crinoids, pelecypod and brachiopods fragments
2 ft 4 inches	Thin-bedded limestone, fine-grained biograinstone, top 5 inches calcitic mudstone, yellow-brown. Limestone with crinoids, some oncolites, echinoid fragments, ramose bryozoans, Composita; mudrock with crinoids and brachiopod fragments
2 ft 0 inches	Thin-bedded, shaly limestone, biowackestone-packstone in lower half, calcitic mudrock above, yellow-brown; crinoids, brachiopod fragments
1 ft 6 inches	Bed of oncolite biopackstone-grainstone, orange-yellow; crinoids, brachiopod and pelecypod fragments
1 ft 0 inches	Concealed
1 ft 0 inches	Bed of limestone, biopackstone, light-yellow-gray; encrusting and ramose bryozoans, some oncolites, crinoids, brachiopod fragments

FLORENCE FORMATION

5 ft 4 inches	Medium-bedded limestone, biowackestone, light-tan-yellow, chert nodules; encrusting bryozoans, crinoids

Measured Section Number: 17

Location: Roadcut and gully into Snake Creek, S/2 sec. 24, T. 32 S., R. 5 E., Cowley County, Kansas
FORT RILEY FORMATION

3 ft 4 inches	Thin- to medium-bedded, shaly limestone, mudstone, light-yellow
1 ft 8 inches	Bed of limestone, shaly mudstone, light-yellow-gray
1 ft 6 inches	Thin-bedded, shaly limestone, mudstone, light-gray
0 ft 8 inches	Unfossiliferous, calcitic shale to shaly lime mudstone, fissile, orange-yellow
2 ft 8 inches	Thick- to medium-bedded limestone, mudstone, locally bioturbated lenses of biowackestone, light-yellow-gray; crinoids
1 ft 5 inches	Bed of shaly limestone, bioturbated mudstone, light-yellow-gray
1 ft 10 inches	Medium-bedded, shaly limestone, mudstone, bioturbated, top 6 inches fissile, light-gray
1 ft 9 inches	Bed of shaly limestone, dark-gray to yellow along the outcrop, mudstone, abundant vertical and sub-vertical burrows filled with coarse-grained biowackestone; crinoids, brachiopod fragments
2 ft 9 inches	Interbeds of mudrock and shaly limestone, sparse biowackestone, medium- up to thin-bedded, sub-vertical burrows in upper half; weathers dark-gray in upper half, light-gray below but fresh color is medium-gray. Rocks contain crinoids, brachiopod fragments. This is the upper part of the "gray zone" referred to in the text
2 ft 4 inches	Thin interbeds of shale and shaly limestone, biowackestone with some lenses of biopackstone, light-yellow-brown to light-gray (but upper 10 inches weathers dark-gray); fenestrate bryozoans, crinoids, brachiopod fragments. This is the lower part of the "gray zone" referred to in the text
1 ft 8 inches	Bed of limestone, oncolite biopackstone, finer-grained and with fewer oncolites than below, brownish-yellow; crinoids, foraminifers, planispiral gastropods
1 ft 6 inches	Concealed
5 ft 4 inches	Medium-bedded limestone, oncolite biopackstone, orange-yellow, relatively large and abundant oncolites; crinoids, foraminifers, planispiral gastropods

FLORENCE FORMATION

1 ft 0 inches	Bed of white limestone, sparse biowackestone; scattered oncolites and ramose bryozoans

Measured Section Number: 18

Location: Roadcut on K–15/US–160, centers of adjoining secs. 20 and 29, T. 32 S., R. 5 E., and railroad cut in N/2 of sec. 30, T. 32 S., R. 5 E., Cowley County, Kansas

ODELL SHALE

0 ft 6 inches	Red, shaly top soil
0 ft 6 inches	Unfossiliferous, light-gray shale, small white chert nodules (silicified evaporites)

WINFIELD LIMESTONE

Luta Member

2 ft 0 inches	Thin-bedded shale and shaly limestone, biowackestone, very abundant silicified Composita, light-gray
1 ft 6 inches	Basal 7 inches bed of limestone, sparse oncolite biowackestone, chert nodules (ramose bryozoans, crinoids); overlain by 3 inches fissile, yellow lime mudstone; overlain by 8 inches biowackestone as at the base of the unit, scattered yellow chert nodules

Cresswell Limestone Member

3 ft 4 inches	Bed of limestone, fines upward from oncolite biopackstone-grainstone to sparsely oncolitic biopackstone, vertical burrows at base, yellow; foraminifers, crinoids
7 ft 0 inches	Thick-bedded limestone, coarsens upward from biowackestone-packstone to biograinstone, porous, vertically burrowed in upper 5 ft, yellow; top 9 inches weathers recessively, and has some brown-weathering, oval chert nodules. Crinoids, ramose bryozoans, brachiopod fragments dominate at base; foraminifers, and accessory crinoids and bryozoans dominate above

Grant Shale Member

1 ft 6 inches	Interbedded mudrock and shaly limestone, mudstone to biowackestone, all oncolitic except for topmost mudrock, yellow-brown; crinoids. Part of the "concretionary zone" referred to in the text
1 ft 10 inches	Thin-bedded, calcitic mudrock to shaly biowackestone, oncolitic, brownish-yellow; ramose bryozoans, crinoids. Part of the "concretionary zone" referred to in the text
1 ft 3 inches	Thin-bedded, calcitic mudrock to shaly limestone, mudstone, brownish-yellow; rare pelecypod fragments
3 ft 4 inches	Unfossiliferous, greenish-yellow brown mudrock

Santa Fe Lake Member

1 ft 0 inches	Laminated, shaly lime mudstone, brownish-gray

Measured Section Number: 19

Location: Roadcut on K–15/US–160, both sides, in NE sec. 25, T. 32 S., R. 4 E., Cowley County, Kansas

DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

2 ft 2 inches	Thin-bedded limestone, fines upward from biowackestone-packstone to sparse biowackestone, bioturbated, thin partings of yellow shale, brown; foraminifers, crinoids, brachiopod fragments
4 ft 0 inches	Unfossiliferous, fissile shale, light-brown
1 ft 5 inches	Thin interbeds of limestone, fine-grained, intraclastic biopackstone with some grainstone laminae, orange spots (foraminifers, brachiopod fragments), and unfossiliferous red-brown-yellow shale

Holmesville Shale Member

4 ft 0 inches	Unfossiliferous, yellow-brown-green shale and mudrock
3 ft 0 inches	Unfossiliferous, yellow-green-black shale and mudrock
1 ft 4 inches	Unfossiliferous, green mudrock
0 ft 6 inches	Unfossiliferous, hard, green mudrock, minor ledge-former
3 ft 0 inches	Unfossiliferous, green mudrock
1 ft 10 inches	Two beds of gray, bioturbated lime mudstone with green shale wisps, separated by a layer of unfossiliferous, brown-gray-tan mudrock
1 ft 8 inches	Unfossiliferous, gray-green shale
0 ft 3 inches	Bed of dark-gray, lime mudstone with desiccation cracks
0 ft 6 inches	Unfossiliferous, dark-green shale

Measured Section Number: 20

Location: Prosser's type area of the Winfield Limestone: intersection of US–160 and dirt road to south, in center W/2 sec. 29, T. 32 S., R. 4 E., west side of Winfield, Cowley County, Kansas

ODELL SHALE

1 ft 0 inches	Unfossiliferous, light-gray shale

WINFIELD LIMESTONE

Luta Member

7 ft 8 inches	Thin-bedded limestone, biowackestone in lower 2 ft, slightly shaly mudstone above, light-gray, scattered small black chert nodules 1 ft 4 inches–5 ft 4 inches above the base; crinoids, brachiopod fragments, scattered ramose bryozoans
1 ft 0 inches	Thin-bedded limestone, shaly, fine-grained biowackestone, yellow; ramose bryozoans, crinoids

Cresswell Limestone Member

10 ft 4 inches	Two beds of limestone, porous biowackestone-packstone at base, biopackstone to grainstone above, although top few inches are biopackstone-wackestone, yellow, scattered brown-weathering, oval chert nodules; foraminifers, bivalve fragments, bryozoans, scattered oncolites, Derbyia

Grant Shale Member

1 ft 5 inches	Thin-bedded limestone, shaly biowackestone, yellow-gray; crinoids, ramose bryozoans, brachiopod fragments

Measured Section Number: 21

Location: Roadcut, south side of Cowley County Highway 18, on side of big hill, NE sec. 7, T. 32 S., R. 4 E., Cowley County, Kansas

DOYLE SHALE

Towanda Limestone Member
(top of Towanda?)

1 ft 8 inches	Bed of limestone, intraclastic biopackstone-grainstone, porous, light-yellow-gray, intraclasts are yellow, shaly lime mudstone; foraminifers, bivalve fragments
1 ft 6 inches	Unfossiliferous mudrock to shaly lime mudstone, yellow
0 ft 6 inches	Bed of hard limestone, intraclastic biopackstone, light-gray, intraclasts are yellow, shaly lime mudstone; foraminifers

Holmesville Shale Member

1 ft 3 inches	Unfossiliferous, yellow mudrock
2 ft 6 inches	Unfossiliferous, yellow mudrock with red streaks, veinlets of gypsum, glaebules and brecciated appearance (paleosol)
3 ft 6 inches	Unfossiliferous, light-gray-green shale and mudrock
3 ft 0 inches	Unfossiliferous, red mudrock (quite silty) to siltstone, gypsum veinlets
0 ft 2 inches	Unfossiliferous, light-gray-green shale and mudrock

Measured Section Number: 22

Location: Exposures along railroad tracks east of Burden, in adjoining secs. 31 and 32, T. 31 S., R. 7 E., and sec. 36, T. 31 S., R. 6 E., Cowley County, Kansas

Comment: This locality is discussed in Bass (1929) and Bayne (1962), and is the location at which a measured section of the Bruno limestone was given by Condra and Upp (1931). Comparison of the measured sections provided by these authors indicates considerable discrepancy among them, particularly within the Matfield Shale. Because of poorer exposures now, we were not able to precisely verify the stratigraphy of the Matfield as given by any of these workers

FLORENCE FORMATION

6 ft 10 inches	Thin- to medium-bedded limestones, in beds 4–10 inches thick,separated by discontinuous layers of chert 1–4 inches thick: mudstones to sparse biowackestones, white, chert nodules also in lower beds; "cannonballs" of chert 2 inches below the top. Rocks contain Composita, crinoids, fenestrate and ramose bryozoans
0 ft 6 inches	Layer of laminated, "cannonball" chert, with included fenestrate bryozoans
1 ft 4 inches	Thin-bedded limestone, sparse biowackestone, in 4–8-inches-thick beds separated by 2-inches-thick chert layers, the limestones also contain chert nodules; white. Rocks contain ramose bryozoans, crinoids, brachiopod fragments
2 ft 0 inches	Three beds of equal thickness of white-light-yellow limestone, sparse biowackestone, separated by 3-inch-thick layers of chert; crinoids, brachiopod fragments, fenestrate bryozoans

Cole Creek Member

3 ft 0 inches	Basal 4 inches of limestone, shaly mudstone to sparse biowackestone, overlain by 2 ft 8 inches of calcitic mudrock with lenses of lime mudstone to sparse biowackestone, yellow-brown; crinoids, bivalve fragments
1 ft 10 inches	Calcitic mudrock with lenses of shaly lime mudstone to sparse biowackestone, yellow-brown; pectinids, Derbyia, ramose bryozoans, crinoids
2 ft 9 inches	Thin-bedded limestone, bioturbated, coarsens upward from biowackestone to biopackstone, light-brown; 4-inches-thick layer of shale 4 inches above the base. Rocks contain foraminifers, crinoids, bivalve fragments, including gastropods, Aviculopecten, Composita, Derbyia

MATFIELD SHALE

Blue Springs Shale Member

6 ft 0 inches	Unfossiliferous, yellow to reddish-brown mudrock (poorly exposed)
2 ft 0 inches	Unfossiliferous, red shale and mudrock
2 ft 6 inches	Basal 2 inches intraclastic mudrock (clasts of black lime mudstone); overlain by 5 inches green mudrock, then 6 inches hard, similarly intraclastic, green-gray mudrock; then 1 ft 5 inches light-greenish-gray shale
2 ft 11 inches	Basal 1 inch unfossiliferous, green shale; overlain by 2 ft 10 inches unfossiliferous, red mudrock
1 ft 9 inches	Bruno limestone bed: basal 1 ft 3 inches, fining-upward section from bioturbated biopackstone (foraminifers, crinoids) to shaly mudstone, light-gray. Overlain by 6-inches-thick bed of limestone that fines upward from coarse-grained, laminated biograinstone to mudstone, white. Rocks contain foraminifers, crinoids, brachiopod fragments, high-spired gastropods
7 ft 0 inches	Concealed

Kinney Limestone Member

2 ft 4 inches	Medium- up to thin-bedded limestone, coarsens upward from biograinstone to coarser-grained biopackstone-grainstone, bioturbated, with brachiopod shell hash, light-gray; foraminifers, crinoids, ramose bryozoans, Composita, Juresania, Derbyia
3 ft 4 inches	Thick-bedded limestone, coarsening-upward section of fine-grained biopackstone-grainstone to porous biograinstone, locally cross stratified, bioturbated, top 6 inches is oncolitic, with brachiopod shell hash, yellow-gray; Composita, Juresania, foraminifers, crinoids
1 ft 3 inches	Thin-bedded, fossiliferous mudrock and lenses of shaly lime mudstone, with a thin lense of biopackstone in the middle, yellow-gray; Composita, crinoids, planispiral gastropods
0 ft 10 inches	Bed of limestone, biopackstone-grainstone, bioturbated,mottled yellow and medium-gray; planispiral and high-spired gastropods, foraminifers

Wymore Shale Member

7 ft 8 inches	Poorly exposed shales: green at base, green-yellow in middle with white calcite nodules (paleocaliche); top 1 ft 6 inches medium-gray mudrock. All rocks are unfossiliferous

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 9 inches	Bed of limestone, coarsens upward from oncolite biowackestone-packstone, with prominent vertical burrows filled with coarser sediment, to biopackstone-grainstone, porous, both units hematitic, orange-yellow; foraminifers, crinoids, Allorisma, Composita
2 ft 6 inches	Poorly exposed, medium-bedded limestone, fines upward from relatively coarse-grained, porous biopackstone to biowackestone, yellow, chert nodules throughout; foraminifers, crinoids, bivalve fragments
8 ft 6 inches	Concealed: somewhere within this interval is the Schroyer–Havensville contact, and the entire Havensville section

Threemile Limestone Member

3 ft 8 inches	Bed of limestone, yellow, porous: basal 7 inches biowackestone, erosional hard ground top (2–4 inches of relief), with brown-weathering, oval, laminated chert nodules. Overlain by coarse-grained, porous, intraclastic biopackstone-grainstone with vertical burrows within 10–12 inches of the top, and fines upward to biopackstone, scattered small chert nodules throughout. Rocks contain crinoids, oncolites, foraminifers, Derbyia
4 ft 4 inches	Thinning-upward beds of limestone with chert nodules, separated by 1–2-inches-thick layers of chert: mudstone to sparse biowackestone, yellow; crinoids, brachiopod fragments, spicules, fenestrate and ramose bryozoans
2 ft 0 inches	Bed of limestone, porous biowackestone to fine-grained biopackstone, yellow, 1.5-inches-thick layer of chert at the base, brown-weathering, oval, laminated chert nodules throughout; crinoids, bryozoans, brachiopod fragments
3 ft 4 inches	Bed of limestone, biowackestone, with small angular chert nodules that appear brecciated, yellow; crinoids, bryozoans, spicules
1 ft 0 inches	Basal 6 inches calcitic mudrock to shaly lime mudstone, yellow-gray, with crinoids, bryozoans; top 6 inches sparse biowackestone, yellow-gray, with Composita, Juresania
2 ft 6 inches	Bed of limestone, slightly shaly biowackestone-packstone, yellow, abundant silicified Composita, chert nodules in middle; crinoids, spicules, ramose bryozoans, rare Reticulatia

0 ft 9 inches	Basal 8 inches shaly limestone, biowackestone-packstone, abundant silicified Composita, yellow, top 1 inch fossiliferous, yellow mudrock; crinoids, spicules, ramose bryozoans, some Derbyia

SPEISER FORMATION

5 ft 0 inches	Poorly exposed, thin-bedded, fossiliferous calcitic mudrock and lenses of shaly mudstone-biowackestone, yellow-gray; small Juresania at top, and crinoids, brachiopod fragments, bryozoans throughout

Measured Section Number: 23

Location: Roadcuts on Cowley County Highway 5, adjoining secs. 3 and 4, T. 31 S., R. 6 E., Cowley County, Kansas

FLORENCE FORMATION

Cole Creek Member

0 ft 7 inches	Bed of limestone, biopackstone, yellow-pink; pelecypod fragments, small planispiral gastropods

MATFIELD SHALE

Blue Springs Shale Member

2 ft 8 inches	Unfossiliferous shale: basal 4 inches green, overlying 8 inches red, overlying 4 inches blue-green, top 1 ft 4 inches yellow
1 ft 8 inches–2 ft 0 inches	Bruno limestone bed: platy-bedded, shaly limestone, biowackestone-packstone, light-gray, with green shale-filled fissures and veins; pelecypod fragments
1 ft 4 inches	Thin interbeds of light-gray, shaly lime mudstone, with green and red shale-filled fissures and veins (bivalve fragments, foraminifers); and unfossiliferous, red and green shale

Kinney Limestone Member

2 ft 0 inches	Bed of limestone, oncolite biopackstone, porous, medium-gray, vertical and sub-vertical burrows, some green shale in the matrix; crinoids, brachiopod fragments
1 ft 8 inches	Bed of slightly shaly limestone, biowackestone-packstone, light-yellow; brachiopod fragments, crinoids, ramose bryozoans, oncolites
7 ft 2 inches	Sparsely fossiliferous, yellow-brown mudrock (rare pelecypod molds, Juresania and Composita), but the top 1 ft 2 inches is unfossiliferous; 5 ft above base is a 1-inch-thick limestone, biopackstone-wackestone, similar fossils
1 ft 4 inches	Bed of shaly limestone, oncolite biopackstone, bioturbated, yellow; brachiopod fragments, foraminifers, crinoids
2 ft 0 inches	Thin- to medium-bedded, shaly limestone, fines upward from biowackestone-packstone to biowackestone, bioturbated, splotchy yellow and medium-gray; Derbyia, accessory Juresania, crinoids, foraminifers

Wymore Shale Member

0 ft 8 inches	Unfossiliferous, chocolate-brown mudrock

Measured Section Number: 24

Location: Roadcut along dirt road in NW sec. 25 and adjoining NE sec. 26, T. 30 S., R. 6 E.; lower 2 ft 7 inches of section measured in a gully to the south of the road along the center of the north line of sec. 19, T. 30 S., R. 7 E., Cowley County, Kansas

FLORENCE FORMATION

4 ft 6 inches	Section of 3-inches-thick limestone beds separated by 2–3-inches-thick layers to discontinuous layers of chert: biowackestone-packstone, light-yellow; the top 3 ft of the section is nearly all residual chert. Rocks contain crinoids, fenestrate and ramose bryozoans; fusulinids in the basal few inches of the section
0 ft 11 inches	Bed of limestone, fine-grained biopackstone, light-yellow; fusulinids, bryozoans
3 ft 1 inches	Section composed of 6–8-inches-thick limestone beds separated by 2-inches-thick layers of chert, thickness of limestone beds increases upsection: fine-grained biopackstone, light-yellow, with brachiopod fragments, ramose and fenestrate bryozoans, fusulinids at the top
1 ft 8 inches	Thin-bedded, shaly limestone, coarsens upward from biowackestone to biopackstone, scattered chert nodules, orange; 3.5 inches thick, fossiliferous, yellow shale at top. Rocks contain bryozoans, crinoids, brachiopod fragments

Cole Creek Member

1 ft 7 inches	Sparsely fossiliferous, yellow-brown mudrock, with a 4-inches- thick layer of lime mudstone just below the middle; brachiopod fragments
2 ft 6 inches	Thin- to medium-bedded limestone, fines upward from biopackstone-grainstone to sparse biowackestone, light-gray; foraminifers, crinoids, pelecypod fragments, planispiral and high-spired gastropods
0 ft 6 inches	Unfossiliferous, yellow-brown shale
1 ft 8 inches	Thin-bedded limestone, biowackestone-packstone, light-yellow; pelecypod fragments, high-spired gastropods

MATFIELD SHALE

Blue Springs Shale Member

6 ft 0 inches	Unfossiliferous, chocolate to yellow-brown mudrock; basal
1 ft 6 inches	not exposed

Kinney Limestone Member

0 ft 7 inches	Bed of limestone, biopackstone, that passes laterally to lime mudstone with wisps of green shale; oncolites, pelecypod fragments
2 ft 0 inches	Bed of limestone, biowackestone, light-gray; bivalve fragments, including planispiral gastropods

Measured Section Number: 25

Location: Roadcuts on both sides of Cowley County Highway 8 in SE sec. 7 and NE sec. 18, T. 31 S., R. 5 E., Cowley County, Kansas

FORT RILEY FORMATION

8 ft 0 inches	Thin- to medium-bedded, shaly limestone, bioturbated mudstone, light-yellow; rare crinoids and brachiopod fragments
1 ft 10 inches	Bed of shaly limestone, mudstone with lenses of biowackestone-packstone increasing in abundance toward the top, light-gray, vertical and sub-vertical burrows, very shaly in the top 1 inch; crinoids, brachiopod fragments
6 ft 2 inches	Thin-bedded, shaly limestone, mudstone with lenses of biowackestone-packstone, some locally graded and with conspicuous brachiopod shell hash; brachiopod fragments, crinoids, foraminifers, some high-spired gastropods in lower beds
5 ft 0 inches	Thin-bedded, almost fissile, medium- to dark-gray, very shaly limestone, bioturbated mudstone (the "gray zone" referred to in the text); rare crinoids, brachiopod fragments, and Orbiculoides
2 ft 6 inches	Concealed
3 ft 4 inches	Medium-bedded limestone, fines upward from oncolite biopackstone-grainstone to biopackstone, light-yellow-gray; crinoids, bivalve fragments
3 ft 0 inches	Medium-bedded limestone, oncolite biopackstone, size of the oncolites increases slightly upsection, light-yellow-gray; crinoids, bivalve fragments
2 ft 4 inches	Bed of limestone, coarsens upward from oncolite biowackestone to fine-grained biopackstone, light-gray, prominent stylolite at base; what appear to be white intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain bivalve fragments, crinoids

FLORENCE FORMATION

1 ft 1 inches	Thin-bedded limestone, oncolite biowackestone, light-gray, prominent stylolite at base and near top; what appear to be white intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain fenestrate and ramose bryozoans, crinoids, brachiopod fragments
1 ft 5 inches	Bed of limestone, fines upward from oncolite biowackestone-packstone to sparse biowackestone, light-tan; what appear to be intraclasts are actually fenestrate bryozoan-encrusted grains; prominent stylolites at base and near top. Rocks contain brachiopod fragments, bryozoans, crinoids
1 ft 8 inches	Bed of limestone, mudstone to sparse biowackestone, light-tan, prominent stylolites at base and at top; what appear to be intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain Composita, crinoids
1 ft 7 inches	Medium-bedded limestone, light-yellow-orange, oncolite biowackestone (number of oncolites decreases upsection), 3 inches thick, discontinuous layer of chert 8 inches below the top; what appear to be intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain crinoids, brachiopod fragments
1 ft 4 inches	Bed of limestone, sparse oncolite biowackestone, light-orange to yellow, prominent stylolite above the base; crinoids, bryozoans, brachiopod fragments
1 ft 4 inches	Medium-bedded limestone, biowackestone, light-gray, with abundant rugose corals attached to what appears to be a brecciated hard ground (coral biostrome referred to in the text), chert nodules; brachiopod fragments, crinoids, bryozoans
4 ft 0 inches	Medium-bedded limestone, coarsens upward from sparse biowackestone to fine-grained biopackstone, light-yellow, chert nodules throughout; ramose bryozoans, crinoids, brachiopod fragments

Measured Section Numbers: 26A and 26B

Location: Section 26A is the roadcut along both sides of K–15, in the SW sec. 31, T. 30 S., R. 4 E.; section 26B is the quarry in the SE NE sec. 2, T. 31 S., R. 3 E., east of Udall, Cowley County, Kansas

Comment: Measured section 26A exposes Gage through basal Luta strata; section 26B exposes upper Cresswell to Luta strata

WINFIELD LIMESTONE

Luta Member
(probable top of the member)

4 ft 8 inches	Thin- to medium-bedded, shaly limestone, mudstone to sparse biowackestone, grayish-tan, scattered small dark-gray chert nodules; ramose bryozoans, Composita, crinoids
3 ft 4 inches	Thin- to medium-bedded, shaly limestone, mudstone to biowackestone, yellow-tan, scattered small dark-gray chert nodules and thin interbeds of yellow-tan shale; ramose bryozoans, Composita, crinoids

Cresswell Limestone Member

2 ft 8 inches	Bed of limestone, porous oncolite biograinstone, grain size fines upward, prominent vertical burrows in lower 6 ft 8 inches, yellow; crinoids, foraminifers, brachiopod fragments
1 ft 4 inches	Bed of porous limestone, oncolite biograinstone, prominent vertical burrows, weathers recessively, yellow; crinoids, foraminifers, brachiopod fragments
2 ft 10 inches	Bed of limestone, porous oncolite biopackstone, bioturbated, vertical burrows in top 4 inches, yellow to light-gray; crinoids, foraminifers, brachiopod fragments, including Derbyia
2 ft 6 inches	Bed of limestone, biowackestone-packstone, bioturbated, yellow-gray, porous in upper 1 ft; brachiopod fragments, ramose bryozoans, crinoids

Grant Shale Member

0 ft 7 inches	Bed of shaly limestone, bioturbated mudstone, yellow-gray; crinoids, bryozoans, brachiopod fragments
3 ft 0 inches	Medium-bedded, shaly limestone, coarsens upward from biowackestone-packstone to oncolite biopackstone, bioturbated, grayish-yellow (the "concretionary bed" referred to in the text); ramose bryozoans, crinoids, brachiopod fragments
4 ft 6 inches	Fossiliferous, calcitic mudrock, greenish-yellow; bryozoans, Reticulatia, Derbyia, crinoids

Santa Fe Lake Member

1 ft 0 inches	Thin-bedded limestone, shaly mudstone to graded calcisiltite, yellow; rare crinoids and brachiopod fragments
2 ft 8 inches	Laminated, shaly lime mudstone, unfossiliferous, light-tan

DOYLE SHALE

Gage Shale Member

4 ft 0 inches	Unfossiliferous, yellow-brown mudrock with laminae/lenses of laminated, shaly lime mudstone in the upper half
3 ft 0 inches	Unfossiliferous, light-tan mudrock with secondary calcite veins
4 ft 4 inches	Unfossiliferous shale, greenish-tan-brown, darker in the lower half
3 ft 8 inches	Unfossiliferous mudrock and shale, grades upward from green to brown-green, some red at base; calcite nodules (paleocaliche) just below the middle, within and above red shale
1 ft 4 inches	Unfossiliferous, red mudrock

Measured Section Number: 27

Location: Two separate roadcuts along K–15, east of Udall, in the NE sec. 3, T. 31 S., R. 3 E. (south side of road) and in the SW sec. 34, T. 30 S., R. 3 E. (north side of road), Cowley County, Kansas

NOLANS LIMESTONE

Herington Member
(probable top of the member)

1 ft 6 inches	Thin-bedded, shaly limestone, mudstone, porous in top 1 ft,yellow-gray
4 ft 5 inches	Thin-bedded to laminated lime mudstone, light-gray
1 ft 4 inches	Bed of recrystallized lime mudstone, calcite geodes, yellow
6 ft 6 inches	Thin- to medium-bedded, dolomitic lime mudstone, scattered calcite geodes, grayish-tan; some thin lenses of finely comminuted biowackestone-packstone just above the base

Paddock Shale Member

2 ft 6 inches	Unfossiliferous, grayish-tan mudrock
15 ft 6 inches	Concealed

Krider Limestone Member

1 ft 1 inches	Thin-bedded, shaly limestone, coarsens upward from biowackestone to biowackestone-packstone, gray; ramose bryozoans, crinoids, pelecypod fragments

0 ft 10 inches	Fissile, black shale to shaly lime mudstone to biowackestone; fenestrate bryozoans, crinoids, pelecypod fragments
2 ft 8 inches	Thin-bedded, shaly limestone, fines upward from oncolite biowackestone-packstone to biowackestone, light-gray (with conspicuous orange fossils); abundant pelecypod casts, crinoids, high-spired gastropods

ODELL SHALE

18 ft 0 inches	Unfossiliferous, grayish-green to greenish-gray mudrock, two prominent paleosols 3 ft and 5 ft below the top

Measured Section Number: 28

Location: Banks of Spring Creek due east of US–77, in NW sec. 33, T. 30 S., R. 4 E., Cowley County, Kansas

DOYLE SHALE

Holmesville Shale Member

3ft 0 inches	Unfossiliferous shale, light-yellow-gray with brown splotches

FORT RILEY FORMATION

1 ft 8 inches	Laminated limestone, shaly mudstone, light-gray, unfossiliferous
2 ft 4 inches	Concealed
1–2 inches	Shaly limestone, mudstone, light-gray; crinoids
3 ft 8 inches	Bed of limestone, porous biopackstone, bioturbated (including some prominent vertical burrows), large surface dissolution vugs, light-tan-gray; foraminifers, crinoids, brachiopod fragments
1 ft 0 inches	Thin-bedded limestone, biowackestone-packstone, porous and gastropod-rich in top 6 inches, light-gray; foraminifers, high-spired gastropods, Composita, crinoids
5 ft 8 inches	Bed of limestone, porous biopackstone, large surface-dissolution vugs, locally bioturbated and seemingly layered (at least in lower half), light-tan-gray; foraminifers, crinoids, bivalve and brachiopod fragments
3 ft 4 inches	Bed of limestone, porous biopackstone, light-gray; foraminifers, crinoids, brachiopod fragments
1 ft 8 inches	Thin-bedded, shaly limestone, biowackestone, bioturbated, yellow-gray; pelecypod fragments, crinoids

Measured Section Number: 29

Location: East bank of Rock Spring, due east of US–77, in the W/2 sec. 21, T. 30 S., R. 4 E., Cowley County, Kansas

FORT RILEY FORMATION

4 ft 0 inches	Medium-bedded limestone, mudstone-biowackestone with lenses of porous biowackestone-packstone, bioturbated, light-tan-gray; crinoids, Composita
4 ft 0 inches	Medium-bedded limestone, mudstone-biowackestone, bioturbated, locally porous, light-yellow (dark below river level); crinoids, brachiopod fragments

Measured Section Number: 30

Location: Roadcuts on US–77 north of Rock, in E/2 sec. 8, T. 30 S., R. 4 E., Cowley County, Kansas

WINFIELD LIMESTONE

Luta Member
(probable top of the member)

2 ft 6 inches	Medium-bedded, shaly limestone, mudstone, bioturbated, small white chert nodules, light-gray; Composita, crinoids, bryozoans
2 ft 8 inches	Medium-bedded limestone, shaly mudstone-biowackestone in 2–5-inches-thick beds separated by thin shales, bioturbated, light-gray; Composita, ramose and fenestrate bryozoans, crinoids, pelecypod fragments, echinoid spines

Cresswell Limestone Member

1 ft 4 inches	Medium-bedded limestone, oncolite biopackstone, finer-grained than below, grayish-yellow; crinoids, ramose bryozoans, brachiopod fragments, foraminifers
2 ft 10 inches	Recessive bed of porous, oncolite biograinstone, prominent vertical burrows, grain size increases up-section, grayish-yellow; crinoids, brachiopod fragments, foraminifers
1 ft 4 inches	Bed of limestone, porous oncolite biopackstone-grainstone, prominent vertical burrows, yellow-gray; crinoids, bivalve fragments, foraminifers
2 ft 3 inches	Bed of limestone, slightly bioturbated: basal 1 ft very porous, coarse-grained biowackestone-

packstone, upper 1 ft 3 inches porous oncolite biopackstone, fine-grained, yellow; ramose bryozoans, crinoids, foraminifers, Derbyia

2 ft 0 inches Bed of limestone, slightly porous biopackstone, bioturbated, yellow-gray; ramose bryozoans, crinoids, brachiopod fragments

Grant Shale Member

1 ft 2 inches Bed of shaly limestone, bioturbated biowackestone, light-yellow; crinoids, brachiopod fragments, ramose bryozoans, some oncolites

5 ft 0 inches Poorly exposed: thin interbeds of shaly lime mudstone and calcitic mudrock, bioturbated, light-yellow-gray, fossiliferous; crinoids, bryozoans, brachiopod fragments, some oncolites

15 ft 0 inches Concealed: the Santa Fe Lake Member, and Doyle–Winfield contact are present in this concealed interval

DOYLE SHALE

Gage Shale Member

4 ft 0 inches Unfossiliferous green mudrock

11 ft 0 inches Unfossiliferous, red mudrock and shale, some layers of siltstone

Measured Section Number: 31

Location: Roadcuts and field exposures along Cole Creek Road, south of Clay Center, near the Blair Ranch, in the NW sec. 27, T. 29 S., R. 6 E., Butler County, Kansas

FLORENCE FORMATION

5 ft 6 inches Section of 3–5-inches-thick beds of limestone separated by layers of chert nodules 2–4 inches thick: mudstone-biowackestone, white; fusulinids, crinoids, fenestrate and ramose bryozoans, some Reticulatia

5 ft 0 inches Section of limestones where there is an upward decrease in bed thickness from 6 inches to 3–4 inches separated by 2–3-inches-thick layers of chert nodules: biowackestone, white. Rocks contain ramose bryozoans, crinoids, scattered fusulinids in lower two beds, Reticulatia

6 ft 5 inches Section of limestones where there is an upward decrease in bed thickness from 6 inches to 3–4 inches separated by 2–3-inches-thick layers of chert nodules: biowackestone, white. Rocks contain fenestrate bryozoans and crinoids in the lower half; fusulinids, fenestrate bryozoans, crinoids, and Reticulatia in the upper half, beginning at lowest of two prominent stylolites in the section

2 ft 4 inches Medium-bedded limestone, biowacke-stone-packstone, white, thin layers of chert, 2-inch layer of biowackestone at the top; fusulinids, crinoids, ramose bryozoans, brachiopod fragments

0 ft 11 inches Thin-bedded, white lime mudstone, thin layer of chert in the middle, and 2–3-inches-thick layer of chert at the top; fusulinids at the top

0 ft 7 inches Bed of limestone, biopackstone-grainstone, white, chert layer at the top ; bryozoans, crinoids

1 ft 0 inches Bed of limestone, biowackestone, light-grayish-white, chert nodules; spicules, brachiopod fragments, ramose bryozoans, Reticulatia

0 ft 8 inches Basal 2 inches biowackestone, white, chert nodules; overlain by 6 inches fossiliferous, yellow mudrock; spicules, crinoids, brachiopod fragments

0 ft 8 inches Fossiliferous, bioturbated, yellow mudrock; crinoids, brachiopod fragments

0 ft 4 inches Bed of limestone, mudstone-biowackestone, light-gray, chert nodules; ramose bryozoans, brachiopod fragments

Cole Creek Member

0 ft 5 inches Bed of limestone, shaly mudstone, light-gray; Reticulatia

1 ft 5 inches Bed of limestone, mudstone, white; high-spired and planispiral gastropods, bivalve fragments, crinoids

2 ft 0 inches Thin- to medium-bedded limestone, fine-grained biopackstone-grainstone, 1-inch-thick calcitic shale at the top, light-gray; prominent pelecypod casts in the middle; bivalves, crinoids, foraminifers, high-spired gastropods

0 ft 8 inches Bed of limestone, biowackestone, light-gray; pelecypod molds, gastropods, crinoids, encrusting foraminifers

0 ft 9 inches Fossiliferous black in basal 6 inches, fossiliferous, laminated and yellow-brown above; pelecypods

0 ft 10 inches Bed of limestone, biowackestone-packstone, yellow-gray; pelecypods, planispiral gastropods, crinoids

MATFIELD SHALE

Blue Springs Shale Member

7 ft 6 inches Poorly exposed: top few inches pelecypod-rich, yellow mudrock

Kinney Limestone Member

2 ft 0 inches Poorly exposed limestone, biograinstone; foraminifers

Measured Section Number: 32

Location: Roadcuts on Cole Creek Road immediately south of Clay Center, in NE sec. 21, T. 29 S., R. 6 E., Butler County, Kansas

MATFIELD SHALE

Kinney Limestone Member

3 ft 2 inches	Medium-bedded limestone, biopackstone-grainstone, current-layered, prominent surface dissolution vugs (horizontal), light-yellow-gray; foraminifers, crinoids
2 ft 10 inches	Concealed
2 ft 3 inches	Medium-bedded, shaly limestone, mudstone-biowackestone, bioturbated, splotchy yellow and medium-gray; Derbyia, Allorisma
6 ft 4 inches	Mostly concealed: sparsely fossiliferous, yellow mudrock; pelecypods, brachiopod fragments
3 ft 2 inches	Medium-bedded, shaly limestone, biowackestone-packstone, bioturbated, light-gray to yellow-gray; Derbyia, Juresania, Composita, Meekella, Myalina, Allorisma, gastropods

(probable base of the member)

Measured Section Number: 33

Location: Guthrie Farm, on tributary to Rock Creek, just north of Clay Center, in sec. 21, T. 29 S., R. 6 E., Butler County, Kansas

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 4 inches	Medium-bedded limestone, biopackstone, light-tan-yellow, small chert nodules; crinoids, ramose and fenestrate bryozoans, brachiopod fragments, echinoid spines
0 ft 7 inches	Layer of dark-gray chert; bryozoans, spicules
0 ft 4 inches	Bed of limestone, biowackestone-packstone, light-yellow; bryozoans, crinoids, brachiopod fragments
1 ft 0 inches	Thin-bedded limestone, biowackestone, tan, chert nodules; spicules, fenestrate and ramose bryozoans, Reticulatia, crinoids

Havensville Shale Member

1 ft 4 inches	Calcitic mudrock with lenses of shaly biowackestone, bioturbated, light-gray; crinoids, ramose bryozoans, Composita
0 ft 8 inches	Bed of shaly limestone, biowackestone-packstone, bioturbated, light-gray; Composita
2 ft 0 inches	Calcitic mudrock with lenses of shaly biowackestone-packstone, bioturbated, light-gray; crinoids, fenestrate and ramose bryozoans, gastropods, Allorisma, brachiopod fragments
2 ft 8 inches	Concealed

Threemile Limestone Member

4 ft 0 inches	Bed of limestone, biopackstone-grainstone wherein grain size decreases upsection, locally bioturbated, with chert along burrows, yellow-brown; crinoids, some oncolites, Composita, Derbyia, ramose bryozoans
1 ft 2 inches	Medium-bedded limestone, coarsens upward from oncolite biowackestone to biowackestone-packstone, bioturbated, yellow-gray, chert nodules, vertical burrows; ramose bryozoans, crinoids

Measured Section Number: 34

Location: Spillway at Butler County State Fishing Lake, NW sec. 8 and SE sec. 5, T. 29 S., R. 7 E., Butler County, Kansas

Comment: The base of the cherty Florence is poorly exposed in the hills around the lake, and lake level at the spillway is the top of the Cole Creek Member.

FLORENCE FORMATION

Cole Creek Member (full thickness)

0 ft 6 inches	Bed of limestone, mudstone-biowackestone, bioturbated, yellow; Reticulatia, Allorisma, crinoids, bryozoans
1 ft 4 inches	Thin-bedded limestone, biowackestone-packstone, basal 2 inches of shale, light-gray; pelecypods, high-spired gastropods, crinoids, fenestrate bryozoans, brachiopod fragments
1 ft 4 inches	Thin-bedded limestone, fine-grained biopackstone, light-yellow to medium-gray; pelecypods, foraminifers, crinoids, high-spired gastropods
0 ft 7 inches	Fossiliferous, calcitic mudrock and lenses of gray biowackestone-packstone; pelecypods, foraminifers, crinoids, high-spired gastropods
0 ft 11 inches	Thin-bedded limestone, biopackstone, light-gray, middle bedding plane with pelecypod casts; foraminifers, crinoids, high-spired gastropods
0 ft 10 inches	Basal 6 inches laminated yellow and black shale overlain by 4 inches black shale, all fossiliferous; pelecypods
1 ft 2 inches	Bed of limestone, shaly at the base, biopackstone, light- to medium-gray; pelecypods, crinoids, small planispiral gastropods, Myalina, Derbyia

MATFIELD SHALE

Blue Springs Shale Member

3 ft 1 inch	Fossiliferous, yellow mudrock; pelecypods
0 ft 9 inches	Probable Bruno limestone bed equivalent: yellow-gray mudrock, red streaks, horizontal calcite veins, unfossiliferous (paleosol)
1 ft 8 inches	Unfossiliferous, green mudrock

Kinney Limestone Member

1 ft 4 inches–1 ft 10 inches	Bed of platy to massive-bedded limestone, coarsens upward from biowackestone-packstone to biopackstone, light-yellow; top 1–3 inches intraclastic biopackstone, yellow shale matrix and green shale in vugs, birds eyes, and sheet cracks. The unit has a scalloped, erosional top, and contains foraminifers, crinoids, pelecypod fragments
0 ft 8 inches	Light-yellow, calcitic mudrock, fossiliferous in lower few inches (crinoids)
3 ft 4 inches	Thick-bedded limestone, fines upward from biograinstone to biopackstone, current-layered, surface dissolution vugs (horizontal), abundant horizontal burrows 1 ft 8 inches below the top, light-yellow; foraminifers, crinoids, foram-coated grains, bivalve fragments
1 ft 11 inches	Unfossiliferous, yellow-green shale and mudrock, red streaks in top 1 ft, calcite nodules in middle (paleocaliche)
0 ft 9 inches	Fossiliferous, yellow-green mudrock, red at the base; pelecypod fragments, crinoids
1 ft 4 inches	Fossiliferous, yellow-green mudrock, lenses of shaly biowackestone-packstone; oncolites, crinoids, brachiopod fragments, foraminifers, ramose bryozoans, pelecypod fragments
3 ft 0 inches	Medium-bedded, shaly limestone, biowackestone-packstone, bioturbated, splotchy yellow-gray; Derbyia, Allorisma, oncolites, crinoids, foraminifers, Myalina

Measured Section Number: 35

Location: Roadcuts on Stony Creek Road in secs. 22 and 23, T. 28 S., R. 7 E., with a supplemental section for the upper Kinney in the roadcut in the NW sec. 25, T. 28 S., R. 7 E., Butler County, Kansas

FLORENCE FORMATION

Cole Creek Member

0 ft 4 inches	Poorly exposed limestone, biowackestone-packstone, orange-yellow; pelecypod fragments

MATFIELD SHALE

Blue Springs Shale Member

5 ft 0 inches	Concealed

Kinney Limestone Member

2 ft 3 inches	Bed of limestone, biopackstone-grainstone, current-layered, surface-dissolution vugs (horizontal), light-yellow-gray; foraminifers, gastropods
2 ft 6 inches	Fossiliferous, yellow-green shale, some red shale streaks and calcite concretions; pelecypod fragments, crinoids, bryozoans
0 ft 11 inches	Fossiliferous, yellow-green shale; brachiopod fragments, Myalina
0 ft 6 inches	Bed of shaly limestone, mudstone-biowackestone, splotchy yellow and medium-gray; Derbyia
5 ft 1 inches	Fossiliferous yellow-gray mudrocks and thin lenses of gray, shaly lime mudstone; Derbyia, Allorisma, crinoids
2 ft 8 inches	Medium-bedded, shaly limestone, mudstone-biowackestone, bioturbated, splotchy yellow and medium-gray; Derbyia, Composita, Allorisma, high-spired gastropods, echinoid spines, fenestrate bryozoans, foraminifers, foram-coated grains

Wymore Shale Member

2 ft 0 inches	Unfossiliferous, yellow-green mudrock, some calcite nodules (paleocaliche)
1 ft 9 inches	Unfossiliferous, red mudrock, calcite nodules (paleocaliche)
0 ft 8 inches	Unfossiliferous, green shale, calcite nodules (paleocaliche)
6 ft 0 inches	Unfossiliferous, red mudrock and shale, scattered lenses of green shale
3 ft 0 inches	Unfossiliferous, green mudrock with calcite nodules (paleocaliche)

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 6 inches	Thick-bedded limestone, coarsens upward from biopackstone in basal 3 inches, to biograinstone; foraminifers, crinoids, bryozoans, bivalve fragments
7 ft 6 inches	Poorly exposed section: some ledges in the gully on the west side of the road of cherty biowackestone-packstone; spicules, bryozoans, crinoids
2 ft 6 inches	Thin- to medium-bedded limestone, fines upward from biowackestone-packstone to biowackestone, yellow, chert nodules; crinoids, bryozoans, spicules

Havensville Shale Member

3 ft 4 inches	Unfossiliferous, yellow-green mudrock; a 2-inches-thick layer of gray, oncolite

	biopackstone-wackestone in the middle (brachiopod fragments, crinoids)

Threemile Limestone Member

1 ft 4 inches	Bed of limestone, fines upward from oncolite biopackstone-grainstone to finer-grained oncolite packstone, shaly, minor grainstone, yellow; brachiopod and pelecypod fragments, crinoids, high-spired gastropods, bryozoans
2 ft 0 inches	Medium-bedded limestone, biowackestone, yellow-gray, abundant chert "eggs"; crinoids, ramose bryozoans, spicules, brachiopod fragments
1 ft 6 inches	Thin-bedded limestone, biowackestone-packstone, very light tan, prominent stylolite near the base; ramose and fenestrate bryozoans, crinoids, brachiopod fragments
1 ft 8 inches	Thin-bedded limestone, mudstone-biowackestone, light-gray; fenestrate bryozoans, crinoids, spicules
0 ft 6 inches	Layer of light-gray, laminated, fossiliferous chert with fenestrate bryozoans, crinoids, spicules
1 ft 10 inches	Bed of limestone, biowackestone-packstone, very light tan, chert nodules; spicules, ramose and fenestrate bryozoans, crinoids, brachiopod fragments
1 ft 5 inches	Medium-bedded limestone, biowackestone-packstone, yellow, large semi-coalesced chert nodules in lower part, chert layer in upper half; spicules, ramose bryozoans, brachiopod fragments, crinoids
1 ft 8 inches	Thin-bedded, laminated limestone, biowackestone-packstone, yellow, anastomosing chert nodules; ramose bryozoans, spicules, some brachiopod fragments and crinoids

SPEISER FORMATION

1 ft 4 inches	Thin-bedded, shaly limestone, bioturbated, yellow-gray (recessive); Composita, pelecypod fragments, ramose bryozoans
2 ft 2 inches	Fossiliferous, yellow-gray mudrock, lenses of shaly biowackestone; pelecypod fragments, crinoids, Composita
5 ft 6 inches	Green to dark-gray, fossiliferous mudrock and shale and lenses of shaly, gray mudstone-biowackestone; Derbyia, crinoids, echinoid spines

Measured Section Number: 36

Location: Roadcut on Stony Creek Road, east side, in NW sec. 11, T. 28 S., R. 7 E., Butler County, Kansas

MATFIELD SHALE

Blue Springs Shale Member

0 ft 2 inches	Unfossiliferous, green shale

Kinney Limestone Member

0 ft 10 inches	Knobby-weathering limestone, biopackstone, yellow-tan; crinoids, pelecypod fragments
0 ft 4 inches	Unfossiliferous, light-tan shale
1 ft 6 inches	Bed of limestone, biopackstone-grainstone that fines upward in top 2 inches to biowackestone, root casts in upper 5 inches, gray, prominent stylolite at base; foraminifers, pelecypod fragments, crinoids
3 ft 2 inches	Bed of limestone, oncolite biopackstone-grainstone, grain size coarsens upward, current-layered, surface-dissolution vugs (horizontal), yellow; foraminifers, crinoids, bivalve fragments
2 ft 0 inches	Medium-bedded limestone, biopackstone, orange; foraminifers, bivalve fragments, crinoids
0 ft 2 inches	Unfossiliferous, yellow shale
9 ft 0 inches	Concealed
1 ft 0 inches	Bed of slightly shaly limestone, biopackstone, relatively coarse-grained, bioturbated, yellow-gray; Composita, Derbyia, crinoids, foraminifers, foram-coated grains, ramose bryozoans, planispiral and high-spired gastropods
0 ft 8 inches	Bed of limestone, fines upward from coarse brachiopod shell hash to biopackstone, yellow; Composita, Derbyia, Juresania
1 ft 0 inches	Bed of limestone, biopackstone-grainstone, bioturbated, light-gray; brachiopod and pelecypod fragments, foraminifers, high-spired and planispiral gastropods, crinoids, echinoid spines, ramose bryozoans

Wymore Shale Member

0 ft 2 inches	Unfossiliferous, yellow shale

Measured Section Number: 37

Location: Composite of three roadcuts on K–96 west of Beaumont, in secs. 30 and 31, T. 27 S., R. 8 E., Butler County, Kansas

FLORENCE FORMATION

1 ft 3 inches	Medium-bedded limestone, biowackestone, light-gray, scattered chert nodules in lower part; crinoids, bivalve fragments, ramose bryozoans, some oncolites
3 ft 0 inches	Bed of limestone, fine-grained biopackstone, very light gray, scattered "cannonball" chert nodules; crinoids, fenestrate and ramose bryozoans, Reticulatia
3 ft 3 inches	Medium- to thick-bedded limestone, porous biowackestone-packstone, very light gray, layers of chert nodules, prominent stylolite at base; fenestrate and ramose bryozoans, fusulinids, crinoids
2 ft 1 inches	Medium-bedded limestone, porous biopackstone, very light gray, scattered chert nodules and a 2-inches-thick layer at 1.5 ft above the base; fenestrate and ramose bryozoans, crinoids, spicules, Reticulatia
1 ft 3 inches	Bed of limestone, porous biowackestone, very light gray, chert nodules and a layer of chert at the top; crinoids, spicules, fenestrate and ramose bryozoans
2 ft 8 inches	Two beds of limestone of equal thickness, fine-grained biowackestone-packstone, bioturbated, porous, light-gray, chert nodules and layers of chert at the top; crinoids, fenestrate bryozoans; fusulinids at the base
0 ft 8 inches	Bed of limestone, fine-grained biopackstone, porous, very light gray, chert nodules, prominent stylolites at the top; fenestrate and ramose bryozoans, crinoids, fusulinids
3 ft 8 inches	Medium-bedded limestone, fine-grained biopackstone, bioturbated, very light gray, scattered chert nodules; ramose and fenestrate bryozoans, crinoids
1 ft 8 inches	Bed of limestone, fine-grained biopackstone, very light gray, layers of chert nodules; fusulinids, ramose bryozoans, crinoids; Reticulatia at top
1 ft 4 inches	Bed of limestone, fine-grained biopackstone-grainstone, very light gray; bryozoans, crinoids; fusulinids at the top
2 ft 7 inches	Medium-bedded limestone, coarsens upward from mudstone-biowackestone to fine-grained biopackstone, bioturbated, very light gray; bryozoans, crinoids, Derbyia, Reticulatia; rugose corals at the top

Cole Creek Member

1 ft 8 inches	Basal 1 ft shaly biowackestone, overlain by 8 inches calcitic shale to shaly lime mudstone, with some chert nodules at the very top; tan-gray; crinoids, fenestrate bryozoans, Reticulatia
0 ft 10 inches	Bed of limestone, fines upward from biowackestone to oncolitic mudstone, bioturbated, yellow; crinoids, ramose bryozoans, brachiopod fragments, Myalina, planispiral and high-spired gastropods at the base; bivalve fragments and oncolites at the top
0 ft 9 inches	Basal 4.5-inches layer of regularly graded limestone, biograinstone to wackestone, overlain by 4.5 inches yellow, calcitic shale; pelecypod and brachiopod fragments, crinoids, planispiral and high-spired gastropods
0 ft 10 inches	Unfossiliferous, olive-green shale, laminated in basal 6inches
1 ft 0 inches	Bed of limestone, biopackstone with lenses of biograinstone, white; high-spired gastropods, foraminifers, pelecypod fragments
0 ft 5 inches	Basal 4 inches biopackstone with lenses of biograinstone, white, overlain by 1 inch tan-brown shale; high-spired gastropods, foraminifers, pelecypod fragments
0 ft 6 inches	Tan-brown shale, unfossiliferous, with laminae of biograinstone, white; foraminifers, high-spired gastropods, pelecypod fragments
1 ft 5 inches	Bed of limestone, biowackestone, orange-gray; pelecypod and brachiopod fragments, high-spired gastropods

Measured Section Number: 38

Location: Roadcut on 82nd St, center of the NE se. 13, T. 27 S., R. 7 E., Butler County, Kansas

MATFIELD SHALE

Blue Springs Shale Member

4 ft 0 inches	Unfossiliferous, red mudrock, with a 6–10-inches layer of green shale at the base infilling dolines

Kinney Limestone Member

0–1 ft 3 inches	Medium-bedded limestone, fines up from biograinstone to packstone, light-gray, with red and green shale in interparticle pores and vugs; top is a marked unconformity with 1 ft 3 inches of relief, defining a series of shallow dolines. Rocks contain foraminifers, bivalve fragments, crinoids
4 ft 6 inches	Thick- up to medium-bedded limestone: basal 3 ft 7 inches bed coarsens upward from biograinstone to coarse-grained biograinstone, current-layered, surface-dissolution vugs (horizontal), very light gray; a hard ground a few inches below the top. Upper 11 inches is a bed of similarly coarse-grained biograinstone, very light gray, with red and some green shale in interparticle pores. Rocks contain foraminifers, crinoids, bivalve fragments

4 ft 6 inches	Fossiliferous, green, calcitic mudrock and layers/lenses of shaly lime mudstone-biowackestone, splotchy yellow and medium-gray, bioturbated; white calcite nodules in upper 2-ft shale bed (paleocaliche). Shale contains pectinids; limestone with pectinids, Derbyia, Juresania, fenestrate and ramose bryozoans

Measured Section Number: 39

Location: Roadcuts along US–54 at Lookout Point, and field to immediate south, in the N/2 sec. 9, SE sec. 5, and NE sec. 8, T. 26 S., R. 8 E., Butler County, Kansas

Comment: The Blue Springs section is relatively poorly exposed along the north side of the road in secs. 5 and 8, but a little digging readily exposes it

FLORENCE FORMATION

3 ft 0 inches	Chert rubble

Cole Creek Member

1 ft 1 inches	Bed of limestone, biopackstone, light-gray to red; pelecypod fragments

MATFIELD SHALE

Blue Springs Shale Member

2 ft 0 inches	Fossiliferous, calcitic yellow mudrock; pelecypod fragments
5 ft 4 inches	Unfossiliferous, yellow shale and mudrock
3 ft 0 inches	Unfossiliferous, red shale and mudrock, with a prominent 6–8-inches-thick, beige paleocaliche at the top (Bruno equivalent)

Kinney Limestone Member

2 ft 6 inches	Thin-bedded, shaly limestone, mudstone, light-gray (poorly exposed)
4 ft 0 inches	Medium-bedded limestone, biograinstone, very light gray; foraminifers, bryozoans, crinoids, brachiopod fragments
8 ft 0 inches	Interbedded shaly limestone, mudstone to biowackestone, blue-gray, and fossiliferous gray shales; black shale occurs in the basal 1 ft of section; thin-bedded grading up to medium-bedded. Rocks contain Derbyia, Reticulatia, Composita, pelecypod fragments, Allorisma
2 ft 8 inches	Medium-bedded, shaly limestone, coarsens upward from biowackestone to biowackestone-packstone, yellow-gray; Derbyia, crinoids, bryozoans, high-spired gastropods, foram-coated grains

Wymore Shale Member

8 ft 0 inches	Unfossiliferous mudrock and shale, green in lower half, yellow in upper half
4 ft 0 inches	Unfossiliferous, red mudrock and shale, abundant laminae of palisades calcite
5 ft 10 inches	Unfossiliferous, green mudrock and shale, abundant laminae of palisades calcite
1 ft 8 inches (maximum thickness)	Unfossiliferous, yellow-green mudrock with beige calcite nodules (paleocaliche)

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 2 inches–3 ft 4 inches	Bed of limestone, oncolite biowackestone--packstone at base grading up to biowackestone in middle, light-gray, capped by beige paleocaliche
1 ft 2 inches	Unfossiliferous light-gray shale, secondary red/green discoloration
5 ft 6 inches	Thick- to thin-bedded (upsection) limestone, biopackstone, yellow, with discontinuous layers of chert ~3 inches thick separating limestone beds 6–8 inches thick in lower two-thirds, scattered chert nodules above that; prominent bed with Composita about 3 ft above base; crinoids, ramose and fenestrate bryozoans throughout

Havensville Shale Member

3 ft 0 inches	Very sparsely fossiliferous, yellow-brown-green shale to mudrock
0 ft 9 inches	Bed of limestone, mudstone-sparse biowackestone, light-gray; crinoids, Derbyia
4 ft 0 inches	Sparsely fossiliferous, bioturbated, fissile, brown-gray shale; Composita, bryozoans

Threemile Limestone Member

1 ft 2 inches	Bed of limestone, biopackstone-grainstone, vertical burrows, light-gray; foraminifers, crinoids, oncolites, brachiopod fragments
1 ft 5 inches	Unfossiliferous mudrock to shaly lime mudstone, bioturbated, yellow-green
2 ft 7 inches	Bed of limestone, coarsens upward from oncolite biopackstone to grainstone, minor erosional base, passes laterally (westward) along the outcrop to a somewhat thinner section of biowackestone-packstone, light-yellow; foraminifers, bryozoans, crinoids, brachiopod fragments
1 ft 7 inches	Thin-bedded to fissile, calcitic shale and lenses of shaly mudstone-biowackestone, yellow, scattered chert nodules; bryozoans, crinoids, brachiopod fragments
4 ft 4 inches	Medium-bedded limestone, biowackestone-packstone, light-yellow: layers of chert nodules in top 2 ft 8 inches, underlain by a 2–3-inches-thick layer of laminated chert (with an uneven top), underlain by 1 ft 5 inches of slightly thinner-bedded limestones with 2-inches-thick layers of laminated chert at the base and 4

	inches above the base. Rocks contain fenestrate and ramose bryozoans, brachiopod fragments, spicules; rare high-spired gastropods near the base
3 ft 4 inches	Medium-bedded limestone, mudstone-biowackestone, light-yellow: layer of chert nodules 3 inches below the top, remainder of unit contains irregularly disposed chert nodules that are angular and which appear brecciated. Rocks contain ramose bryozoans, crinoids, spicules
1 ft 6 inches	Bed of limestone, sparse biowackestone, yellow, small chert nodules and a 3-inches-thick layer of chert 5 inches below the top; ramose bryozoans, crinoids, spicules

SPEISER FORMATION

8 ft 0 inches	Thin-bedded, calcitic and fossiliferous mudrocks and thin shaly biowackestones, bioturbated, gray to yellow-gray; Derbyia, Reticulatia, crinoids, pelecypod fragments

Measured Section Number: 40

Location: Quarry on Crowdis Farm, sec. 15, T. 29 S., R. 3 E., Butler County, Kansas

NOLANS LIMESTONE

Herington Member
(probable top of the member)

2 ft 0 inches	Thin-bedded limestone, shaly mudstone, porous, calcite geodes, yellow-gray
2 ft 0 inches	Medium-bedded, shaly calcitic dolomudstone, laminated, calcite geodes, gray
0 ft 9 inches	Bed of shaly limestone, mudstone, laminated, gray
2 ft 6 inches	Medium-bedded, shaly dolomudstone, laminated, yellow-gray
1 ft 6 inches	Bed of shaly dolomudstone, faintly laminated, calcite geodes, yellow-gray

Paddock Shale Member

2 ft 5 inches	Unfossiliferous, gray-yellow mudrock with lenses of shaly lime mudstone and calcite geodes

Note: in a roadcut in nearby sec. 10 (at the entrance to the drive that heads south to the Crowdis Farm), there is a section of lower Herington and upper Paddock that exposes 4 ft 2 inches of Paddock shales.

Measured Section Number: 41

Location: Quarry along Walnut River due west of Douglass (immediately east of Adams Road), and adjoining roadcuts at intersection of Adams Road and 210th St, in SW sec. 18 and N/2 sec. 19, T. 29 S., R. 4 E., Butler County, Kansas
ODELL SHALE (roadcuts)

3 ft 0 inches	Unfossiliferous, red shale with abundant quartz geodes (silicified evaporites)
3 ft 0 inches	Unfossiliferous, light-gray shales, with abundant calcite and quartz geodes and laminae of palisades calcite (replaced evaporites)
5 ft 0 inches	Unfossiliferous, green shale with abundant layers of palisades calcite and some quartz geodes (replaced evaporites)

WINFIELD LIMESTONE (in quarry)

Luta Member

7 ft 8 inches	Medium-bedded, shaly mudstone to sparse biowackestone, bioturbated, grades upward to very thin bedded, shaly lime mudstone to very calcitic shale, unfossiliferous; both light-gray. Fossils in the lower half of section only include crinoids, Composita, ramose bryozoans, some Orbiculoides

Cresswell Limestone Member

2 ft 10 inches	Thick-bedded limestone, fines upward from oncolite biograinstone (slightly finer grained than below) with prominent vertical burrows, porous, to oncolite biopackstone-wackestone, yellow; ramose bryozoans, crinoids, foraminifers, brachiopod fragments
1 ft 2 inches	Bed of limestone, oncolite biograinstone, prominent vertical burrows, weathers recessively, yellow; ramose bryozoans, crinoids, foraminifers, brachiopod fragments
3 ft 4 inches	Bed of limestone, coarse-grained biopackstone, yellow, appears to have an erosional base (but it could be a joint); crinoids, ramose bryozoans, brachiopod fragments
0 ft 7 inches	Bed of limestone, fine-grained biopackstone-wackestone, porous, bioturbated, yellow; crinoids, ramose bryozoans, brachiopod fragments

Measured Section Number: 42

Location: Steep roadcut, south side of 210th St east of Douglass, in the NW sec. 23, . 29 S., R. 4 E., Butler County, Kansas

WINFIELD LIMESTONE

Cresswell Limestone Member

~3 ft 0 inches Too high to reach: massive Cresswell limestone

Grant Shale Member

~4 ft 0 inches Too high to reach: shales and limestones

DOYLE SHALE

Gage Shale Member

0 ft 8 inches Yellow-green grading rapidly up to dark-green mudrock, unfossiliferous, compact (upper part is a paleosol)

14 ft 4 inches Unfossiliferous, fissile, jointed shale, light-gray to slightly yellow-gray, forms a vertical face on the outcrop

3 ft 0 inches Unfossiliferous shale, brownish-green except in the top 8 inches, where it is dark-gray-green, and a zone 8–16 inches below the top, which is red

14 ft 0 inches Unfossiliferous red shale and mudrock, silty in the basal 1 ft, with scattered layers throughout of green shale and mudrock as much as 1 ft thick. The green shales/mudrocks locally are rooted; gypsum veinlets occur sporadically throughout the section

1 ft 2 inches Interbedded unfossiliferous, red and green shale and two thin beds of limestone, light-gray mudstone with desiccation cracks

Measured Section Number: 43

Location: Bannon (Southwest Butler) quarry, center of S/2 sec. 29, T. 28 S., R. 4 E., Butler County, Kansas

MATFIELD SHALE

Blue Springs Shale Member

3 ft 0 inches Unfossiliferous, red mudrock

4 ft 0 inches Bruno limestone bed: Thick-bedded, shaly limestone, mudstone, bioturbated, yellow-gray; crinoids and fragments of pelecypods and brachiopods

5 ft 4 inches Highly weathered, yellow-gray, calcitic mudrocks and shaly lime mudstones (beds of which occur at the top and base of this unit), bioturbated but otherwise unfossiliferous

Kinney Limestone Member

6 ft 4 inches Bed of limestone that fines upward from locally cross stratified biowackestone-packstone, to locally bioturbated mudstone, light-gray; foraminifers, crinoids, brachiopod and pelecypod fragments, gastropods. This is the "lowstand carbonate wedge" referred to in the text

3 ft 0 inches Bed of limestone, porous biopackstone-grainstone, prominent vertical burrows, yellow-gray; foraminifers, crinoids, pelecypod and brachiopod fragments, Aviculopecten, planispiral gastropods. As referred to in the text, this bed is the regionally recognized upper Kinney limestone

7 ft 6 inches Medium-bedded, shaly limestone, mudstone-biowackestone, bioturbated, dark-bluish-gray; crinoids, Derbyia, Reticulatia, pelecypod fragments, including Allorisma. As referred to in the text, this is the middle Kinney

Measured Section Number: 44

Location: Roadcuts (both sides) on 170th St. at the intersection with Hopkins Switch Road, in the SE sec. 25 and the NE sec. 36, T. 28 S., R. 4 E., Butler County, Kansas

Comment: According to topographic relationships, there is about 50–55 ft of concealed Doyle section between the top of the Fort Riley and the base of the Winfield Limestone in this area; uppermost Fort Riley strata are exposed at measured section number 45, and in a ditch along the south side of the road (170th St) approximately 0.55 ft west of the outcrops that compose measured section number 44

WINFIELD LIMESTONE

Cresswell Limestone Member

2 ft 3 inches Bed of limestone, porous oncolite biograinstone with prominent vertical burrows, light-yellow-tan; crinoids, Derbyia, ramose bryozoans

6 ft 8 inches Bed of limestone: basal 2 ft is slightly porous, bioturbated biopackstone with a hint of cross stratification, and a thin layer of shaly biowackestone at the base, light-yellow-tan.

The overlying 1 ft is very porous, bioturbated biopackstone, fine-grained, light-yellow-tan. The upper 3 ft 8 inches is porous, coarse-grained biograinstone, bioturbated, some oncolites, light-yellow-tan. Rocks contain crinoids, ramose bryozoans, foraminifers, Derbyia

Grant Shale Member

1 ft 1 inches	Fossiliferous and bioturbated, yellow, calcitic mudrock and lenses/layers of shaly biowackestone, grayish-yellow; crinoids, ramose bryozoans, Derbyia
2 ft 4 inches	Gray-yellow, calcitic and oncolitic mudrock; this is the "concretionary zone" referred to in the text; echinoid spines, Reticulatia
0 ft 10 inches	Unfossiliferous, tan shale, laminated in the basal 1.5 inches, and thicker-layered above (may be the Santa Fe Lake Member)
0 ft 8 inches	Unfossiliferous, dark mudrock, root-mottled (paleosol)
0 ft 8 inches	Unfossiliferous, tan, calcitic mudrock, root-mottled (paleosol)

Stovall Limestone Member

1 ft 8 inches	Thin-bedded, recrystallized lime mudstone, very porous, with abundant secondary calcite veins and laminae of palisades calcite, yellow

DOYLE SHALE

Gage Shale Member

4 ft 0 inches	Unfossiliferous shale, fissile, almost varve-like, olive-green. The top 1 ft consists of hard shales, the lower 3 ft contains laminae of palisades calcite

Measured Section Number: 45

Location: Roadcut on Hopkins Switch Road due north of 170th St (measured section number 44), and due south of the Little Walnut River, in the NW sec. 30, T. 28 S., R. 5 E., Butler County, Kansas

FORT RILEY FORMATION

13 ft 0 inches	Thin-bedded, shaly lime mudstone, sparsely fossiliferous, locally bioturbated, light-gray; pelecypod casts, crinoids

Measured Section Number: 46

Location: Roadcuts on Cole Creek Road, both sides, and in gully to southeast of bridge, in secs. 15 and 16, T. 28 S., R. 6 E., Butler County, Kansas

Comment: Farther south on Cole Creek Road, within a mile of this outcrop, one can see poorly exposed outcrops across the Florence–Fort Riley contact on the east side of the road, including the rugose coral biostrome near the top of the Florence

FLORENCE FORMATION
(within a few feet of the top of the member)

2 ft 0 inches	Thin-bedded, very cherty limestone, mudstone-biowackestone, yellow, chert nodules; abundant rugose corals, accessory bryozoans, crinoids. This is the coral biostrome referred to in the text
2 ft 0 inches	Medium-bedded limestone, biowackestone, yellow-gray; some rugose corals, and fenestrate bryozoans, crinoids
13 ft 0 inches	Medium-bedded limestone, biowackestone to fine-grained biopackstone, white, discontinuous layers of chert nodules separating beds of limestone that are ~1 ft thick; fenestrate and ramose bryozoans, crinoids, Reticulatia; abundant fusulinids in basal 5 ft
4 ft 3 inches	Thin- to medium-bedded limestone, porous biowackestone to fine-grained biopackstone, white, with 1-inch-thick shales at the top and base of the unit; layers of chert nodules separate limestone beds that are ~6 inches thick. Rocks contain fenestrate and ramose bryozoans, crinoids, Reticulatia
3 ft 5 inches	Thin- to medium-bedded limestone, mudstone to fine-grained biopackstone, white, layers of chert nodules separate limestone beds that are ~6 inches thick; fusulinids, crinoids, bryozoans, Reticulatia
2 ft 0 inches	Basal 5 inches of calcitic shale, yellow-gray, overlain by 1 ft 7 inches of thin-bedded limestone, biowackestone-packstone beds separated by thin shales, all bioturbated; fenestrate bryozoans, crinoids, brachiopod fragments
2 ft 0 inches	Bed of limestone, biowackestone, bioturbated, yellow-gray; discontinuous layer of chert nodules 3 inches thick about 5 inches below the top. Rocks contain fenestrate and ramose bryozoans, crinoids, spicules, small gastropods, Reticulatia

Cole Creek Member

3 ft 11 inches	Basal 1 ft 7 inches medium-bedded limestone, biowackestone, very coarse-grained and bioturbated (conspicuous horizontal burrows). Overlain by 7 inches of calcitic shale to shaly biowackestone. Top 1 ft 9 inches of thin-bedded biowackestone, shale partings; all yellow-gray. Rocks contain pelecypod fragments, gastropods, foraminifers, crinoids

1 ft 8 inches	Basal 5 inches black, fossiliferous shale, top 1 ft 3 inches gray, calcitic mudrock to shaly lime mudstone, bioturbated; brachiopod and bivalve fragments
1 ft 7 inches	Medium- to thin-bedded limestone, fines upward from biopackstone-grainstone to biowackestone, bioturbated, gray; pelecypod fragments, crinoids, foraminifers, gastropods, brachiopod fragments

MATFIELD SHALE

Blue Springs Shale Member

2 ft 0 inches	Fossiliferous, calcitic mudrock, bioturbated, yellow-gray; pelecypod fragments, Myalina
1 ft 4 inches	Bruno limestone bed: biowackestone, shaly and bioturbated, yellow-gray; pelecypod fragments
4 ft 3 inches	Unfossiliferous mudrock, yellow-green in lower half, yellow-green-gray-red in upper half

Kinney Limestone Member (in the gully)

5 ft 0 inches	Bed of limestone that coarsens upward from biopackstone to biograinstone, surface-dissolution vugs, light-gray; foraminifers, bivalve fragments

Measured Section Number: 47

Location: Creekbank and roadcut to immediate east of MacGregor House on 138th St., in the SE sec. 9, T. 28 S., R. 6 E., Butler County, Kansas

MATFIELD SHALE

Kinney Limestone Member

1 ft 6 inches	Bed of limestone, porous biopackstone-grainstone, current- layered, surface-dissolution vugs (horizontal), yellow-white; foraminifers, crinoids
4 ft 0 inches	Concealed
0 ft 8 inches	Bed of shaly limestone, biowackestone-packstone, medium-gray; Derbyia, crinoids, some oncolites, foraminifers, ramose bryozoans
1 ft 8 inches	Alternating thin beds of slightly shaly lime-stone, biowackestone-packstone, and very shaly mudstone-biowackestone, bioturbated, splotchy yellow-gray; Derbyia, foraminifers, crinoids
4 ft 0 inches	Fossiliferous, yellow-brown mudrock, with a 1-inch-thick bed of biowackestone at the base; pelecypod fragments, Derbyia, crinoids
2 ft 2 inches	Basal 1 ft 2 inches fossiliferous, green mudrock overlain by 1 ft of fossiliferous, yellow-brown shale; pelecypod fragments, Derbyia, crinoids
2 ft 8 inches	Medium-bedded, shaly limestone, coarsens upward from biowackestone in lower third, to coarse-grained, oncolite biopackstone, bioturbated, yellow-gray; Derbyia, foraminifers, crinoids, ramose bryozoans; high-spired gastropods common in upper part of the unit

Measured Section Number: 48

Location: Hickory Hollow Ranch, due west of Cole Creek Road along Hickory Creek, in the NE sec. 16, T. 28 S., R. 6 E., Butler County, Kansas

Comments: The section was measured behind the main house, and east of it, along the dirt road leading out to Cole Creek Road. This section ties in with that at nearby measured section number 46

MATFIELD SHALE

Blue Springs Shale Member

0 ft 6 inches	Bruno limestone bed: bed of limestone, biowackestone, light-gray; pelecypod fragments
2 ft 0 inches	Concealed
4 ft 0 inches	Poorly exposed: unfossiliferous, green shale and mudrock

Kinney Limestone Member

1 ft 6 inches	Thin-bedded limestone, fines upward from biopackstone to biowackestone, light-gray; top is brecciated, with green shale-filled vugs and incipient paleocaliche; pelecypod fragments, foraminifers, crinoids
3 ft 4 inches	Bed of limestone, fines upward from biograinstone-packstone, current-layered, surface-dissolution vugs (horizontal), to fine-grained biopackstone-grainstone in top 4 inches, very light gray; foraminifers, crinoids, bivalve fragments, high-spired gastropods, ramose bryozoans
1 ft 2 inches	Medium-bedded limestone, biograinstone, light-yellow-tan; foraminifers, crinoids, foram-coated grains, bivalve fragments
1 ft 0 inches	Bed of limestone, biopackstone, light-tan-gray; crinoids, bivalve fragments, ramose bryozoans, foraminifers
6–8 ft	Concealed (includes the lower Kinney and Wymore Members)

WREFORD LIMESTONE

Schroyer Limestone Member

3 ft 6 inches	Bed of limestone, coarsens upward from biopackstone to biograinstone, and then fines upward in the top 6 inches to biopackstone with abundant Derbyia, some vertical burrows, light yellow; foraminifers, crinoids
1 ft 2 inches	Unfossiliferous, yellow-brown shale
0 ft 3 inches	Chert rubble

Measured Section Number: 49

Location: Two closely spaced roadcuts on K–96, both sides (but mainly on the north side), in the NW sec. 27, T. 27 S., R. 6 E., east of Leon, Butler County, Kansas

FLORENCE FORMATION
(within a few feet of the top of the formation)

0 ft 7 inches	Bed of limestone, biowackestone, yellow, chert nodules; rugose corals, foraminifers, brachiopod fragments, crinoids. This is the coral biostrome referred to in the text
0 ft 6 inches	Basal 3 inches biowackestone, yellow, top 3 inches concealed; brachiopod fragments, ramose bryozoans, crinoids
2 ft 8 inches	Highly weathered chert rubble; in situ limestone is mudstone-biowackestone, and basal 4 inches is fossiliferous shale to shaly biowackestone, light-yellow-gray; bryozoans, crinoids, brachiopod fragments
2 ft 6 inches	Medium-bedded limestone, biopackstone-wackestone, light-gray, layers of chert nodules; bryozoans, crinoids, brachiopod fragments
2 ft 8 inches	Medium-bedded limestone, biowackestone-packstone, porous, light-gray, chert nodules; fusulinids, crinoids, ramose bryozoans
9 ft 2 inches	Bedded porous limestone, fine-grained biopackstone, light-gray, prominent stylolite about 1 ft above the base; bed thickness increases upsection from 6-inches-thick limestone beds separated by 2-inches-thick layers of chert nodules in the lower 1 ft of section, to 8–12 inches thick limestone beds separated by 2–3 inches thick layers of chert nodules above; top 6–8 inches is chert rubble. Rocks contain foraminifers, crinoids, brachiopod fragments, including Reticulatia, ramose and fenestrate bryozoans
3 ft 11 inches	Medium-bedded limestone, fine-grained biopackstone, with 2-inches-thick layers of calcitic shale (fenestrate bryozoan-rich) at top and base, light-gray; section consists of 6-inches-thick limestone beds separated by 2–3 inches thick layers of chert nodules. Rocks contain crinoids, fenestrate bryozoans, brachiopod fragments, including Reticulatia, crinoids
1 ft 5 inches	Thin-bedded limestone, fine-grained biopackstone, light-gray, layers of chert nodules in middle and at top, 3-inches-thick layer of chert at base; fusulinids, crinoids, bryozoans
2 ft 2 inches	Medium-bedded limestone, porous, fine-grained biopackstone, light-gray, chert nodules at base, 3-inches-thick chert band in middle; fusulinids, crinoids, foraminifers
1 ft 2 inches	Bed of limestone, fine-grained biopackstone, white-yellow, chert nodules; crinoids, brachiopod fragments, foraminifers, spicules
1 ft 1 inches	Calcitic mudrock to shaly lime mudstone-biowackestone, yellow, scattered chert nodules; crinoids, brachiopod fragments, foraminifers, spicules
0 ft 8 inches	Bed of limestone, biowackestone, light-gray, chert nodules; pelecypod fragments, brachiopod fragments, some oncolites, crinoids, bryozoans

Cole Creek Member

2 ft 7 inches	Basal 7 inches is bed of limestone, biowackestone, with abundant pelecypod casts. Overlain by a thin layer of yellow, calcitic shale, and then, 2-ft bed of limestone, biowackestone-packstone, horizontal burrows, conspicuous coarse pelecypod hash near base, yellow-gray. Rocks contain pelecypod fragments, brachiopod fragments, some oncolites, bryozoans, crinoids
1 ft 5 inches	Bed of limestone, biowackestone-packstone, conspicuous bed of coarse pelecypod hash in middle, yellow to tannish-gray; pelecypod fragments, crinoids, gastropods
1 ft 6 inches	Fossiliferous, laminated, yellow shale; pelecypod fragments
3 ft 0 inches	Fossiliferous, chocolate-grown mudrock, with a 2-inches-thick layer of biowackestone 7 inches above the base in the center of the outcrop, but which thickens to 1 ft of pink, pelecypod-rich biowackestone to packstone along the west side of the outcrop; pelecypod fragments

Note: the basal 4 ft 6 inches of this member was erroneously included within the Blue Springs in Mazzullo and Teal (1994) and Mazzullo et al. (1995)

MATFIELD SHALE

Blue Springs Shale Member

0 ft 10 inches	Fossiliferous mudrock to shaly biowackestone, yellow; pelecypod fragments
1 ft 4 inches	Unfossiliferous, brown shale
1 ft 2 inches	Unfossiliferous, brownish-yellow mudrock and lenses of shaly lime mudstone
4 ft 8 inches	Unfossiliferous, brownish-yellow shale and mudrock
1 ft 4 inches	Unfossiliferous, greenish-gray shale
1 ft 8 inches	Bruno equivalent: Paleocaliche, yellow-gray in upper part, red in lower part
6 ft 8 inches	Unfossiliferous, red mudrock; basal 1 ft is green shale with splotches of red and yellow shale

Kinney Limestone Member (south and north sides of road)

0 ft 7 inches	Bed of limestone, biowackestone, bioturbated and chalky in upper part, light-gray; pelecypod fragments, foraminifers, crinoids
1 ft 10 inches	Thin-bedded, shaly limestone, mudstone to sparse biowackestone, light-gray; pelecypod fragments, crinoids
1 ft 5 inches	Bed of limestone, fines upward from biograinstone to biopackstone, light-gray; foraminifers, some crinoids, bryozoans, pelecypod fragments

Measured Section Number: 50

Location: "Browntown" quarry, NE sec. 9, T. 28 S., R. 4 E., Butler County, Kansas

FORT RILEY FORMATION

Comment: Very close to the top of the formation; see measured section number 53 for the remainder of the uppermost part of the formation at a nearby outcrop

2 ft 6 inches	Thin- to medium-bedded, shaly limestone, mudstone-biowackestone, bioturbated (subvertical burrows), gray, with a 10-inches- thick zone at the base of fissile, light-gray shale; brachiopod and pelecypod fragments
6 ft 0 inches	Thick-bedded limestone, porous biopackstone-grainstone, cross stratified in the upper half, surface dissolution vugs, yellow; foraminifers, crinoids, brachiopod fragments
3 ft 0 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, tan-gray; crinoids, brachiopod and pelecypod fragments, some echinoid spines
16 ft 0 inches	Cliff face: thin-bedded limestone, shaly mudstone-biowackestone and interbedded calcitic mudrocks, bioturbated, light-gray; brachiopod and pelecypod fragments, crinoids
2 ft 0 inches	Thin-bedded, calcitic shale to mudrock, dark-gray; scattered brachiopod fragments, Orbiculoides. This is the "gray zone" referred to in the text
2 ft 0 inches	Thin-bedded, shaly limestone, biowackestone, gray; pelecypod fragments, crinoids, foraminifers, bryozoans
3 ft 10 inches	Bed of limestone, fines upward from oncolite biopackstone-grainstone with large oncolites in the basal 2 ft 8 inches, to finer-grained oncolite biowackestone-packstone above, light-tan; crinoids, bivalve fragments, foraminifers, bryozoans, brachiopod fragments
1 ft 10 inches	Bed of limestone, fine-grained, oncolite biowackestone-packstone (orange oncolites), tan; crinoids, bivalve and brachiopod fragments, bryozoans

FLORENCE FORMATION

4 ft 10 inches	Bed of limestone, fines upward from oncolite biowackestone-packstone in lower half, to oncolite biowackestone in upper half (orange oncolites). The basal 1 ft 6 inches is soft, chalky, and white, the remainder of the unit is light-yellow-tan; chert nodules 1 ft above the base. The top and base of the unit are defined by prominent stylolites, and there are stylolites within. Rocks contain bivalve fragments, bryozoans, crinoids
1 ft 10 inches	Medium-bedded limestone, oncolite biowackestone to fine-grained packstone, light-tan, 2-inches-thick layer of chert at the top, chert nodules throughout; bivalve fragments, bryozoans
2 ft 3 inches	Medium-bedded limestone, oncolite biowackestone, light-tan, chert nodules; bryozoans, rugose corals, crinoids. This bed is the coral biostrome referred to in the text

Measured Section Number: 51

Location: Composite of roadcut on Diamond Road and adjoining streambank exposures along Four Mile Creek, in the SW sec. 17, T. 28 S., R. 4 E.; a small quarry in the SW sec. 8 and adjoining NW sec. 17, T. 28 S., R. 4 E.; and exposures along a dirt road leading to pumpjacks in the NE sec. 17, T. 28 S., R. 4 E., Butler County, Kansas

FORT RILEY FORMATION

3 ft 0 inches	(maximum) Bed of limestone, porous, cross stratified and bioturbated biopackstone-grainstone, orange-yellow, locally with 8-inches-thick lense of porous biowackestone at the base; foraminifers
15 ft 0 inches	Thin-bedded, shaly mudstone-biowackestone, scattered lenses of biopackstone, bioturbated, gray-tan; brachiopod and pelecypod fragments, crinoids
4 ft 0 inches	Fossiliferous, calcitic shale to mudrock, dark-gray, the "gray zone" referred to in the text; brachiopod fragments, including Orbiculoides, crinoids
1 ft 5 inches	Thin-bedded limestone, shaly biowackestone, tan; crinoids, brachiopod fragments
2 ft 0 inches	Bed of limestone, oncolite biopackstone, yellow; crinoids
1 ft 4 inches	Thin-bedded limestone, oncolite biopackstone-grainstone, tan; crinoids
2 ft 8 inches	Bed of limestone, oncolite biopackstone, tan; crinoids, pelecypod fragments, bryozoans
1 ft 8 inches	Bed of limestone, oncolite biopackstone, white to tan; crinoids, pelecypod fragments

FLORENCE FORMATION

1 ft 2 inches — Thin-bedded limestone, oncolite biowackestone, tan, three closely spaced stylolites at the top; ramose bryozoans, brachiopod and pelecypod fragments, crinoids

2 ft 2 inches — Bed of limestone, oncolite biopackstone, prominent brachiopod shell hash at top, yellow-tan; crinoids, pelecypod fragments, ramose bryozoans

1 ft 10 inches — Concealed

2 ft 4 inches — Thin-bedded limestone, mudstone-biowackestone, yellow-tan and gray, chert nodules, locally with silicified rugose corals; Reticulatia, crinoids, ramose bryozoans. This bed is the coral biostrome referred to in the text

3 ft 0 inches — Medium-bedded limestone, mudstone, gray-yellow, chert nodules

Measured Section Number: 52

Location: Quarries behind Lytle House, NW sec. 35, T. 27 S., R. 4 E., Butler County, Kansas

FORT RILEY FORMATION

13 ft 0 inches — Thin-bedded, shaly limestone, mudstone-biowackestone, bioturbated, tan to light-gray; brachiopod fragments, including Composita, crinoids

5 ft 7 inches — Bed of limestone, fines upward from oncolite biopackstone in basal 1 ft, to finer-grained oncolite biowackestone-packstone above, yellow-tan; crinoids, bryozoans, foraminifers, bivalve fragments

2 ft 4 inches — Upper part of a single bed of limestone, fine-grained oncolite biowackestone-packstone, light-tan, prominent stylolite at the top; crinoids, brachiopod fragments

FLORENCE FORMATION

3 ft 0 inches — Lower part of a single bed of limestone, mudstone-biowackestone, scattered oncolites, light-tan, prominent stylolite at top, and two stylolites below; crinoids, brachiopod fragments

0 ft 11 inches — Thin-bedded, oncolite biowackestone-packstone, light-tan; bryozoans, crinoids, brachiopod fragments

Measured Section Number: 53

Location: Roadcut on US–77 and adjoining small north-south road to the immediate east, immediately south of the bridge over the Walnut River, in the SW NE sec. 34, T. 27 S., R. 4 E., Butler County, Kansas

Comment: The Florence–Fort Riley contact likely is present on the southern bank of the Walnut River to the immediate northeast of this outcrop, but was not exposed at the time this section was measured

FORT RILEY FORMATION (upper part)

3 ft 0 inches — Thin-bedded limestone, mudstone-biowackestone, prominent vertical and sub-vertical burrows at the top, light-grayish-tan; crinoids, brachiopod fragments

1 ft 8 inches — Thin-bedded, shaly limestone, mudstone-biowackestone, tannish-yellow; crinoids, brachiopod fragments

5 ft 4 inches — Thick-bedded limestone, biopackstone-grainstone, porous, bioturbated, some cross stratification, yellow; foraminifers

1 ft 1 inches — Medium-bedded limestone, biowackestone-packstone, bioturbated, yellow; foraminifers

1 ft 6 inches — Thin-bedded, shaly limestone, mudstone-biowackestone, bioturbated, tannish-gray; brachiopod fragments, crinoids

Measured Section Number: 54

Location: Roadcut, both sides of US–54 west of Augusta, in NW sec. 29, T. 27 S., R. 4 E., Butler County, Kansas

WINFIELD LIMESTONE

Cresswell Limestone Member

2 ft 8 inches — Bed of limestone, porous oncolite biograinstone-packstone, prominent vertical burrows, yellow; crinoids, ramose bryozoans, Derbyia

4 ft 8 inches — Thick-bedded limestone, relatively coarse-grained, porous biowackestone-packstone, locally vertically bioturbated, and cross stratified in the upper half, light-yellow; crinoids, ramose bryozoans, brachiopod fragments

Grant Shale Member

0 ft 10 inches — Thin-bedded, shaly limestone, biowackestone, yellow-gray, with calcite geodes; crinoids, ramose bryozoans, brachiopod fragments

1 ft 2 inches — Thin-bedded, shaly limestone, fines upward

	from biowackestone to mudstone, some calcite geodes, yellow; crinoids, brachiopod fragments, high-spired gastropods, ramose bryozoans
4 ft 0 inches	Fossiliferous, calcitic mudrock and lenses of shaly biowackestone, yellow-gray; crinoids, brachiopod fragments, high-spired gastropods, rare oncolites

DOYLE SHALE

Gage Shale Member

12 ft 8 inches	Unfossiliferous shale and mudrock, yellow-green; a 3–8-inches-thick bed of shaly, fossiliferous biowackestone occurs approximately 7 ft below the top of the section, and contains pelecypod fragments

Measured Section Number: 55

Location: Roadcuts on Santa Fe Lake Road (both sides) and streambank exposures along Dry Creek to the immediate east of the road, in the NW sec. 18, T. 27 S., R. 4 E. and the NE sec. 13, T. 27 S., R. 3 E., Butler County, Kansas (east of Santa Fe Lake)

WINFIELD LIMESTONE

Luta Member
(probable top of the member)

3 ft 2 inches	Medium- and thin-bedded, shaly limestone: basal 4 inches is biowackestone-packstone, the overlying section is mudstone, very thin bedded in top 10 inches, light-gray with mottles of medium-gray; Composita, echinoid fragments, crinoids
1 ft 0 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, light-yellow-gray; Composita, crinoids

Cresswell Limestone Member

9 ft 1 inch	Very thick bedded limestone: basal 2 ft 4 inches is porous, light-yellow biowackestone. Overlain by 2 ft 8 inches of bioturbated biowackestone-packstone, porous in lower 1 ft 1 inch, which in turn is ; overlain by 4 ft 1inch of porous, light-yellow, oncolite biopackstone, that grades upward to sparsely oncolitic biowackestone in the top 8 inches, prominent vertical burrows in lower half. Rocks contain foraminifers, crinoids, ramose bryozoans, Derbyia
0 ft 8 inches	Bed of shaly limestone, biowackestone, light-yellow; crinoids, bryozoans, brachiopod fragments

Grant Shale Member

1 ft 1 inch	Thin-bedded, shaly limestone, mudstone, with lenses of biowackestone, bioturbated, light-grayish-yellow; brachiopod fragments, bryozoans, crinoids
3 ft 2 inches	Mudrock: dark-gray-green in the lower 8 inches, unfossiliferous; light-yellow-gray and fossiliferous (in the middle part) in the upper 2 ft 8 inches (pelecypod and brachiopod fragments, crinoids)

Santa Fe Lake Member

3 ft 5 inches	Laminated to thin-bedded, shaly lime mudstone, unfossiliferous, somewhat gradational top and sharp base, calcite-lined vugs, light-yellowish-gray

DOYLE SHALE

Gage Shale Member

9 ft 0 inches	Unfossiliferous shale and mudrock, light-greenish-yellow in the lower half, greenish-yellow-brown in the upper half
1 ft 2 inches	Thin-bedded, very porous, recrystallized limestone, secondary calcite veins
5 ft 0 inches	Interbedded green and red mudrocks, unfossiliferous

Measured Section Number: 56

Location: Roadcut along US–54 and gorge to the immediate west of the Santa Fe Railroad tracks, both on the south side of the road, in sec. 25, T. 27 S., R. 3 E., Butler County, Kansas (east of Andover)

WELLINGTON FORMATION

"Pearl Shale"

2 ft 8 inches	Unfossiliferous, red mudrock with "cauliflower" chert nodules (replaced evaporites)
0 ft 10 inches	Unfossiliferous, yellow-brown mudrock
0 ft 8 inches	Thin-bedded, shaly dolomudstone with abundant laminae of palisades calcite
1 ft 8 inches	Unfossiliferous, light-brown mudrock

NOLANS LIMESTONE

Herington Member

1 ft 9 inches	Thin, shaly dolomudstone beds at the top and base of this unit, separated by unfossiliferous, yellow-brown shale (gradational Herington–Wellington contact)

2 ft 0 inches	Thin-bedded, calcitic and shaly dolomudstone, some shale partings, calcite geodes, yellow-brown
1 ft 0 inches	Basal 3 inches of yellow-brown dolomudstone, porous, with small calcite geodes; overlying 9 inches unfossiliferous, yellow shale

Measured Section Number: 57

Location: Roadcut along both sides of US–54, west of Augusta, along the center lines of secs. 21 and 28, T. 27 S., R. 4 E., Butler County, Kansas

FORT RILEY FORMATION

2 ft 10 inches	Thick-bedded limestone, porous biograinstone, hint of cross stratification, bioturbated, surface-dissolution vugs, yellow; foraminifers, crinoids, brachiopod fragments
12 ft 0 inches	Thin-bedded, shaly lime mudstone-biowackestone, scattered lenses of biopackstone, and calcitic shales, bioturbated, tan-gray; brachiopod fragments, including Derbyia, crinoids, some foraminifers
3 ft 4 inches	Thin-bedded, shaly limestone, mudstone with wavy layers of calcitic shale, bioturbated, some lenses of biowackestone, light-gray; crinoids, brachiopod fragments
3 ft 4 inches	Medium-bedded limestone, upward decrease in bed thickness: shaly mudstone, some lenses of biowackestone, bioturbated, light-gray to light-tan; crinoids, brachiopod fragments
1 ft 4 inches	Thin-bedded, shaly limestone, mudstone, bioturbated, light-gray; crinoids, brachiopod fragments
1 ft 8 inches	Calcitic mudrock to shaly lime mudstone, bioturbated, dark-gray; brachiopod fragments, including Orbiculoides, crinoids. This is the "gray zone" referred to in the text
2 ft 8 inches	Thin-bedded limestone, biowackestone-packstone, bioturbated, light-tan; crinoids, brachiopod fragments, foraminifers
7 ft 8 inches	Thick-bedded limestone, fines upward from oncolite biopackstone-grainstone to oncolite biowackestone-packstone, surface-dissolution vugs, tan to white; bryozoans, crinoids, brachiopod fragments, some foraminifers

FLORENCE FORMATION

2 ft 8 inches	Bed of limestone, oncolite biowackestone-packstone, yellow-tan, prominent stylolites at the top; what appear to be intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain bryozoans, crinoids, brachiopod fragments, foraminifers
1 ft 6 inches	Bed of limestone, oncolite biowackestone, soft and chalky, light-tan; what appear to be intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain bryozoans, crinoids
1 ft 5 inches–1 ft 8 inches	Bed of limestone with uneven top (erosional surface?): oncolite biowackestone-packstone, yellow-tan, scattered chert nodules; crinoids, foraminifers, bryozoans, brachiopod fragments
1 ft 10 inches	Thin-bedded limestone, biowackestone, yellow-tan; crinoids, bryozoans, brachiopod fragments, foraminifers

Measured Section Number: 58

Location: Roadcut, west side, in the SE sec. 17, T. 27 S., R. 4 E., Butler County, Kansas

DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

3 ft 8 inches	Thin-bedded, shaly lime mudstone, cryptalgal-laminated, calcite geodes, rootcasts at top, yellow-gray
3 ft 8 inches	Thin- to medium-bedded (upsection), shaly lime mudstone, faintly cryptalgal-laminated, lower 8 inches porous, yellow-gray
1 ft 10 inches	Thin-bedded, shaly lime mudstone, yellow-gray
1 ft 2 inches	Bed of limestone, oolite packstone-grainstone, lenses of biopackstone with conspicuous white, macerated skeletal fragments (pelecypods) at the top
1 ft 8 inches	Medium-bedded, coarse-recrystallized limestone, with lenses of breccia (clasts of recrystallized limestone),orange-yellow; some foraminifers

Measured Section Number: 59

Location: Fields immediately west and east of Buffalo Road, center of sec. 8, T. 27 S., R. 4 E., Butler County, Kansas

Comments: 1—The outcrops in the field to the west of the road abut against the Myers quarry, measured section number 60. 2—There is a well-exposed thrust fault in the upper Doyle along the base of the cliff in the fields on the west side of the road

WINFIELD LIMESTONE

Santa Fe Lake Member

2 ft 0 inches	Thin-bedded, shaly limestone, mudstone: basal 4 inches of interlaminated mudstone and fine-grained foraminiferal calcisilitites; middle part of the section has ripple forms on bedding planes, light-gray

DOYLE SHALE

Gage Shale Member

8 ft 0 inches — Unfossiliferous, fissile, light-yellow-gray shale
1 ft 8 inches — Unfossiliferous, medium-bedded, yellow-gray mudrock (paleosol?)
4 ft 8 inches — Unfossiliferous mudrock: along the length of the outcrop the basal 2 ft appears medium-bedded, and yellowish-gray (paleosol?). This section is overlain by, and passes laterally into, slightly greenish-gray mudrock
13 ft 0 inches — Unfossiliferous, red mudrock and shale, the top 5 ft with~4-inches-thick layers of light-reddish-gray, silty mudrock with abundant laminae of palisades calcite interbedded with red shale locally with desiccation cracks. The top of this unit is distorted by soft-sediment deformation and clastic dikes. There is an 8-inches-thick layer of green mudrock 1 ft below the top

Towanda Limestone Member (east side of the road)

4 ft 0 inches — Thin-bedded, porous, coarse-recrystallized limestone, light-yellow-gray

Measured Section Number: 60

Location: Myers quarry at 21st St and Diamond Road east of Wichita, in the NE sec. 7, T. 27 S., R. 4 E., Butler County, Kansas (west of Diamond Road)

Comment: Section measured along the eastern wall of the quarry

ODELL SHALE

0 ft 2 inches — Recrystallized, white limestone
4 ft 0 inches — Thin-bedded to fissile, unfossiliferous shale with abundant marble-size anhydrite nodules, brownish-tan
3 ft 0 inches — Fissile, unfossiliferous shale, abundant marble-size anhydrite nodules, brownish-gray

WINFIELD LIMESTONE

Luta Member

6 ft 6 inches — Thin-bedded, shaly lime mudstone and calcitic mudrocks, abundant calcite geodes and marble-size anhydrite nodules, brownish-gray
2 ft 6 inches — Medium-bedded, shaly limestone, mudstone, light-gray
1 ft 0 inches — Fissile, fossiliferous, calcitic shale, grayish-yellow; Derbyia

Cresswell Limestone Member

4 ft 2 inches — Bed of limestone, fines upward from oncolite biograinstone to less oncolitic biopackstone, prominent vertical burrows, apparent large, northwest-dipping foresets, light-yellow; crinoids, ramose bryozoans, Derbyia
1 ft 1 inches — Bed of limestone, biowackestone-packstone, bioturbated, yellow; crinoids, Derbyia
4 ft 6 inches — Bed of limestone, biopackstone, porous in the middle, relatively fine-grained, yellow; crinoids, brachiopod fragments, ramose bryozoans

Grant Shale Member

1 ft 4 inches — Bed of shaly limestone, mudstone, bioturbated, gray; crinoids, brachiopod fragments

Measured Section Number: 61

Location: East side of Augusta Lake, in NE sec. 15, T. 27 S., R. 4 E., Butler County, Kansas

Comment: The middle and upper Fort Riley are exposed in the spillway on the southern end of the lake, and some Towanda strata are exposed at the extreme northern end of the lake

DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

5 ft 0 inches — Poorly exposed section of thin-bedded strata: calcitized evaporite nodule-bearing bed at base, overlain by ~6 inches of biowackestone-packstone-grainstone (pelecypod fragments, crinoids, foraminifers), the overlying section mostly shaly lime mudstone
1 ft 6 inches — Concealed
1 ft 4 inches — Bed of limestone, mudstone to biowackestone at the base, partly brecciated, overlain by gray biowackestone passing laterally into coarse-grained biopackstone with conspicuous white, macerated pelecypod fragments (see measured section number 58); foraminifers, crinoids, gastropods, pelecypod fragments
1 ft 0 inches — Bed of coarse breccia, clasts of lime mudstone cemented by coarse calcite, gray-orange (likely evaporite dissolution-collapse breccia)
1 ft 8 inches — Bed of coarse-recrystallized limestone, brecciated, calcite geodes, orange

Measured Section Number: 62

Location: Roadcut on US–54–77 east of Augusta, on the south side of the road beginning immediately east of the bridge over the Walnut River, in sec. 26, T. 27 S., R. 4 E., Butler County, Kansas

DOYLE SHALE

Holmesville Shale Member

3 ft 0 inches	Unfossiliferous, red shale passing upward to topsoil, with marble-size calcite nodules
2 ft 8 inches	Unfossiliferous, orange to greenish-yellow mudrock

FORT RILEY FORMATION

4 ft 0 inches	(maximum thickness) Fissile, fossiliferous, shaly lime mudstone, light-gray, with large-scale, east-dipping foresets; Composita. This unit is referred to in the text as a possible tidal channel-filling deposit
0–1 ft 4 inches	Bed of limestone, erosional top beneath overlying unit: coarse-grained biograinstone, intraclastic, porous, yellow-gray; foraminifers
3 ft 0 inches	Medium-bedded, shaly limestone, mudstone-biowackestone, bioturbated, light-gray, erosional top beneath the tidal channel-filling deposit; pelecypod and gastropod fragments, crinoids
4 ft 0 inches	Bed of limestone, fine-grained biograinstone, porous, light-gray; foraminifers
15 ft 0 inches	Thin-bedded, shaly limestones, mudstones-biowackestones and interbedded calcitic mudrocks, bioturbated, gray; brachiopod and pelecypod fragments, crinoids
5 ft 4 inches	Thin-bedded, calcitic mudrock and shaly mudstone to biowackestone, dark-gray; brachiopod fragments, including Orbiculoides, crinoids. This is the "gray zone" referred to in the text
5 ft 0 inches	Thick-bedded limestone, oncolite biopackstone-wackestone, light-yellow; crinoids, brachiopod fragments

Measured Section Number: 63

Location: Roadcut along 80th St. and adjoining field exposures to the south, in the SE sec. 8 and NE sec. 17, and bedding plane exposures along the road (80th St.) in the SW sec. 9, T. 27 S., R. 5 E., Butler County, Kansas

FORT RILEY FORMATION (uppermost beds)

2 ft 0 inches	Medium-bedded, shaly and calcitic dolomudstone, laminated (cryptalgal), calcite geodes, light-yellow-gray
2 ft 8 inches	Medium-bedded, shaly and calcitic dolomudstone, laminated (cryptalgal), porous, light-yellow-gray
5 ft 0 inches	Thin-bedded to fissile, faintly laminated, shaly limestone, mudstone, light-gray, prominent 9-inches-thick, dark-gray, bioturbated beds (with Planolites) 1 ft above the base; bryozoans, brachiopod fragments, pectinid casts
1 ft 2 inches	Thin-bedded limestone, biowackestone-packstone, light-gray; foraminifers, brachiopod fragments, crinoids
1 ft 10 inches	Thin-bedded limestone, biopackstone-grainstone, light-gray; foraminifers

Measured Section Number: 64

Location: "Pumpjack Hill" on US–54–77/K–96, north side, in the E/2 sec. 27, T. 27 S., R. 5 E., Butler County, Kansas

DOYLE SHALE

Holmesville Shale Member

2 ft 0 inches	Red, clayey topsoil
3 ft 4 inches	Unfossiliferous, green-yellow mudrock, with a 1 ft 4 inches–1 ft 8 inches thick bed of light-gray paleocaliche at the top
4 ft 0 inches	Unfossiliferous, orange-yellow shale and mudrock with calcite geodes and laminae of palisades calcite
3 ft 4 inches	Unfossiliferous, green-gray mudrock with calcite nodules (paleocaliche)

FORT RILEY FORMATION

3 ft 2 inches	Basal 1 ft 9 inches white, calcitic dolomudstone, laminated (cryptalgal), with long casts of evaporite crystals and possible embryonic tepees; overlain by 5 inches of light-gray, fine-grained biograinstone (foraminifers); top 1 ft of light-gray lime mudstone (pelecypod fragments)
1 ft 3 inches	Thin-bedded, shaly limestone, biopackstone, light-gray; brachiopod and pelecypod fragments, planispiral gastropods
3 ft 0 inches	Dark-greenish-gray shale at the base, grading up to black, shaly lime mudstone and interbedded dark-greenish-gray mudrock. The entire section is bioturbated and sparsely fossiliferous; Composita, crinoids, pelecypod casts
3 ft 4 inches	Thin-bedded, shaly limestone, mudstone, bioturbated, yellow-gray; crinoids, brachiopod fragments

Measured Section Number: 65

Location: Huff quarry on Haverhill Road, sec. 10, T. 27 S., R. 5 E., Butler County, Kansas

DOYLE SHALE

Holmesville Shale Member

1 ft 4 inches	Unfossiliferous, yellow-orange shale

FORT RILEY FORMATION

1 ft 4 inches	Thin-bedded, shaly limestone, mudstone, possibly cryptalgal, light-gray
1 ft 4 inches	Medium-bedded, shaly limestone, laminated (cryptalgal) mudstone, light-yellow-gray
5 ft 2 inches	Thin-bedded to fissile, shaly limestone, mudstone, top 10 inches is light-gray, underlying section is very dark gray, bioturbated, locally with Planolites; rare Orbiculoides, Composita, pelecypod casts, Bellerophon
0 ft 10 inches–1 ft 4 inches	Bed of limestone, biopackstone, yellow-tan; foraminifers, crinoids, brachiopod and pelecypod fragments
3 ft 2 inches	Bed of limestone, biopackstone-grainstone, bioturbated, yellow-tan; foraminifers, crinoids, brachiopod fragments
5 ft 1 inch	Bed of limestone, coarsening upward section from mudstone at base, to mudstone-biowackestone in middle, to biowackestone-packstone at the top, bioturbated, grayish-tan; foraminifers, crinoids, brachiopod fragments
0 ft 9 inches	Thin-bedded limestone, biograinstone-packstone, brownish-tan; crinoids, brachiopod fragments
1 ft 3 inches	Thin-bedded limestone, biopackstone-grainstone with clasts of lime mudstone that are desiccated, light-gray; foraminifers, crinoids
8 ft 0 inches	To pond level: thin-bedded, shaly limestone, mudstone-biowackestone and calcitic mudrock, bioturbated, light-gray; prominent 4-inches-thick layer of coarse brachiopod hash about 2 ft below the top; Derbyia, crinoids

Measured Section Number: 66

Location: Roadcut on Hopkins Switch Road, west side, beneath overpass of US–54–77, in sec. 25, T. 27 S., R. 4 E., Butler County, Kansas

WINFIELD LIMESTONE

Cresswell Limestone Member

2 ft 6 inches	Bed of porous limestone, oncolite biograinstone, coarse-grained, prominent vertical burrows and large sweeping, northwest-dipping foresets, light-yellow; foraminifers, crinoids, locally silicified Derbyia
1 ft 4 inches	Thin-bedded limestone, oncolite biowackestone-packstone, bioturbated, grayish-yellow; crinoids, ramose bryozoans, Derbyia
4 ft 10 inches	Bed of limestone: basal 2 ft 4 inches biowackestone-packstone, grayish-yellow. Overlying 1 ft 8 inches porous biowackestone, grayish-yellow. Top 10 inches biowackestone, yellow. Rocks contain crinoids, ramose bryozoans, foraminifers, locally silicified Derbyia

Grant Shale Member

1 ft 1 inch	Thin-bedded, shaly limestone, mudstone-biowackestone, calcite geodes, yellow; crinoids, bryozoans, brachiopod fragments
4 ft 0 inches	Fossiliferous, fissile, light-yellow, calcitic shale; crinoids, Composita, Derbyia, Allorisma, pectinid casts, bryozoans

DOYLE SHALE

Gage Shale Member

7 ft 0 inches	Unfossiliferous, fissile, medium-gray shale

Measured Section Number: 67

Location: Peck quarry, along south bank of Walnut River, and low field exposures to the east, in the SE and SW sec. 24, T. 27 S., R. 4 E., Butler County, Kansas

NOLANS LIMESTONE

Herington Member

2 ft 0 inches	Thin-bedded limestone, laminated mudstone, calcite geodes, light-gray
15 ft 0 inches	Concealed Paddock and Krider Members, and Odell Shale

WINFIELD LIMESTONE

Luta Member

2 ft 0 inches	Medium-bedded limestone, mudstone-biowackestone, porous at top, abundant silicified crinoids, light-yellow
10 ft 0 inches	Thin- to medium-bedded, shaly limestone, mudstone-biowackestone, bioturbated, light-yellow; Composita, crinoids
12 ft 4 inches	Medium-bedded, shaly limestone, mudstone (beds ~10 inches thick), and interbedded calcitic mudrocks (beds ~5 inches thick), light-gray to tannish-gray; rare crinoids, Composita, planispiral and high-spired gastropods, bryozoans

1 ft 8 inches	Thin-bedded, shaly limestone, biowackestone, yellow-gray; ramose and fenestrate bryozoans, Composita, crinoids
2 ft 2 inches	Thin-bedded, shaly limestone, biowackestone-packstone, bioturbated, light-yellow; crinoids, Composita, ramose bryozoans; Derbyia at base

Cresswell Limestone Member

3 ft 7 inches	Thick-bedded limestone, oncolite biopackstone, shaly at top, surface-dissolution vugs, light-yellow; crinoids, brachiopod fragments, including Derbyia
2 ft 1 inch	Bed of limestone, oncolite biopackstone-grainstone, light-yellow; crinoids, Derbyia

Measured Section Number: 68

Location: Roadcut and field to west, south of Kansas Turnpike overpass, in sec. 28, T. 26 S., R. 4 E., Butler County, Kansas

WINFIELD LIMESTONE

Grant Shale Member

1 ft 10 inches	Medium-bedded limestone, biowackestone, calcite geodes, yellow and gray; crinoids, brachiopod fragments
7 ft 8 inches	Sparsely fossiliferous, gray-brown and yellow-greenish-gray-brown mudrocks, calcitic; brachiopod and pelecypod fragments

DOYLE SHALE

Gage Shale Member

15 ft 0 inches	Unfossiliferous, yellow-green shale and mudrock, with a 3-inches-thick layer of black mudrock 3 inches below the top (paleosol)
1 ft 0 inches	Bed of limestone, very hard biowackestone, brownish- orange; crinoids, ramose bryozoans, brachiopod fragments
3 ft 0 inches	Unfossiliferous, green-gray mudrock
2 ft 0 inches	Unfossiliferous, red mudrock

Measured Section Number: 69

Location: Fath's (1921) type area of the Towanda, roadcut along the bluffs and in a small quarry north of the town of Towanda, in the NW sec. 9, and roadcuts on 3rd St. in town, in the SW sec. 9, T. 26 S., R. 4 E., Butler County, Kansas

Roadcut along Bluffs and quarry:

DOYLE SHALE

Gage Shale Member

0 ft 4 inches	Thin bed of limestone, laminated mudstone, yellow-orange; (pelecypod fragments)
2 ft 8 inches	Unfossiliferous, red shale

Towanda Limestone Member

2 ft 4 inches	Medium- to thin-bedded (upsection) limestone, porous, recrystallized mudstone, calcite geodes, yellow-orange
1 ft 2 inches	Thin-bedded, shaly limestone, laminated to brecciated mudstone, layers of palisades calcite at the top
1 ft 6 inches	Unfossiliferous, yellow-orange mudrock
1 ft 4 inches	Interbedded thin layers of recrystallized limestone, yellow-orange, and unfossiliferous, yellow mudrock

Holmesville Shale Member

6 ft 0 inches	Basal 1 ft 6 inches dark-gray-green shale, upper 1 ft 6 inches orange-yellow mudrock, middle section not exposed
1 ft 4 inches	Bed of recrystallized limestone, porous, calcite geodes, yellow

Roadcut in Town:

DOYLE SHALE

Towanda Limestone Member

1 ft 6 inches	Thin-bedded limestone, laminated and recrystallized mudstone, hard, orange-tan
5 ft 0 inches	Thin-bedded limestone, fine-grained biowackestone-packstone, porous, tan to light-yellow-gray; pelecypod and gastropod fragments
1 ft 5 inches	Concealed
0 ft 7 inches	Bed of limestone, fine-grained biopackstone, recrystallized, hard, porous, yellow: foraminifers, bivalve fragments
2 ft 0 inches	Thin-bedded limestone, fine-grained biowackestone-packstone, hard, locally recrystallized, light-yellow; foraminifers, pelecypod and gastropod fragments

Measured Section Number: 70

Location: Composite of roadcuts at intersection of Kechi Road and Ohio St. in NW sec. 14 (lower to middle part of the section), and nearby creekbank exposures in the NW sec. 15 (middle to upper part of the section), both in T. 26 S., R. 4 E., Butler County, Kansas

FORT RILEY FORMATION

1 ft 0 inches	Bed of limestone, porous biograinstone; foraminifers
4 ft 0 inches	Thin-bedded limestone, mudstone-biowackestone, bioturbated, light-gray; 1 ft 6 inches thick lense of biowackestone-packstone at base, light-yellow. Rocks contain crinoids, brachiopod fragments
3 ft 4 inches	Medium- to thick-bedded limestone, porous biograinstone, bioturbated, crinoid-rich, yellow; foraminifers, Derbyia
11 ft 6 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, bioturbated, yellow-gray; crinoids, brachiopod fragments
3 ft 6 inches	Calcitic, fossiliferous shale to mudrock, gray; crinoids, brachiopod fragments, including Orbiculoides. This is the "gray zone" referred to in the text

Measured Section Number: 71

Location: Roadcut on US–77–54 (southbound lanes), south of El Dorado, in secs. 13 and 14, T. 26 S., R. 5 E., Butler County, Kansas

FORT RILEY FORMATION

2 ft 8 inches	Bed of limestone, porous biopackstone-grainstone, bioturbated, yellow-tan; foraminifers
1 ft 10 inches	Bed of limestone, mudstone, yellow-tan; foraminifers, crinoids, brachiopod fragments
3 ft 3 inches	Thin- to medium-bedded, shaly limestone, mudstone-biowackestone, orange-tan; foraminifers, crinoids, brachiopod fragments
2 ft 6 inches	Bed of limestone: along the roadcut on the eastern side, this unit is represented by a section that coarsens upward from mudstone-biowackestone at the base, to porous biograinstone in the middle, to biopackstone at the top, tan (foraminifers, high-spired gastropods, Composita, Derbyia). At the southern end of the roadcuts on both the eastern and western sides of the road, this unit changes facies to a thick bed of porous, cross stratified limestone with clasts of desiccated lime mudstone, tan (foraminifers). This unit is correlated to the basal part of the cross stratified, upper Fort Riley section at measured section number 72
2 ft 4 inches	Bed of limestone, biowackestone, grayish-tan; brachiopod fragments, including Derbyia, crinoids, foraminifers
1 ft 2 inches	Yellow, unfossiliferous, calcitic shale
2 ft 6 inches	Medium-bedded, shaly limestone, mudstone-biowackestone, medium-gray; crinoids, gastropods, Composita, Derbyia
0 ft 11 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, bioturbated, light-gray; crinoids, gastropods, Composita, Derbyia
2 ft 3 inches	Thin-bedded, shaly limestone, biowackestone-mudstone, with a lens of biopackstone-grainstone near the top, bioturbated, tan; crinoids, Composita, Derbyia
3 ft 10 inches	Thin-bedded, shaly limestone, mudstone-biowackestone and thin, wavy layers of shale, bioturbated, light-tannish-gray; crinoids, high-spired gastropods, brachiopod fragments
6 ft 2 inches	Medium-bedded, shaly limestone, mudstone and minor lenses of biowackestone, bioturbated, upward decrease in bed thickness from 8 inches to 3–4 inches, light-gray, sparsely fossiliferous; crinoids, brachiopod fragments

Measured Section Number: 72

Location: Two closely spaced roadcuts on both sides of US–54 on the eastern edge of El Dorado, opposite the El Dorado State Correctional Facility, in sec. 6, T. 26 S., R. 6 E., Butler County, Kansas

Comment: Prior permission from the warden of the correctional facility is required to stop and examine the roadcuts on the south side of the road, which are within the jurisdiction of the prison

FORT RILEY FORMATION
(close to the top of the formation)

0 ft 9 inches	Bed of limestone, bioturbated biowackestone, light-gray; brachiopod fragments, crinoids
3 ft 6 inches	Bed of limestone, porous biograinstone with large-scale, cross stratified sets with bimodal-bipolar dips ("herringbone"), and some interbeds and clasts of desiccated lime mudstone, light-yellow; foraminifers, accessory brachiopod and pelecypod fragments, some Bellerophon and ammonite fragments
1 ft 8 inches	Thin interbeds of mudstone, commonly desiccated and/or vertically bioturbated at the tops of individual layers, and porous, cross stratified biograinstone with clasts of desiccated lime mudstone, light-gray; foraminifers
2 ft 0 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, bioturbated, yellow-gray; crinoids, brachiopod fragments
1 ft 8 inches	Bed of limestone, porous biograinstone, large-scale, cross stratified sets with bimodal-bipolar dips ("herringbone"), yellow-tan; foraminifers

1 ft 6 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, bioturbated, yellow-gray; crinoids, brachiopod fragments
~20 ft	Concealed
3 ft 0 inches	Medium-bedded limestone, porous oncolite biopackstone-grainstone, surface-dissolution vugs, yellow-tan; some crinoids
2 ft 4 inches	Bed of limestone, oncolite biopackstone, surface-dissolution vugs, light-yellow-gray; some crinoids, Reticulatia

FLORENCE FORMATION

2 ft 8 inches	Bed of limestone, oncolite biowackestone, surface-dissolution vugs, light-yellow-gray, prominent stylolites at top; some Reticulatia, crinoids, rare tabulate corals
1 ft 6 inches	Bed of limestone, oncolite biowackestone, local cross strata, surface-dissolution vugs, gray, prominent stylolite at the top; some crinoids, Reticulatia
0 ft 10 inches	Thin-bedded limestone, oncolite biopackstone, light-grayish-yellow, 2–3-inches-thick chert layer at the top; fenestrate and ramose bryozoans, crinoids, brachiopod fragments
1 ft 2 inches	Thin-bedded limestone, biowackestone, white to light-yellow, chert nodules; bryozoans, crinoids, brachiopod fragments
0 ft 11 inches	Very thin bedded limestone, biowackestone-packstone, white; bryozoans, crinoids, brachiopod fragments
2 ft 2 inches	Medium-bedded limestone, oncolite biopackstone-wackestone, white, chert nodules in upper half; fenestrate and ramose bryozoans, crinoids, brachiopod fragments
2 ft 3 inches	Bed of limestone, biopackstone-wackestone, white, chert nodules; ramose and fenestrate bryozoans, crinoids, Reticulatia, rugose corals. This bed is the coral biostrome referred to in the text
2 ft 2 inches	Medium-bedded limestone, biowackestone-packstone, white, small chert nodules; fenestrate and ramose bryozoans, crinoids, Reticulatia, fusulinids

Measured Section Number: 73

Location: Quarry due south of US–54 east of El Dorado, in the NW NE sec. 9, T. 26 S., R. 6 E., Butler County, Kansas

FORT RILEY FORMATION
(probable top of the formation)

2 ft 0 inches	Medium-bedded limestone, biowackestone-packstone, with abundant horizontal trace fossils, light-gray; foraminifers, crinoids, brachiopod fragments
0 ft 8 inches	Bed of limestone, fines upward from biopackstone to mudstone, gray; pelecypod fragments, crinoids
7 ft 4 inches	Thick-bedded limestone, porous, coarse-grained biograinstone, each bed is a large-scale, cross stratified set, yellow-tan; some layers and intraclasts of commonly desiccated lime mudstone, light-gray. Rocks contain foraminifers, some crinoids
4 ft 0 inches	Fossiliferous, calcitic mudrock, bioturbated, with lenses of lime mudstone to intraclastic biowackestone, gray; crinoids, brachiopod fragments
1 ft 4 inches	Basal 1 ft of fossiliferous, calcitic, yellow-gray mudrock; top 4-inches-thick bed of limestone, mudstone to fine-grained biopackstone, bioturbated, gray. Rocks contain crinoids, foraminifers, brachiopod fragments
4 ft 3 inches	Thin-bedded, shaly limestone, mudstone to sparse biowackestone and thin interbeds of calcitic shale, gray, possible hard ground at the top (which is correlated to the equivalent section at measured section number 74); scattered crinoids and brachiopod fragments
6 ft 0 inches	Thin-bedded, shaly limestone, mudstone, light-gray
4 ft 4 inches	Thin-bedded to fissile, fossiliferous and calcitic shale, some lenses of mudstone-biowackestone, gray (some crinoids and brachiopod fragments); this bed is the "gray zone" referred to in the text
2 ft 8 inches	Very thin bedded, shaly limestone, mudstone-biowackestone, light-tan; brachiopod fragments, crinoids
5 ft 0 inches	Thin- to medium-bedded limestone, fines upward from biopackstone with large oncolites, to biowackestone-packstone with scattered smaller oncolites, tan to yellow-gray; crinoids, brachiopod fragments, bryozoans, foraminifers
2 ft 6 inches	Medium-bedded, gray limestone, oncolite biopackstone, size of the oncolites (which are orange) decreases upsection; what appear to be intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain crinoids, brachiopod fragments, bryozoans

FLORENCE FORMATION

4 ft 8 inches	Medium-bedded limestone, oncolite biowackestone, tannish-gray, prominent stylolites at the top; what appear to be intraclasts are actually fenestrate bryozoan-encrusted grains. Rocks contain crinoids, bryozoans
0 ft 9 inches	Bed of limestone, oncolite mudstone-biowackestone, yellow, chert nodules; crinoids, bryozoans

Measured Section Number: 74

Location: Dolese Bros. quarry north of the railroad tracks in secs. 5 and 6, T. 26 S., R. 6 E., Butler County, Kansas

FORT RILEY FORMATION
(close to the top of the formation)

3 ft 6 inches	Medium-bedded limestone, mudstone-biowackestone with lenses of locally cross stratified biopackstone-grainstone, some desiccation cracks yellow; foraminifers, crinoids, brachiopod fragments, high-spired gastropods
1 ft 5 inches	Bed of limestone, mudstone-biowackestone with a lens of cross stratified biopackstone-grainstone, yellow; top few inches of yellow-gray, calcitic shale. Rocks contain foraminifers, crinoids, high-spired gastropods
1 ft 4 inches	Bed of limestone, biowackestone, with conspicuous layers of Derbyia shell hash, light-grayish-tan; crinoids, foraminifers
1 ft 8 inches	Thin-bedded limestone, coarsens upward from mudstone to coarse-grained biowackestone with Derbyia shell-hash layers, light-tan-gray; crinoids, foraminifers
2 ft 6 inches	Medium-bedded limestone: basal 4 inches coarsens upward from mudstone to biograinstone; upper 2 ft 2 inches is mudstone to biowackestone, cross stratified in lower 2 inches, light-tan. Rocks contain crinoids, foraminifers, Derbyia
4 ft 8 inches	Thin-bedded, shaly lime mudstone, with lenses of biopackstone-grainstone with intraclasts at the top of the section, and interbeds of shale, bioturbated, light-gray; brachiopod fragments, crinoids
8 ft 8 inches	Thin-bedded, shaly limestone, mudstone and interbedded mudrocks, bioturbated, gray, possible hard ground at the top of the section (which correlates to the equivalent zone in measured section number 73); scattered brachiopod fragments
6 ft 0 inches	Thin-bedded, shaly limestone, mudstone-biowackestone with some lenses of biopackstone, bioturbated, light- to medium-gray; some brachiopod fragments; this bed is the "gray zone" referred to in the text
0 ft 8 inches	Bed of limestone, mudstone, tan
1 ft 6 inches	Fossiliferous, calcitic shale with lenses of shaly lime mudstone, bioturbated, tan; brachiopod fragments
6 ft 4 inches	Thin- to medium-bedded limestone: basal few inches are oncolite biowackestone-packstone with an apparent erosional base; middle part is oncolite biowackestone-grainstone; upper 1 ft is oncolite biowackestone, tan. Rocks contain crinoids, bryozoans
2 ft 6 inches	Medium-bedded limestone, oncolite biowackestone-packstone, large dissolution vugs filled with red soil, yellow to grayish-tan; crinoids, foraminifers, bryozoans

FLORENCE FORMATION

4 ft 8 inches	Bed of limestone, oncolite biopackstone, light-tan, prominent stylolites at the top and immediately above the base; crinoids, bryozoans
3 ft 2 inches	Thin- to medium-bedded limestone, coarsens upward from biowackestone to biopackstone with oncolites at the top, tan-gray, chert nodules and thin layers of chert at the top; crinoids, bryozoans, foraminifers

Measured Section Number: 75

Location: Streambank exposures along Four Mile Creek in NE sec. 4, T. 25 S., R. 4 E., Butler County, Kansas

NOLANS LIMESTONE

Herington Member

1 ft 4 inches	Bed of fine-grained dolobiowackestone-packstone, intraclastic, yellow; pelecypod fragments, planispiral gastropods
2 ft 2 inches	Thin- to medium-bedded (upsection) dolomudstone with a bed of porous, dolowackestone-packstone in the middle, yellow; the porous bed contain molds of foraminifers, pelecypods, and gastropods
1 ft 10 inches	Thin interbeds of dolomudstone and shale, calcite geodes, yellow; scattered Aviculopecten

Paddock Shale Member

6 ft 0 inches	Unfossiliferous mudrock, slightly greenish-gray in the lower half, light-yellow-gray in the upper half
4 ft 0 inches	Sparsely fossiliferous shale and mudrock, splotchy yellow and dark-gray; pectinid casts, fenestrate bryozoans, Derbyia, Composita

Krider Limestone Member

2 ft 0 inches	Basal 9 inches and upper 8 inches bed are yellow, shaly dolomudstone, middle 7 inches is yellow mudrock; Aviculopecten in the basal dolomite
1 ft 0 inches	Sparsely fossiliferous calcitic mudrock, mottled dark-gray and yellow-gray; Myalina
0 ft 10 inches	Bed of shaly dolomudstone, light-yellow-gray; Aviculopecten
0 ft 9 inches	Unfossiliferous, light-yellow, dolomitic mudrock with hint of fenestral fabric

ODELL SHALE

2 ft 7 inches — Unfossiliferous mudrock, light-green in lower half, yellowish-green in upper half; at the base of this unit is a few inches of siltstone

3 ft 0 inches — Unfossiliferous, green mudrock

1 ft 0 inches — Unfossiliferous, red shale

Measured Section Number: 76

Location: Roadcut on US–77, east side, in the center N/2 sec. 26, T. 24 S., R. 5 E., Butler County, Kansas

WINFIELD LIMESTONE

Luta Member

1 ft 6 inches — Thin-bedded limestone, sparsely fossiliferous biowackestone, light-gray; Composita

Cresswell Limestone Member

4 ft 0 inches — Bed of limestone, biowackestone-pack-stone, light-yellow, with brown-weathering oval chert nodules; crinoids, bryozoans, some oncolites

Grant Shale Member

5 ft 0 inches — Light-yellow-gray, fossiliferous mudrock; Derbyia, Composita, crinoids, bryozoans

Measured Section Number: 77

Location: Quarry in NE SW sec. 6, T. 24 S., R. 4 E., near Potwin, Butler County, Kansas

NOLANS LIMESTONE

Herington Member
(likely the full thickness of the member)

1 ft 0 inches — Thin-bedded, shaly dolomudstone, yellow, scattered small, dark-gray chert nodules; pelecypod molds

1 ft 4 inches — Thin-bedded, shaly dolomudstone and dolomitic mudrock, yellow, calcite geodes, scattered small, dark-gray chert nodules

2 ft 0 inches — Thin-bedded section that fines upward from shaly dolomudstone in the lower half, to dolomitic mudrock in the upper half, yellow, abundant calcite geodes and scattered small, dark-gray chert nodules

0 ft 11 inches — Bed of dolomudstone, light-yellow, calcite geodes and small, dark-gray chert nodules

2 ft 6 inches — Medium- to thin-bedded (upsection) dolomudstone, lightly yellow-gray, calcite geodes

1 ft 4 inches — Bed of dolomite, fine-grained biopackstone, porous, yellow; molds of pelecypods and gastropods

Measured Section Number: 78

Location: Roadcut on River Valley Road, north of Potwin, in the SW SW sec. 21 and NW sec. 28, T. 23 S., R. 4 E., Butler County, Kansas

Comment: This locality is the southernmost occurrence of the Stovall Member. A down-to-north fault likely separates the outcrop in sec. 28 from that in sec. 21

WINFIELD LIMESTONE

Luta Member

7 ft 6 inches — Highly weathered and soft, unfossiliferous, light-yellow, calcitic mudrock or shaly lime mudstone

Cresswell Limestone Member

3 ft 4 inches — Bed of limestone that coarsens upward from shaly lime mudstone in the basal 3 inches, to relatively coarse-grained and porous, oncolite biopackstone-grainstone above; and then fines upward in the top few inches to oncolite biopackstone, light-yellow; some black (brown-weathering), oval chert nodules. Rocks contain foraminifers, crinoids, Allorisma, Derbyia

Grant Shale Member

8 ft 0 inches — Concealed

Stovall Limestone Member

1 ft 4 inches — Bed of limestone, fine-grained biopackstone, light-yellow- gray, abundant angular, gray chert nodules; foraminifers, crinoids, Reticulatia, Derbyia

DOYLE SHALE

Gage Shale Member

5 ft 0 inches — Very thin bedded, fossiliferous, light-yellow, calcitic shale, very abundant large, curved, brown-colored, flattened horizontal burrows; echinoid fragments, Derbyia, Reticulatia, crinoids

Measured Section Number: 79

Location: Streambank exposures along the Walnut River, SE SW sec. 20, T. 23 S., R. 6 E., Butler County, Kansas

FORT RILEY FORMATION

0 ft 8 inches	Fossiliferous, light-yellow, calcitic mudrock; fenestrate bryozoans, Derbyia, Reticulatia, echinoid fragments
0 ft 10 inches	Bed of limestone that fines upward from sparsely oncolitic biowackestone-packstone to biowackestone, yellow; crinoids, foraminifers, Derbyia, Composita
0 ft 11 inches	Bed of limestone, oncolite biopackstone, light-yellow-gray; crinoids, foraminifers, Derbyia, Composita
2 ft 6 inches	Platy-bedded limestone, fines upward from oncolite biopackstone to less oncolitic mudstone-biowackestone, light-yellow; crinoids, fenestrate and ramose bryozoans, echinoid fragments

FLORENCE FORMATION

1 ft 4 inches	Bed of limestone that first coarsens upward from biowackestone to oncolite biowackestone-packstone, with relatively large oncolites, light-yellow to light-gray; and then fines upward in the top few inches to very dark gray, silty and shaly oncolite biopackstone with very large oncolites; this dark limestone is considered to be the Oketo-equivalent. Rocks contain Derbyia, crinoids

Measured Section Number: 80

Location: Roadcuts on Kansas Turnpike, north and south sides, at mile marker 101, in SW sec. 16, T. 22 S., R. 8 E., Chase County, Kansas
Comment: Prior permission to stop and examine roadcuts on the turnpike must be obtained from the Turnpike Authority

WREFORD LIMESTONE

Schroyer Limestone Member
(likely very close to the top of the member)

1 ft 6 inches	Poorly exposed: float that fines upward from very coarse grained, porous biograinstone to finer-grained biograinstone, white; foraminifers, crinoids, planispiral gastropods
2 ft 4 inches	Thin-bedded, shaly limestone, coarsens upward from mudstone to less shaly, bioturbated biopackstone, light-yellowish-gray; foraminifers, crinoids, brachiopod fragments
1 ft 4 inches	Bed of limestone, biowackestone, light-gray; crinoids, brachiopod fragments
1 ft 3 inches	Lower half of the section is a bed of shaly lime mudstone, light-gray; upper half is yellowish-gray, calcitic mudrock. Rocks contain crinoids, fenestrate bryozoans, Reticulatia, echinoid fragments
2 ft 1 inches	Thin-bedded, shaly limestone: basal 5 inches is porous biowackestone with a layer of chert at top, light-yellow (crinoids, spicules, Composita). Overlying beds are lime mudstone to sparse biowackestone, light-yellow (fenestrate bryozoans, crinoids, Reticulatia, echinoid fragments)
2 ft 0 inches	Medium-bedded limestone, mudstone, light-yellow; a 1-inch-thick layer of chert 2 inches above the base, a 6-inches-thick layer 1 ft above the base, and a 3-inches-thick layer at the top; crinoids, brachiopod fragments

Havensville Shale Member

3 ft 0 inches	Sparsely fossiliferous, very dark gray mudrock; pectinid casts
0 ft 9 inches	Fossiliferous, light-gray shale and mudrock; crinoids, pelecypod and brachiopod fragments
1 ft 0 inches	Fossiliferous, dark-gray shale; Composita, ramose and fenestrate bryozoans, crinoids, echinoid fragments
1 ft 3 inches	Bed of dolomite, shaly and silty mudstone, with white calcite-anhydrite-quartz nodules, unfossiliferous
4 ft 4 inches	Unfossiliferous, light-gray, silty and calcitic mudrock, some rootcasts; top 6 inches is fissile and very dark gray
1 ft 8 inches	Fossiliferous, dark-gray to black shale, fissile, with a concentration of coarse skeletal hash in the middle; crinoids, fenestrate and ramose bryozoans, Composita, Derbyia, echinoid fragments, trilobite debris
1 ft 8 inches	Very fossiliferous, dark-gray, calcitic mudrock to shaly biowackestone, less fossiliferous at the top; crinoids, brachiopod fragments, ramose and fenestrate bryozoans, planispiral gastropods

Threemile Limestone Member

0 ft 11 inches	Fossiliferous, medium-gray shale with chert nodules overlain by a bed of shaly biowackestone, medium-gray, chert nodules; crinoids, ramose bryozoans, brachiopod fragments
1 ft 9 inches	Bed of limestone, biopackstone, very light yellowish gray, chert nodules in the upper half; fenestrate and ramose bryozoans, crinoids, brachiopod fragments
2 ft 11 inches	Medium-bedded limestone, mudstone, very light gray, prominent stylolites in the middle and at the top, chert nodules; crinoids, brachiopod fragments, bryozoans

4 ft 0 inches — Medium-bedded limestone, fines upward from biowackestone-packstone to mudstone, light-gray; discontinuous layers of chert nodules, many laminated. Rocks contain fenestrate bryozoans, crinoids, spicules, brachiopod fragments

1 ft 4 inches — Basal 8 inches bed of shaly limestone, biowackestone-packstone, upper 8 inches of fossiliferous, bioturbated, light-yellow mudrock with some chert nodules. Rocks contain spicules, fenestrate and ramose bryozoans, Composita

2 ft 6 inches — Bed of limestone, biowackestone-packstone with increasing skeletal content upsection, very light gray, layers of anastomosing chert nodules following burrows; bryozoans, crinoids, brachiopod fragments

SPEISER FORMATION

5 ft 0 inches — Poorly exposed: fossiliferous, calcitic mudrock and lenses of shaly mudstone-sparse biowackestone, yellow-gray; Composita, Derbyia, crinoids

4 ft 0 inches — Unfossiliferous, red mudrock and shale with a concentration of calcite nodules 1 ft 4 inches below the top (paleocaliche)

Measured Section Number: 81

Location: Texaco Hill, SE sec. 35, T. 22 S., R. 9 E., Chase County, Kansas

Comment: This location marks the point of facies change in the lower Kinney from Derbyia-rich beds to the south, and intraclastic beds to the north

MATFIELD SHALE

Kinney Limestone Member

1 ft 8 inches — Bed of limestone, porous, fine-grained biograinstone, current-layered, surface-dissolution vugs, light-gray; foraminifers, pelecypod and brachiopod fragments, crinoids

0 ft 8 inches — Bed of limestone, porous biopackstone, light-yellow; foraminifers, crinoids, fenestrate bryozoans, planispiral gastropods

1 ft 7 inches — Medium-bedded, shaly limestone, coarsens upward from mudstone to porous biopackstone, yellow with dark spots; foraminifers, crinoids, brachiopod fragments

4 ft 2 inches — Concealed

0 ft 10 inches — Bed of limestone, intraclastic (orange), Derbyia-rich biopackstone, light-yellow; foraminifers, crinoids, high-spired gastropods

Measured Section Number: 82

Location: Roadcut on Kansas Turnpike, at mile marker 107, south side, in SE sec. 30, T. 21 S.,R. 9 E., Chase County, Kansas

FLORENCE FORMATION

Cole Creek Member

0 ft 10 inches — Thin-bedded limestone, fines upward from intraclastic biopackstone to biowackestone, and then coarsens upward to biopackstone, yellow-orange; pelecypod fragments, foraminifers

MATFIELD SHALE

Blue Springs Shale Member

0 ft 7 inches — Fossiliferous, light-yellow mudrock; pelecypod fragments

6 ft 0 inches — Unfossiliferous, fissile shale, green in the lower half, progressively yellow-green to yellow toward the top, which has some splotches of red shale and calcite nodules (paleocaliche)

Kinney Limestone Member

1 ft 10 inches — Medium-bedded limestone, coarsens upward from biopackstone-grainstone to biopackstone, with a 0.5-inch-thick layer of fenestral lime mudstone in the middle; green shale in vugs and interparticle pores in the upper half of the unit, which is light gray; prominent stylolite just above the base. Rocks contain foraminifers, crinoids, pelecypod fragments

0 ft 10 inches — Stylolite-bounded, thin beds of limestone, coarsens upward from biowackestone to biograinstone, white; foraminifers, crinoids, pelecypod fragments

0 ft 10 inches — Bed of limestone, coarse-grained biograinstone, white; foraminifers, crinoids

2 ft 0 inches — Bed of limestone that coarsens upward from mudstone to fine-grained biopackstone to biograinstone, and then fines upward to shaly biopackstone, light-yellow; foraminifers, crinoids

0 ft 8 inches — Fossiliferous, calcitic, yellow shale; crinoids

1 ft 2 inches — Bed of limestone, fine-grained biopackstone that becomes shaly and finer-grained in the top 1 inch, light-gray; foraminifers, crinoids

1 ft 9 inches — Unfossiliferous, yellow-brown mudrock

1 ft 4 inches — Fossiliferous, very dark gray mudrock; crinoids, brachiopod fragments

1 ft 8 inches — Fining-upward section from basal 1-ft bed of medium-gray, shaly limestone, biowackestone (foraminifers, crinoids, some oncolites) to fossiliferous, calcitic, medium-gray mudrock (crinoids, foraminifers)

3 ft 6 inches — Sparsely fossiliferous, fissile, calcitic shale, dark gray in the lower part, lighter gray above; crinoids, Derbyia

Measured Section Number: 83

Location: Roadcut along dirt road that leads north to Cedar Point, in SW NW sec. 8, T. 21 S., R. 6 E., Chase County, Kansas

Comment: The uppermost Florence, including the Oketo, and the basal Fort Riley are exposed in a small quarry 0.1 mi to the east, along another dirt road that intersects this outcrop at its southern end

FLORENCE FORMATION

6 ft 0 inches	Bed of limestone, sparse biowackestone, light-yellow, with angular, brecciated-appearing chert nodules throughout; bryozoans, crinoids, Reticulatia
3 ft 0 inches	Bed of limestone, biowackestone, white to light-yellow, with partly discontinuous layers of chert; crinoids, bryozoans
0 ft 8 inches	Two beds of limestone, light-yellow biopackstone with small chert nodules, each grading up to 1 inch of yellowish-green, fossiliferous shale; bryozoans, spicules
0 ft 10 inches	Bed of limestone, sparse biowackestone, light-gray, bioturbated, and with chert nodules, that grades up to 1 inch of yellow-brownish-green, fossiliferous shale; crinoids, echinoid fragments, ramose and fenestrate bryozoans, Derbyia, Composita, Reticulatia, Meekella

Cole Creek Member

1 ft 3 inches	Thin-bedded, shaly limestone, mudstone-biowackestone, light-gray, overlain by 7 inches of very fossiliferous, yellow-orange mudrock; crinoids, echinoid fragments, ramose and fenestrate bryozoans, Derbyia, Composita, Reticulatia, Meekella
1 ft 1 inches	Basal 7 inches shaly limestone, light-yellow mudstone, overlain by 6 inches fossiliferous, yellow mudrock; ramose bryozoans, Derbyia, crinoids, Bellerophon, Permophorus

MATFIELD SHALE

Blue Springs Shale Member

3 ft 9 inches	Thin-bedded layers of splotchy yellow-orange, calcitic shale and thicker layers of less calcitic, light-yellow mudrock, fossiliferous and bioturbated throughout; Permophorus, Aviculopecten, Allorisma, Derbyia
1 ft 2 inches	Fossiliferous, compact mudrock, light-yellow-green at base, light-yellow at top; Permophorus, Aviculopecten
3 ft 0 inches	Unfossiliferous, brownish-green mudrock
0 ft 10 inches	Bruno limestone bed: basal 3 inches orange-yellow paleocaliche; overlain by 2 inches laminated, medium-brown, fossiliferous shale; top 5 inches shaly, intraclastic lime mudstone to biowackestone, greenish-gray, with foraminifers, pelecypod fragments
4 ft 7 inches	Unfossiliferous mudrock, grayish-green at the base, becomes slightly light-grayish-green toward the top, with the top 8 inches being yellow-grayish-green

Measured Section Number: 84

Location: Roadcut on US–50, and railroad cut to the immediate south of the road, in SW NE NE sec. 31, T. 20 S., R. 6 E., about 1 mi northeast of Cedar Point, Chase County, Kansas. Outcrop has since been destroyed by highway work

MATFIELD SHALE

Blue Springs Shale Member

4 ft 7 inches	Unfossiliferous mudrock, basal 7 inches bright green, overlying section red

Kinney Limestone Member

3 ft 0 inches	Medium-bedded limestone, light-yellow to light-gray: basal 1 ft biopackstone-grainstone, middle 1 ft 4 inches biowackestone, upper 8 inches biowackestone; green shale in vugs and fissures in the top two beds. Rocks contain foraminifers, crinoids, pelecypod and brachiopod fragments
2 ft 0 inches	Recessive unit of limestone, yellow: basal 4 inches bed fines upward from biopackstone to mudstone, overlying 1 ft 8 inches bed coarsens upward from mudstone to biowackestone; foraminifers
6 ft 6 inches	Poorly exposed shale, medium-greenish-gray at the base, grayish-green with yellow tint at the top, sparsely fossiliferous; pectinid casts, Derbyia
3 ft 10 inches	Fossiliferous, calcitic mudrock with lenses of shaly lime mudstone, yellow-brown; prominent ledge of Derbyia-rich shale from 0 to 1 ft 4 inches above the base; conspicuous thin lenses with abundant fossils, including curved spines, in upper 2 ft 6 inches of the unit. Rocks contain echinoid spines, ramose and fenestrate bryozoans, crinoids
0 ft 5 inches	Two inches of fossiliferous, yellow-brown shale overlain by 3 inches bed of shaly biowackestone, light-yellow; Derbyia, crinoids, foraminifers
1 ft 6 inches	Basal 4 inches of fossiliferous, yellow mudrock overlain by 1 ft 2 inches of thin-bedded biowackestone-packstone, light-yellow; Derbyia, crinoids, foraminifers
1 ft 0 inches	Bed of limestone, biowackestone-packstone, surface-dissolution vugs, hint of cross stratification at the top, very light yellow: foraminifers, lesser pelecypod and brachiopod fragments, crinoids, planispiral gastropods

4 ft 10 inches — Poorly exposed mudrock, yellow-brown, sparsely fossiliferous but unfossiliferous in the top 8 inches which includes abundant calcite nodules (paleocaliche); some crinoids, Derbyia

1 ft 1 inches — Thin-bedded, shaly limestone, fines upward from biowackestone to mudstone, splotchy medium-gray and yellow; Derbyia, Composita

1 ft 0 inches — Calcitic mudrock to shaly biowackestone, bioturbated, light-yellow; Derbyia

1 ft 2 inches — Bed of shaly limestone, biowackestone-packstone, bioturbated, splotchy yellow and medium-gray; Derbyia, Composita, echinoid fragments, crinoids, spicules, ramose bryozoans

0 ft 10 inches — Basal 5 inches bed of shaly limestone, mudstone, light-gray, overlain by 5 inches fossiliferous, calcitic mudrock to shaly mudstone, gray; crinoids, Derbyia

Wymore Shale Member

4 ft 0 inches — Poorly exposed mudrock, unfossiliferous, medium-greenish-gray in the lower part, yellowish-brown in the upper part

Measured Section Number: 85

Location: Bluffs along Doyle Creek in the NW NE sec. 28, and roadcut to immediate west in NE NW sec. 28, in T. 21 S., R. 4 E., Marion County, Kansas

WINFIELD LIMESTONE

Grant Shale Member

3 ft 0 inches — Poorly exposed shale

Stovall Limestone Member

2 ft 6 inches — Bed of limestone, light-yellow biowackestone with abundant angular, brecciated-appearing, light-yellow and gray chert nodules; Reticulatia, ramose bryozoans, crinoids

DOYLE SHALE

Gage Shale Member

5 ft 4 inches — Sparsely fossiliferous mudrock, light- to medium-greenish-yellow; pectinid casts

1 ft 5 inches — Unfossiliferous mudrock, yellow-brown, underlain by a 1-inch-thick bed of shaly lime mudstone with laminae of palisades calcite

0 ft 10 inches — Unfossiliferous, yellow to medium-brown shale

1 ft 5 inches — Unfossiliferous, light-yellow, calcitic mudrock with rootcasts

3 ft 0 inches — Basal 4 inches of shaly limestone, intraclastic biowackestone-mudstone (foraminiferal), yellow-orange. Overlain by 2 ft of unfossiliferous, calcitic, yellow mudrock. Top 8 inches of thin-bedded, shaly limestone, biowackestone, dark-gray and orange (with crinoids, Composita)

4 ft 0 inches — Unfossiliferous, green shale and mudrock

10 ft 0 inches — Basal 5 ft not exposed; upper 5 ft of unfossiliferous, red mudrock

5 ft 0 inches — Poorly exposed, unfossiliferous, green shale and mudrock

Towanda Limestone Member

1 ft 0 inches — Thin-bedded limestone, fine-grained biopackstone, medium-gray and yellow; foraminifers

Measured Section Number: 86

Location: "Indian Guide" (Townsend Memorial): roadcut and adjoining field exposures and outcrops along Doyle Creek in SW sec. 30, T. 21 S., R. 4 E., Marion County, Kansas

NOLANS LIMESTONE

Herington Member

1 ft 9 inches — Thin-bedded dolomitic limestone, mudstone, yellow

Paddock Shale Member

8 ft 6 inches — Thin-bedded to fissile shale: mottled dark-gray and yellow in the basal 4 ft, which is sparsely fossiliferous (pectinid casts, Derbyia, fenestrate bryozoans), and yellow-orange and unfossiliferous in the upper 4 ft 6 inches, which includes scattered calcite nodules

Krider Member

1 ft 8 inches — Thin-bedded, shaly limestone, yellow mudstone, with a 2-inches-thick layer of mottled dark-gray and yellow, fossiliferous and bioturbated shale 8 inches above the base; pectinid casts

0 ft 8 inches — Sparsely fossiliferous, calcitic mudrock, mottled dark-gray and yellow; fenestrate bryozoans, pectinid casts

1 ft 11 inches — Thin-bedded, very shaly limestone, highly jointed mudstone, yellow with orange splotches, gradational top, sharp base; pectinid casts

ODELL SHALE

2 ft 6 inches — Unfossiliferous, fissile, yellow to light-green shale, laminated, numerous layers with halite

	crystal casts, including large hopper crystals. A 3-inches-thick layer of yellow-orange paleocaliche occurs 1 ft below the top
1 ft 6 inches	Unfossiliferous mudrock, color is light-greenish-gray in the basal 4 inches, and grades upward from dark-greenish-gray to lighter-greenish-gray above
2 ft 6 inches	Unfossiliferous, medium- to dark- grayish-green shale, splintery
7 ft 6 inches	Unfossiliferous, red mudrock with layers of green shale at 1.5 inches, 3 ft, and 6 ft 6 inches above the base
1 ft 2 inches	Unfossiliferous, green shale
1 ft 3 inches	Thin-bedded, hard, reddish-brown mudrock, unfossiliferous
1 ft 2 inches	Unfossiliferous, green mudrock
1 ft 3 inches	Unfossiliferous, fissile shale, color grades upward from medium- and dark-greenish-gray to yellow-brown
0 ft 8 inches	Unfossiliferous, light-yellow-gray shale, fissile
2 ft 4 inches	Unfossiliferous, light-brownish-gray mudrock
6 ft 0 inches	Concealed

WINFIELD LIMESTONE

Luta Member

10 ft 0 inches	Medium-bedded, shaly limestone, mudstone, light-gray (too covered with lichen to determine fossil content)

Measured Section Number: 87

Location: Roadside outcrops along US–77 near the confluence of the Cottonwood River and Doyle Creek, south of Florence, in NW sec. 18, T. 21 S., R. 5 E., and a supplemental section (of the Fort Riley) in a gully in the center S/2 of this section east of the highway, Marion County, Kansas

DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

5 ft 0 inches	Thin-bedded limestone, mudstone and interbedded/admixed lenses of biopackstone-grainstone, medium-gray; foraminifers, some crinoids and brachiopod fragments
0 ft 11 inches	Basal bed is lime mudstone, upper bed is coarse-grained, intraclastic biopackstone with an erosional base, yellow; foraminifers and some crinoids, gastropods, Derbyia
2 ft 0 inches	Thin-bedded to laminated limestone, mudstone with a lense of fine-grained biopackstone at the base, yellow; foraminifers and some crinoids, gastropods, Derbyia
2 ft 0 inches	Thin-bedded limestone, basal 1-ft beds of shaly limestone, intraclastic mudstone, yellow; upper two beds coarsen upward from fine-grained biopackstone to intraclastic biograinstone, yellow, the top of the unit is an erosional surface. Rocks contain foraminifers, crinoids, and brachiopod, pelecypod and gastropod fragments

Holmesville Shale Member

3 ft 4 inches	Unfossiliferous mudrock, light-greenish-gray in the lower half, yellow in the upper half
1 ft 8 inches	Thin-bedded, shaly limestone, porous and recrystallized mudstone with laminae of palisades calcite, calcite geodes, yellow to brownish-green
2 ft 1 inch	Unfossiliferous, splintery shale, dark-greenish-gray
1 ft 3 inches	Unfossiliferous, hard, yellow-brown, calcitic mudrock
6 ft 0 inches	Thin-bedded, unfossiliferous, calcitic shale, light-yellow-gray in the lower part, grading up to yellow-brown. In the middle of this unit is a 6-inches-thick bed of dark-greenish-gray mudrock. The basal 1 ft of section contains calcite geodes, which also are developed sporadically throughout the section. A few inches of shaly limestone occurs near the top, and is intraclastic mudstone at the base, grading up to biowackestone (pelecypod fragments)

FORT RILEY FORMATION

5 ft 0 inches	Thin-bedded, shaly limestone, mudstone, light-yellow-gray
5 ft 10 inches	Thin-bedded section: basal 1 ft 4 inches fines upward from shaly biowackestone to mudstone, light-brownish-yellow. The overlying 3 ft 10 inches is lime mudstone with Planolites, light-gray (Myalina, crinoids, brachiopod fragments); the top 8 inches of this unit is dark-gray, fossiliferous, calcitic shale (Derbyia, high-spired gastropods)
1 ft 2 inches	Bed of shaly limestone, mudstone, that coarsens upward to more of a shaly biowackestone, light-grayish-yellow; Derbyia, Myalina, echinoid fragments
5 ft 0 inches	Fossiliferous, calcitic mudrock to shaly lime mudstone, abundant Planolites, some lenses of shaly biowackestone, dark-gray; foraminifers, crinoids, brachiopod fragments
6 ft 4 inches	Thin-bedded to laminated, shaly limestone, mudstone, with Planolites burrows filled with foraminiferal biowackestone-packstone, light-yellow-gray, although the basal 2 ft weathers a prominent dark gray. In the upper half of the section the laminites are physically deposited laminae, locally with desiccation cracks and intraclasts. Along the southern end of the outcrop of this unit, the mudstone passes into a 2-ft-thick lense of porous, coarse-grained, intraclastic biopackstone to grainstone that occurs from 1 ft 10 inches to 3 ft 10 inches

below the top of this unit. The unit as a whole contains some crinoids, foraminifers, and Composita; the packstone-grainstone lenses contains foraminifers
In the gully exposures in sec. 18, this equivalent horizon is represented by 2 ft 8 inches of prominently large-scale cross stratified biopackstone, porous, yellow, with foraminifers and bivalve fragments

4 ft 0 inches	Thin-bedded, shaly limestone, mudstone, bioturbated, light-gray, the top 3 inches is a bed of light-brown biowackestone; crinoids, Derbyia

Measured Section Number: 88

Location: Roadcut in the extreme NE sec. 16, T. 21 S., R. 5 E., ~0.5 mi south of the Cottonwood River, Marion County, Kansas

MATFIELD SHALE

Blue Springs Shale Member

6–7 ft	Concealed section beneath cherty Florence along the road

Kinney Limestone Member

1 ft 4 inches	Medium-bedded limestone, biopackstone-grainstone, light-gray; foraminifers
3 ft 4 inches	Thick-bedded limestone, coarsens upward from biopackstone to biograinstone, surface-dissolution vugs, stylolites near the top, light-gray; foraminifers, and some crinoids and brachiopods

Measured Section Number: 89

Location: Martin Marietta Sunflower quarry (formerly Jones quarry), SE sec. 6, T. 21 S., R. 5 E., Marion County, Kansas (Prosser's type locality of the Florence)

Comment: The upper Florence and lower Fort Riley are exposed directly across the road, to the east, in the W/2 sec. 5 in the Florence Rock Company quarry

DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

2 ft 8 inches	Thin-bedded, shaly limestone, biowackestone-packstone, and thin interbeds of unfossiliferous shale, yellow; foraminifers
1 ft 7 inches	Interbeds of limestone, biograinstone, and unfossiliferous shale, yellow; foraminifers
0 ft 8 inches	Thin-bedded limestone, biograinstone, yellow; foraminifers
0 ft 7 inches	Basal 6-inches bed of limestone that grades upward from mudstone to biograinstone, and which is overlain by and passes laterally into a maximum of 7 inches of shaly limestone, mudstone, yellow; foraminifers
1 ft 4 inches	Thin-bedded limestone, mudstone, yellow
1 ft 9 inches	Thin interbeds of yellow, calcitic and unfossiliferous shale and limestones, beds of the latter which fine upward from biopackstone to biowackestone; the basal few inches of shale in this unit are fissile and black. Rocks contain pelecypod fragments, foraminifers
0 ft 8 inches	Bed of shaly limestone, mudstone, yellow

Holmesville Shale Member

5 ft 0 inches	Unfossiliferous mudrocks: basal 11 inches are light brown; overlain by 2 inches dark green, and then, 1 ft 2 inches of light-brown mudrock, then 2 ft orange gray, top 9 inches is light yellow tan
1 ft 2 inches	Unfossiliferous, dark-green shale
2 ft 11 inches	Unfossiliferous, light-yellow-green mudrock
0 ft 8 inches	Unfossiliferous, dark-green shale
0 ft 9 inches	Bed of shaly lime mudstone
2 ft 0 inches	Unfossiliferous, dark-green mudrock with rootcasts

FORT RILEY FORMATION

4 ft 0 inches	Thin- to medium-bedded, shaly limestone, mudstone, laminated (cryptalgal), with fenestral fabric and abundant celestite molds, light-yellow
3 ft 10 inches	Medium-bedded, shaly limestone, mudstone, vaguely laminated, with abundant calcite-lined geodes and celestite molds, light-yellow-tan
0 ft 8 inches	Unfossiliferous shale, orange-brown grading up to dark-green
8 ft 10 inches	Thin-bedded, shaly limestone, mudstone, abundant calcite-lined geodes, light-gray; rare crinoids
7 ft 4 inches	Thin- to medium-bedded, shaly limestone, mudstone, rare mm-thick lenses of biowackestone-packstone, generally light-gray (although the section from 2 ft 6 inches to 5 ft 6 inches above the base conspicuously weathers dark gray); brachiopod fragments, crinoids
2 ft 7 inches	Thin-bedded limestone, mudstone with Skolithos and some desiccation cracks, and erosional-based layers of intraclastic biowackestone-packstone, yellow; crinoids, brachiopod fragments, foraminifers
3 ft 7 inches	Medium-bedded, shaly limestone, mudstone, with upward-thinning layers of biowackestone-packstone, some Skolithos, light-gray; crinoids, brachiopod fragments
0 ft 8 inches	Basal 3 inches of dark-gray shale with Planolites; upper 5 inches of laminated, shaly lime mudstone, yellow
1 ft 0 inches	Bed of shaly limestone that fines upward from biopackstone to graded layers of mudstone and

	biopackstone, yellow; foraminifers, crinoids, brachiopod fragments, ramose bryozoans
2 ft 4 inches	Basal 2 ft 1 inch of medium-bedded limestone, mudstone, bioturbated, light-yellow; overlain by 3 inches of light-yellow, fossiliferous shale; crinoids, brachiopod fragments
1 ft 4 inches	Bed of limestone, sparse biowackestone, bioturbated, light-yellow; crinoids, brachiopod fragments
1 ft 4 inches	Bed of limestone, fines upward from sparse biowackestone to shaly, sparse biowackestone, light-yellow; crinoids, brachiopod fragments, foraminifers
4 ft 0 inches	Bed of limestone, biowackestone, prominent sub-vertical burrows at the top, light-yellow; crinoids, brachiopod fragments, ramose bryozoans
3 ft 4 inches	Bed of limestone, mudstone, light-yellow; brachiopod fragments, crinoids, ramose bryozoans
1 ft 4 inches	Bed of limestone, mudstone, light-yellow, stylolites at base, middle, and top; crinoids, brachiopod fragments
1 ft 4 inches	Bed of shaly limestone, biopackstone, silty, light-yellow; abundant echinoid spines, and Reticulatia, crinoids, Composita, Derbyia, fenestrate and ramose bryozoans

FLORENCE FORMATION

Oketo Shale Member

2 ft 9 inches	Highly fossiliferous, dark-gray up to dark- and yellow-gray, silty mudrock, bioturbated; Composita, Amphiscapha, gastropods, crinoids, echinoid fragments, ramose bryozoans; oncolitic in lower half, including large oncolites

Middle part of the formation

1 ft 6 inches	Bed of limestone, oncolite biowackestone-packstone, light-yellow; contact with Oketo is somewhat gradational; ramose and fenestrate bryozoans, crinoids, Derbyia
3 ft 5 inches	Bed of limestone, biowackestone, very light yellow, with discontinuous layers of chert nodules and scattered nodules throughout; fenestrate bryozoans, spicules, crinoids, Reticulatia, ramose bryozoans
1 ft 0 inches	Interbedded light-yellow, fossiliferous mudrock and shaly limestone, mudstone-biowackestone; crinoids, fenestrate and ramose bryozoans, echinoid fragments, Composita, Derbyia
1 ft 9 inches	Bed of limestone that coarsens upward from mudstone to biowackestone-packstone, bioturbated, very light gray, layers of discontinuous chert nodules; ramose bryozoans, crinoids, Composita, planispiral gastropods, some rugose corals
3 ft 1 inches	Bed of limestone, biowackestone, very light gray, with 3-inches-thick layers of discontinuous chert nodules; spicules, ramose bryozoans, crinoids, fenestrate bryozoans, Derbyia
5 ft 4 inches	Bed of limestone that coarsens upward from sparse biowackestone to biopackstone, very light gray, with 3-inches-thick layers of discontinuous chert nodules and scattered small chert nodules throughout; prominent stylolite about 1 ft above the base. Rocks contain spicules, ramose and fenestrate bryozoans, Derbyia, Reticulatia
2 ft 4 inches	Bed of limestone, sparse biowackestone, light-gray, abundant small vugs in the lower part; crinoids. This bed likely is the "cellular" limestone referred to by Prosser (1895)
3 ft 0 inches	Bed of limestone, sparse biowackestone, very light yellowish-gray, with orange-stained vugs, and 3-inches-thick, discontinuous layers of chert nodules and nodules throughout; fenestrate bryozoans, brachiopod fragments
3 ft 9 inches	Bed of limestone, biowackestone, very light yellow gray, dissolution vugs in upper part, with 3-inches-thick, discontinuous layers of chert nodules; ramose and fenestrate bryozoans, crinoids, Derbyia
3 ft 4 inches	Medium-bedded limestone, fines upward from biopackstone to slightly shaly biowackestone-packstone, light-gray: limestone beds are 8–9 inches thick, separated by layers of chert ~3 inches thick. Rocks contain fenestrate bryozoans, crinoids, brachiopod fragments; fusulinids in the upper half
2 ft 5 inches	Fining-upward section: basal 9 inches of shaly limestone, biowackestone, bioturbated, dark-gray, chert nodules. Overlain by 8 inches dark gray, fissile, fossiliferous shale. Top 1 ft of medium-gray, fossiliferous mudrock, bioturbated, chert nodules. Rocks contain ramose and fenestrate bryozoans, crinoids, Derbyia, Allorisma, Amphiscapha

Measured Section Number: 90

Location: Presently inactive Martin Marietta quarry, SE sec. 4, T. 21 S., R. 4 E., Marion County, Kansas

WINFIELD LIMESTONE

Luta Member

7 ft 0 inches	Thin- to medium-bedded limestone, shaly, mostly all bioturbated (horizontal, some vertical burrows), light-yellow, scattered small, light-gray chert nodules throughout (typically replacing burrows). Few inches of laminated (cryptalgal) and desiccated lime mudstone about 1 ft 6 inches above the base. Rocks contain scattered echinoid spines, planispiral gastropods, crinoids, Reticulatia
4 ft 6 inches	Thick-bedded limestone, light-yellow, slightly shaly at top, mudstone. The top 5 inches is thin bedded to laminated, and the rest of the unit is bioturbated; calcite geodes throughout and a

	thin, discontinuous layer of light-gray chert at the base. Rocks contain rare crinoids
4 ft 6 inches	Medium-bedded, shaly limestone, mudstone, light-yellow, scattered silicified fossils and small, light-gray chert nodules with evaporite-crystal relicts; some crinoids, brachiopod fragments, bryozoans

Measured Section Number: 91

Location: Martin Marietta North Marion quarry, NW sec. 28, T. 19 S., R. 4 E., Marion County, Kansas

Comments: This is an active quarry, and some parts of the quarry where we have measured sections have since been infilled. The descriptions below are a composite of sections measured in the northeast, southeast, and southwest parts of the quarry during 1995 and 1996

Nearby measured section number 91A supplements this exposure with outcrops of the Gage Member of the Doyle Shale up to the Cresswell Member of the Winfield Limestone.

ODELL SHALE

6 ft 0 inches	Along the presently active southeast wall of the quarry, this unit is unfossiliferous, red shale capped by top soil

WINFIELD LIMESTONE

Luta Member

6 ft 0 inches	Along the southwest wall of the quarry this unit is medium-bedded limestone, porous and cross stratified biograinstone, partly oolitic, coarse-grained and with some intraclasts of lime mudstone, light-gray. Along the southeast wall of the quarry, this unit is represented by, in ascending order: (a) 1 ft 10 inches of thin-bedded, shaly lime mudstone with evaporite nodule molds, and small intraclasts of lime mudstone at the top, light-gray; (b) 10 inches of thin-bedded, fine-grained oolite grainstone, some intraclasts of lime mudstone, light-gray; (c) 6 inches of thin-bedded, shaly lime mudstone, recrystallized, with evaporite nodule molds, light-gray; and (d) 1 ft 4 inches of breccia: clasts of light-gray lime mudstone with evaporite nodule molds; the unit has an irregular top
3–4 inches– 3 ft 10 inches	Unfossiliferous shale: along the south-west wall, this unit is mostly light gray with a 6-inches-thick layer of red shale at the top, and includes abundant anhydrite nodules and a thin lense of lime mudstone just below the top. Along the southeast wall this freshly exposed unit is light gray and calcitic. Along the now-covered northeast wall of the quarry, this unit was 2 ft 3 inches (overlying the desiccated, cryptalgal laminites of the Luta: see underlying unit) of unfossiliferous, dark-greenish-gray shale; this unit is the "Odell-like shale" referred to in the text
16 ft 0 inches	Thin- to mostly medium-bedded, shaly limestone, mudstone: bioturbated and with small, light-gray chert nodules throughout except for in the top 2 ft, which is a conspicuous bed of cryptalgally laminated mudstone with large desiccation cracks, and on the top bedding plane, large-diameter (2–3 ft) desiccation polygons. Anhydrite nodules are common throughout, but increase dramatically in abundance in the top 2 ft 2 inches of the unit. There is an 8–9-inches-thick bed about 6 ft above the base with desiccation cracks. The unit contains rare crinoids below the top.

Cresswell Limestone Member

0 ft 10 inches	Bed of shaly limestone, oncolite biowackestone, light-gray; some crinoids
1 ft 8 inches– 2 ft 1 inch	Bed of limestone, oncolite biopackstone-grainstone, yellow, with large, oval, black chert nodules that weather brown; crinoids, some bryozoans

Grant Shale Member

~11 ft 0 inches	This unit was exposed along the northeast end of the, but is now infilled. There, it was fossiliferous mudrock and shaly mudstone-sparse biowackestone, bioturbated, dark-gray, with calcite and chert geodes; the top 3 ft of this unit is unfossiliferous, gray shale with anhydrite nodules (exposed along the southwest wall of the quarry). Fossils included brachiopod fragments, including Derbyia, fenestrate bryozoans, crinoids, echinoid fragments

Measured Section Number: 91A

Location: Streambank outcrop immediately west of US–77, in the SE SE sec. 3, and roadside outcrop along dirt road in the NE NE sec. 10, in T. 20 S., R. 4 E., Marion County, Kansas (a few miles southeast of measured section number 90)

Comment: This outcrop exposes the thickest Stovall section we have seen anywhere in the study area

WINFIELD LIMESTONE

Cresswell Limestone Member

2 ft 8 inches	Bed of limestone, sparse oncolite biopackstone, light-brown, with oval nodules of black chert that weather brown; crinoids, some ramose bryozoans

3 ft 3 inches	Concealed contact between the Grant and Cresswell

Grant Shale Member

2 ft 9 inches	Sparsely fossiliferous, light-gray mudrock with abundant golfball-size chert nodules; Reticulatia, Derbyia, crinoids, echinoid fragments
1 ft 11 inches	Basal 1 ft 2 inches bed of shaly limestone, biowackestone, light-yellow, with silicified fossils; overlain by thin-bedded, shaly limestone, mudstone, with scattered silicified fossils, light-yellow, and calcite-lined geodes. Basal 1 ft 2 inches with abundant Composita and lesser Reticulatia, crinoids, echinoid fragments; overlying beds with considerably lesser numbers of the same fossils

Stovall Limestone Member

2 ft 8 inches	Bed of limestone, dense biowackestone, light-gray, with light-gray, angular chert nodules except in the top 3 inches (which, instead, includes abundant silicified fossils); very abundant Composita, and crinoids, ramose and fenestrate bryozoans, echinoid spines, Reticulatia
0 ft 7 inches	Bed of limestone, coarse-grained biowackestone, light-yellow-gray, silicified fossils, angular chert nodules at the very top; crinoids, some brachiopod fragments

DOYLE SHALE

Gage Shale Member

1 ft 1 inches	Bed of shaly limestone, biowackestone, light-yellow, small anhydrite-calcite nodules; crinoids, brachiopod fragments
1 ft 8 inches	Sparsely fossiliferous, light-gray to yellow mudrock, slightly calcitic to more calcitic toward the top; pelecypod casts, crinoids, Orbiculoides

Measured Section Number: 92

Location: Luta type locality quarry ("crusher quarry"), in W/2 NW sec. 15, T. 19 S., R. 4 E., Marion County, Kansas

Comment: Part of the Luta section is also exposed in the creek valley that crosses the dirt road to the immediate north of the quarry

NOLANS LIMESTONE

Herington Member

1 ft 0 inches	Thin-bedded, calcitic dolomite, coarsens upward from mudstone to porous, fine-grained biowackestone, yellow; molds of foraminifers, pelecypods, and gastropods

Paddock Shale Member

7 ft 0 inches	Poorly exposed: sparsely fossiliferous, mottled dark-gray and yellow shale and mudrock in lower half (Derbyia, crinoids), yellow and apparently unfossiliferous mudrock in upper half, with calcite nodules

Krider Member

0 ft 8 inches	Thin-bedded, shaly dolomudstone, splotchy yellow-orange; fenestrate bryozoans, pelecypod fragments, Composita
0 ft 11 inches	Fossiliferous, calcitic mudrock, splotchy dark-gray and yellow; pectinid casts
0 ft 10 inches	Thin- to medium-bedded, shaly dolomudstone, splotchy yellow-orange; Aviculopecten, Permophorus

ODELL SHALE

2 ft 6 inches	Unfossiliferous mudrock and shale, yellow-green at base, slightly darker-green above, becoming greenish-yellow toward the top
0 ft 9 inches	Unfossiliferous, splintery green shale
4 ft 0 inches	Unfossiliferous, dominantly red mudrock, with thin layers of green shale and/or mudrock 1 ft, 1 ft 6 inches, and 3 ft above the base
1 ft 10 inches	Unfossiliferous mudrock, dark-green-gray grading up to red and green
0 ft 5 inches	Ledge of medium-gray, calcitic and unfossiliferous mudrock
1 ft 4 inches	Unfossiliferous mudrock, medium-gray grading up to reddish-green

WINFIELD LIMESTONE

Luta Member

5 ft 6 inches	Thin-bedded, shaly dolomudstone, white, scattered calcite-quartz-anhydrite nodules and vugs from their dissolution; scattered light-gray chert nodules in the lower beds; the top 1 ft 5 inches is very thin bedded and very shaly
1 ft 10 inches	Medium-bedded, calcitic dolopackstone, white, pinches out to the south along the west-facing wall of the quarry, where it is replaced by dolomudstone; pelecypod and gastropod fragments
2 ft 6 inches	Dolomitic mudrock, white, with calcite-quartz-anhydrite nodules, and a discontinuous, 1-inch-thick layer of light-gray chert at the base. Highly fossiliferous at the top (planispiral gastropods, ammonites [Perrinites or Properrinites], Allorisma, high-spired gastropods, Aviculopecten)

1 ft 4 inches	Bed of very shaly dolomudstone, cryptalgal laminated, light-yellow; scattered light-gray chert nodules at the base, calcite-quartz-anhydrite nodules and vugs from their dissolution
4 ft 7 inches	Dolomitic mudrock, light-yellow, with increasing amount of calcite-quartz-anhydrite nodules upsection, and vugs from their dissolution. Locally bioturbated (but otherwise unfossiliferous), with some small, light-gray chert nodules (some of which follow burrows) throughout. An 8-inches-thick bed of more resistant shaly dolomudstone at the base
0 ft 8 inches	Bed of shaly dolomudstone, very light yellow gray, some calcite-quartz-anhydrite nodules
1 ft 9 inches	Bed of shaly dolomudstone, very light yellow gray, some calcite-quartz-anhydrite nodules
2 ft 10 inches	Bed of shaly dolomudstone, light-yellow, scattered calcite-quartz-anhydrite nodules and vugs from their dissolution
3 ft 9 inches	Thick-bedded, shaly dolomudstone, white, crudely laminated, calcite-quartz-anhydrite nodules and vugs from their dissolution
1 ft 8 inches	Medium-bedded, shaly, calcitic dolomite, white, fines upward from sparse biowackestone to mudstone, discontinuous layers of small, black chert nodules (crinoids)
4 ft 0 inches	Medium-bedded, shaly dolomudstone, white and yellow-orange, some calcite-quartz-anhydrite nodules

Cresswell Limestone Member

1 ft 0 inches	Bed of limestone, relatively coarse-grained biopackstone, light-yellow, with oval, black chert nodules that weather brown; crinoids, ramose bryozoans
0 ft 4 inches	Thin-bedded limestone, mudstone, nodules of black chert

Measured Section Number: 93

Location: Roadcuts, both sides of K–177, 1.3 mi south of the intersection of K–177 and US–56, in SW SE sec. 23, T. 16 S., R. 8 E., Morris County, Kansas

Comment: This section was measured from only the Kinney to the base of the Florence; an additional few feet of Florence are present here on the east side of the road

MATFIELD SHALE

Blue Springs Shale Member

1 ft 10 inches	Unfossiliferous, yellow to brownish-green mudrock with calcite nodules (paleocaliche)
1 ft 9 inches	Bruno limestone bed: bed of shaly limestone, mudstone, greenish-yellow, rootcasts throughout
2 ft 11 inches	Unfossiliferous, light-green mudrock
4 ft 6 inches	Unfossiliferous mudrock: interbedded green and red in the basal 1 ft, red above

Kinney Limestone Member

2 ft 10 inches	Medium-bedded limestone, fine-grained and porous biograinstone, cross stratified, some intraclasts of lime mudstone. The top 8 inches fines upward from biopackstone to mudstone with foram-encrusted intraclasts of green, shaly mudstone with large quartz grains. On the east side of the road the top of the member is light gray, intraclastic, shaly, and dolomitic. Prominent stylolite about 1 ft 4 inches below the top. Rocks contain foraminifers, pelecypod fragments
2 ft 0 inches	Two beds of limestone, fine-grained, porous biopackstone, bioturbated, intraclastic (lime mudstone) at the top, light-yellow-gray; foraminifers, pelecypod fragments
1 ft 6 inches	Fossiliferous, yellow-brown mudrock to shaly lime mudstone; pelecypod fragments

Measured Section Number: 94

Location: Roadcuts on US–56, north side, in SW sec. 11, T. 16 S., R. 9 E., Morris County, Kansas

Comment: This section exposes facies of the Threemile that do not include "reef" deposits as in other measured sections of the Wreford in this county

WREFORD LIMESTONE

Havensville Shale Member

0 ft 6 inches	Very fossiliferous, gray, bioturbated mudrock, large horizontal burrows; ramose bryozoans, crinoids, Derbyia, Reticulatia, Chonetes, Composita, fenestrate bryozoans, Amphiscapha

Threemile Limestone Member

1 ft 2 inches	Thin-bedded, shaly limestone, biowackestone, large skeletal fragments, light-yellow-gray, chert nodules; ramose bryozoans, crinoids, Derbyia, Reticulatia, Chonetes, Composita, fenestrate bryozoans, Amphiscapha
0 ft 6 inches	Layer of chert
3 ft 0 inches	Medium-bedded limestone, coarsens upward from biowackestone through fine-grained and then very coarse grained biopackstone, very porous (blade-shaped pores),white; rare chert nodules, and a thin layer of chert 1 ft below the top. Rocks contain crinoids, fenestrate and ramose bryozoans, brachiopod fragments; very abundant ramose bryozoans at the top

3 ft 1 inches Thick-bedded limestone, coarsens upward from mudstone to biowackestone to packstone, porous, white; scattered round to discoidal chert nodules, and a 4-inches-thick layer of chert at the top. Rocks contain fenestrate and ramose bryozoans, crinoids, brachiopod fragments

0 ft 8 inches Chert layers at top and base separated by white, porous lime mudstone with blade-shaped pores; fenestrate bryozoans, crinoids, brachiopod fragments, gastropods

2 ft 0 inches Medium-bedded limestone, mudstone, light-yellow at base, white at top; chert nodules in lower bed, prominent layer of chert in the middle. Rocks contain crinoids, brachiopod fragments

1 ft 8 inches Fossiliferous, calcitic mudrock in lower half, calcitic mudrock to shaly biowackestone in upper half, yellow; crinoids, bryozoans

2 ft 4 inches Medium-bedded limestone, coarsens and then fines upward from mudstone (basal bed) to biowackestone (middle two beds) to biopackstone-wackestone (upper bed), light-gray, layers of chert and chert nodules; crinoids, bryozoans, brachiopod fragments

SPEISER FORMATION

2 ft 0 inches Fossiliferous, yellow shale (crinoids, Derbyia, echinoid fragments)

2 ft 0 inches Concealed

2 ft 0 inches Unfossiliferous mudrock, green grading upward to yellow-green

3 ft 0 inches Unfossiliferous, red mudrock, becomes yellow-green at the top

2 ft 0 inches Beige paleocaliche

Measured Section Number: 95

Location: Composite of four closely spaced localities: (1) roadcut on US–56 east of Council Grove, SW sec. 11, T. 15 S., R. 9 E.; (2) roadcut on US–56 east of Council Grove, SW sec. 7, T. 16 S., R. 9 E., NE sec. 13, T. 16 S., R. 8 E., and NW sec. 18, T. 16 S., R. 9 E.; (3) roadcut on K–177, about 1.5 mi north of Council Grove, in SE sec. 2, T. 16 S., R. 8 E.; and (4) roadcut on K–177, in SW sec. 23, T. 15 S., R. 8 E., Morris County, Kansas

WREFORD LIMESTONE

Schroyer Limestone Member
(top of the member)

3 ft 1 inch Bed of limestone, coarsens upward from fine-grained biopackstone to biograinstone, with a hint of cross stratification, with green shale in interparticle pores and vugs at the top, light-gray; foraminifers, pelecypod fragments, crinoids, Derbyia

3 ft 4 inches Thin-bedded, shaly limestone, mudstone, white, rare small chert nodules, and some thin beds of shale (1–2 inches thick) in the top 10 inches; crinoids, pelecypod and echinoid fragments, Composita, Reticulatia

2 ft 4 inches Bed of limestone, fines upward from very coarse grained biopackstone-grainstone to biowackestone with lenses of biopackstone, very light gray, surface-dissolution vugs; bounded at top and base by prominent stylolites. Rocks contain crinoids, some brachiopod fragments

0 ft 7 inches Basal 3 inches of unfossiliferous, yellow shale overlain by 4 inches of yellow lime mudstone with dark speckles

3 ft 0 inches Medium-bedded limestone, very cherty (almost completely replaced by thick layers of chert: slightly shaly mudstone-sparse biowackestone, light-yellow. The top 5 inches is noncherty and nonshaly biowackestone-packstone, very light gray. Fossils in the lower half of the unit are Composita, crinoids, fenestrate and ramose bryozoans; in the upper half, crinoids and brachiopod fragments

2 ft 0 inches Thin-bedded, shaly limestone, mudstone, light-gray, the top 3 inches–12 inches being a lense of fossiliferous and calcitic mudrock, scattered chert nodules; crinoids, Composita; and also echinoid fragments at the top

Havensville Shale Member

2 ft 0 inches Fossiliferous, yellow-brown mudrock; pectinid casts, brachiopod fragments

1 ft 10 inches Ledge of thin-bedded, shaly limestone, mudstone-sparse biowackestone, becomes more shaly upsection, medium-gray grading up to very dark gray in the top 6 inches; crinoids, brachiopod fragments, ramose and fenestrate bryozoans, echinoid fragments

1 ft 11 inches Sparsely fossiliferous, light-yellow-gray, calcitic mudrock; crinoids, rare casts of pectinids

Threemile Limestone Member

1 ft 0 inches Thin-bedded, shaly limestone, mudstone, white to light-gray; crinoids

1 ft 8 inches Platy-bedded limestone, biowackestone, white, small chert nodules, and a thin layer of chert at the base; crinoids, brachiopod and echinoid fragments, ramose and fenestrate bryozoans

1 ft 5 inches Bed of limestone, biowackestone, white, scattered chert nodules; bryozoans, crinoids, Composita: "reef facies" referred to in the text

3 ft 11 inches Bed of limestone, very porous, layers of ramose bryozoan-rich biowackestone and packstone, very light yellow to white; crinoids, Chonetes, fenestrate bryozoans; in the top 3 inches, also with echinoid fragments, some Reticulatia and rugose corals: "reef facies" referred to in the text

3 ft 0 inches Bed of ramose bryozoan-rich limestone, porous, light-yellow grading up to white: basal 1 ft 3 inches of biowackestone-packstone, the lower 9 inches of which weather recessively and contain

	abundant celestite molds. Overlying facies are biowackestone, with scattered, small chert nodules at the top; two prominent stylolites in the middle of the unit. Rocks contain crinoids, Chonetes, fenestrate bryozoans: "reef facies" referred to in the text
5 ft 2 inches	Medium-bedded limestone, fines and then coarsens upward from sparse biowackestone to mudstone, and then to biowackestone-packstone, light- and white; layers of chert in lower half, and some chert nodules near base. Rocks contain crinoids, brachiopod fragments, spicules, bryozoans
1 ft 8 inches	Basal 10 inches fossiliferous, fissile, calcitic shale, yellow-gray (spicules, lesser fenestrate bryozoans, crinoids, Reticulatia, Chonetes, Composita, Derbyia, echinoid fragments); upper 10 inches calcitic mudrock to shaly biowackestone, yellow (crinoids, bryozoans, spicules)
2 ft 4 inches	Thin- to medium-bedded limestone, coarsens upward from mudstone in the basal bed to biowackestone in the overlying two beds, and then fines upward from biopackstone to biowackestone in the upper bed, light-gray, layers of chert near the base and top, scattered chert nodules in the middle; crinoids, spicules, fenestrate bryozoans, high-spired gastropods

SPEISER FORMATION

2 ft 0 inches	Fossiliferous, yellow mudrock; crinoids, Derbyia, ramose bryozoans, pectinid casts
2 ft 0 inches	Concealed
2 ft 0 inches	Unfossiliferous, green mudrock, yellow-green at the top
3 ft 0 inches	Unfossiliferous, red mudrock, yellow-green at the top
2 ft 0 inches	Bed of beige paleocaliche

Measured Section Number: 96

Location: Quarry in NE sec. 11, T. 16 S., R. 8 E., to the immediate north of the Kansas Instruments Building, due east of K–177, about 1.5 mi north of Council Grove, Morris County, Kansas

WREFORD LIMESTONE

Threemile Limestone Member (probable top of the member)

5 ft 6 inches	Bed of limestone, porous ramose bryozoan-rich biowackestone, white, thin layers of chert; Composita, echinoid fragments: "reef facies" referred to in the text
7 ft 0 inches	Bed of limestone, very porous, ramose bryozoan-rich layers of biowackestone and packstone, very light yellow to white, rare chert nodules; Composita, echinoid fragments: "reef facies" referred to in the text
4 ft 6 inches	Bed of limestone, porous: basal 1 ft 3 inches of light-yellow biowackestone-packstone, the lower 9 inches of which weathers recessively and contains celestite molds. Overlying rocks are white biowackestone, scattered small chert nodules; two prominent stylolites at and just below the middle; brachiopod fragments, cryozoans, crinoids, echinoid fragments
1 ft 6 inches	Thin-bedded limestone, biowackestone-packstone, light-yellow and white, thin layers of chert at top and in the middle; brachiopod fragments, crinoids, some bryozoans

Measured Section Number: 97

Location: Two closely spaced roadcuts on K–177, in the NW sec. 26, T. 15 S., R. 8 E., Morris County, Kansas

MATFIELD SHALE

Kinney Limestone Member

2 ft 0 inches	Thin-bedded limestone, intraclastic biopackstone-grainstone, top 2 inches of mudstone with lenses of biopackstone; intraclasts are yellow, shaly lime mudstone. Rocks contain foraminifers, some crinoids and pelecypod fragments
0 ft 8 inches	Two beds of limestone, intraclastic biowackestone-grainstone, yellow, intraclasts are yellow, shaly lime mudstone; foraminifers, pelecypod fragments, crinoids, Composita, Derbyia

Wymore Shale Member

10 ft 0 inches	Unfossiliferous, light-gray, calcitic mudrock, abundant calcite nodules in the top 4 ft (paleocaliche)
2 ft 1 inch	Unfossiliferous, green mudrock, with a 7-inches-thick paleosol at the top
2 ft 4 inches	Unfossiliferous, red mudrock
2 ft 6 inches	Concealed: likely, green shale/mudrock

WREFORD LIMESTONE

Schroyer Limestone Member

3 ft 0 inches	Bed of limestone, coarsens upward from biowackestone-packstone at the base to biograinstone at the top, with green shale in vugs and interparticle pores, light-gray; foraminifers, some crinoids and pelecypod fragments
0 ft 2 inches	Bed of limestone, mudstone, light-yellow with dark spots

Measured Section Number: 98

Location: Roadcut and streambank exposures along the Middle Branch of Munker Creek, SE sec. 31 and SW sec. 32, T. 14 S., R. 9 E., Morris County, Kansas

FLORENCE FORMATION

4 ft 0 inches	Thin- to medium-bedded limestone, very cherty mudstone, light-yellow: limestone beds about 3 inches thick separated by ~3-inches-thick layers of discontinuous chert nodules. Rocks contain crinoids, brachiopod fragments, ramose and fenestrate bryozoans
0 ft 9 inches	Basal 3-inches-thick layer of chert overlain by 6 inches of fossiliferous, yellow, calcitic mudrock with chert nodules; crinoids, brachiopod fragments
3 ft 8 inches	Thick-bedded limestone (three beds that thin upsection), light-yellow: basal bed fines upward from coarse-grained biopackstone to wackestone, middle bed is lime mudstone, upper bed is relatively coarse-grained biowackestone, scattered chert nodules, and layers of chert separate the three limestone beds. Rocks contain fenestrate bryozoans, brachiopod fragments, crinoids, spicules, ramose bryozoans in lower beds; crinoids, brachiopod fragments, and bryozoans in upper beds
1 ft 8 inches	Fossiliferous, calcitic mudrock, bioturbated, yellow-brown; scattered chert nodules in top 8 inches, where the shale includes very coarse grained skeletal hash. Rocks contain crinoids, echinoid fragments, Derbyia, Composita, Reticulatia, ramose and fenestrate bryozoans

Cole Creek Member

1 ft 4 inches	Thin-bedded, shaly limestone, biowackestone; crinoids, Chonetes, fenestrate bryozoans, Reticulatia, Composita

MATFIELD SHALE

Blue Springs Shale Member

1 ft 8 inches	Concealed
1 ft 6 inches	Unfossiliferous, green shale, splintery
2 ft 5 inches	Unfossiliferous, gray-green shale in lower part, grades up to yellowish, light-gray-green mudrock with abundant calcite nodules (paleocaliche) in upper part
2 ft 4 inches	Unfossiliferous, light-green-gray mudrock
0 ft 8 inches	Unfossiliferous, greenish-red shale
2 ft 8 inches	Unfossiliferous shale, interbedded red and red-tinted green; prominent 4-inches-thick ledge of red, silty mudrock at the top
6 ft 0 inches	Unfossiliferous, green mudrock with a reddish tint, crumbly

Kinney Limestone Member

1 ft 7 inches	Two beds of shaly limestone that fine upward from biopackstone to mudstone, light-yellow-gray; pelecypod fragments, crinoids
8 ft 5 inches	Unfossiliferous mudrock and shale: yellow-brownish-green in the lower part, darker-grayish-green in upper part with sporadic layers of red shale in the upper 3 ft
0 ft 7 inches	Bed of limestone, coarsens upward from intraclastic biowackestone to packstone, abundant brachiopod hash at the top; intraclasts are yellow, shaly lime mudstone. Rocks contain Derbyia, Composita, Juresania, foraminifers, ramose bryozoans, curved spines
1 ft 1 inches	Fossiliferous, light-yellow-brown mudrock; crinoids, echinoid fragments, Derbyia
2 ft 2 inches	Bed of limestone, coarsens upward from intraclastic biopackstone with disrupted layers of desiccated lime mudstone, to intraclastic biopackstone-grainstone, light-yellow-gray; intraclasts are yellow, shaly lime mudstone. Rocks contain foraminifers, crinoids, brachiopod fragments; Aviculopecten at the top
1 ft 10 inches	Unfossiliferous, fissile, yellow-brown shale
0 ft 4 inches	Ledge of shaly limestone, intraclastic biowackestone, yellow; intraclasts are yellow, shaly lime mudstone. Rocks contain spicules, some crinoids, foraminifers, brachiopod fragments

Wymore Shale Member

9 ft 4 inches	Unfossiliferous, yellow-brown shale, fissile
2 ft 8 inches	Unfossiliferous, green mudrock
0 ft 6 inches	Unfossiliferous, red shale

Measured Section Number: 99A and 99B

Location: Composite: measured section 99A encompasses the roadcuts on US–56, about 9 mi west of Council Grove, in SW sec. 15 and NW sec. 22, T. 16 S., R. 7 E. Measured section 99B encompasses roadcut and streambank exposures along Ralls Creek, in NW sec. 9 and NE sec. 8, T. 14 S., R. 6 E. (just south of Skiddy), and the roadcuts in the NE sec. 5, T. 14 S., R. 6 E. (due northeast of Skiddy), in Morris County, Kansas

FORT RILEY FORMATION

1 ft 4 inches	Medium-bedded limestone, sparse biowackestone, porous, light-gray; Derbyia, Composita, crinoids
4 ft 0 inches	Bed of limestone, porous, light-yellow: basal 2 ft is vertically burrowed biopackstone (foraminifers, some crinoids, oncolites, ramose

bryozoans); upper 2 ft fines upward from biowackestone to mudstone (crinoids, brachiopod fragments, ramose bryozoans). This bed is the Fort Riley main ledge referred to in the text

1 ft 10 inches — Platy-bedded, shaly limestone, biopackstone, light-yellow; abundant echinoids and lesser crinoids, ramose bryozoans, brachiopod fragments, Allorisma

FLORENCE FORMATION

Oketo Shale Member

2 ft 0 inches — Sparsely fossiliferous, yellow to greenish-brown mudrock; ramose bryozoans, Allorisma, Derbyia, crinoids

3 ft 0 inches — Fossiliferous, yellow-brown mudrock, calcitic; ramose bryozoans, Allorisma, Derbyia, crinoids

Middle part of the formation

1 ft 4 inches — Thin-bedded, shaly limestone, coarsens upward from mudstone to biowackestone, light-yellow; crinoids, Derbyia, locally abundant ramose bryozoans

2 ft 0 inches — Poorly exposed limestone, mudstone, light- to medium-gray, rare chert nodules at the top

2 ft 8 inches — Medium-bedded limestone, biowackestone, light-yellow, with layers and scattered "balls" of chert; ramose and fenestrate bryozoans, echinoid fragments, crinoids, Reticulatia

2 ft 8 inches — Medium-bedded limestone, biowacke-stone-packstone, light-yellow, with discontinuous layers of large chert nodules at 3 inches and 2 ft 2 inches above the base, and chert "balls" scattered throughout, especially abundant 7 inches above the base; fenestrate and ramose bryozoans, echinoid fragments, crinoids, Reticulatia

3 ft 8 inches — Thin-bedded limestone, coarsens upward from mudstone to sparse biowackestone, to biowackestone-packstone at the top, light-yellow; conspicuous chert "balls" and dumb-bell shaped chert nodules (the latter following burrows), and prominent chert layers at 6 inches, 1 ft, 2 ft, and 3 ft above the base. Rocks contain Composita, crinoids, ramose bryozoans, Reticulatia, Aviculopecten

2 ft 0 inches — Thin-bedded limestone, mudstone, with conspicuous blade-shaped pores and abundant stylolites, white to light-yellow; white intraclasts in the middle of the unit. Rocks contain pelecypod fragments, lesser Composita, Reticulatia, echinoid fragments

6 ft 0 inches — Thin- to medium-bedded limestone, very cherty mudstone, with sparse biowackestone in the top 2 ft, light-yellow; limestone beds ~3 inches thick separated by ~3-inches-thick layers of discontinuous chert nodules. Rocks contain crinoids, brachiopod fragments, fenestrate and ramose bryozoans

Cole Creek Member

0 ft 3 inches — Fossiliferous, calcitic mudrock, yellow; brachiopod fragments, crinoids

Measured Section Number: 100

Location: Roadcut on K–10, in SW sec. 25, T. 14 S., R. 5 E., ~8 mi southwest of Skiddy, Morris County, Kansas

WINFIELD LIMESTONE

Cresswell Limestone Member

2 ft 0 inches — Bed of dolomitic limestone, shaly and silty mudstone, light-brownish-yellow, abundant calcite-quartz-anhydrite nodules at the base and scattered throughout, appears laminated at the top; ramose and fenestrate bryozoans, crinoids, Derbyia

Grant Shale Member

9 ft 6 inches — Fossiliferous, light-gray mudrock, bioturbated, but the top 1 ft 6 inches is unfossiliferous and contains abundant calcite-quartz-anhydrite nodules; Derbyia, Composita, crinoids, ramose bryozoans

Stovall Limestone Member

1 ft 10 inches — Bed of limestone, biowackestone, light-gray, small and larger, anastomosing chert nodules, gray; crinoids, echinoid fragments, fenestrate and ramose bryozoans, Reticulatia

DOYLE SHALE

Gage Shale Member

7 ft 10 inches — Greenish-yellow mudrock, fossiliferous at least in the upper half; Derbyia, crinoids, fenestrate and ramose bryozoans, echinoid fragments, Composita

1 ft 0 inches — Prominent ledge of orange, calcitic mudrock with abundant calcite veinlets and lined vugs, porous and fossiliferous; foraminifers, brachiopod fragments

1 ft 11 inches — Unfossiliferous, yellow mudrock, with a prominent ledge in the lower half with vertical root tubules

4 ft 7 inches — Unfossiliferous, yellow-brown mudrock with sporadic layers of fossiliferous, green shale in the upper half of the unit; pelecypod fragments, planispiral gastropods

12 ft 0 inches — Basal 4 ft not exposed; upper 8 ft is unfossiliferous, redmudrock with a 1 ft 2 inches thick layer of green mudrock 2 ft 6 inches below the top

Measured Section Number: 101

Location: Roadcut in SW NW sec. 6, T. 14 S., R. 6 E., just southwest of Skiddy, Morris County, Kansas

DOYLE SHALE

Towanda Limestone Member

1 ft 0 inches	Shaly limestone, mudstone, laminated (cryptalgal), light-gray
0 ft 8.5 inches	Basal 1.5 inches of shaly lime mudstone overlain by 7 inches of biopackstone, light-gray; foraminifers, some crinoids and pelecypod fragments
0 ft 8 inches	Breccia, clasts of yellow, shaly lime mudstone
0 ft 7 inches	Basal 1 inch of shaly lime mudstone overlain by 6 inches of yellow, unfossiliferous shale
1 ft 4 inches	Thin-bedded limestone, biopackstone at top and base, shaly lime mudstone in the middle, greenish-gray; foraminifers, pelecypod fragments
0 ft 10 inches	Thin-bedded, shaly limestone, coarsens upward from lime mudstone to biopackstone, green-gray; foraminifers

Holmesville Shale Member

5 ft 0 inches	Unfossiliferous, yellow mudrock
1 ft 6 inches	Unfossiliferous, olive-green mudrock

Measured Section Number: 102

Location: Roadcut on US–77 in SW sec. 24, T. 16 S., R. 4 E., southeast end of Herington, Dickinson County, Kansas

NOLANS LIMESTONE

Herington Member
(probable top of the member)

0 ft 4 inches	Bed of calcitic dolomudstone, brecciated and calcite-cemented, light-yellow
2 ft 10 inches	Thin-bedded, shaly dolomudstone and dolomitic mudrock, light-yellow
0 ft 8 inches	Basal 4 inches of dolomitic shale overlain by 4 inches of interlayered shaly dolomudstone and fine-grained, porous, dolobiopackstone; molds and fragments of pelecypods and gastropods
0 ft 8 inches	Bed of dolomite that fines upward from porous, fine-grained dolobiopackstone to shaly dolomudstone with vugs, light-yellow; molds and fragments of pelecypods and gastropods
4 ft 2 inches	Thin-bedded, shaly dolomudstone, and toward the top, thin layers of dolomitic mudrock, both with vugs, light-yellow. The top bed is sparsely fossiliferous (molds and fragments of pelecypods and gastropods)

Paddock Shale Member

1 ft 0 inches	Unfossiliferous, light-yellow mudrock

Measured Section Number: 103

Location: Hamm's Sand and Gravel quarry, SW NE sec. 2, T. 16 S., R. 4 E., ~ 1 mi north of Herington, Dickinson County, Kansas

Comment: The upper Luta to basal Herington section is exposed along the south wall of the quarry; the upper Luta to Odell is exposed along the west wall of the quarry, where exposures of the Luta are superb

NOLANS LIMESTONE

Herington Member

1 ft 6 inches	Basal 8 inches light-yellow dolomudstone-wackestone with vugs; upper 10 inches is porous, fine-grained dolobiopackstone (fragments and molds of pelecypods, gastropods, brachiopods)

Paddock Shale Member

10 ft 0 inches	Alternating yellow and gray mudrock, unfossiliferous in basal 4 ft, sparsely fossiliferous above (Derbyia)

Krider Member

1 ft 6 inches	Thin-bedded, shaly dolomudstone, light-yellow; rare pectinid casts
1 ft 3 inches	Basal 2 inches of light-yellow-gray, shaly dolomudstone with fenestral texture; top 1 ft 1 inch of unfossiliferous, medium- to light-green mudrock

ODELL SHALE

1 ft 3 inches	Unfossiliferous, light-green mudrock
9 ft 0 inches	Unfossiliferous mudrock: 9 inches of red siltstone at the base, overlain by interbeds of silty, red and green mudrock; thin interbeds with calcite nodules (paleocaliche) just below the middle
1 ft 6 inches	Basal 6-inches-thick ledge of light-gray, calcitic mudrock overlain by light-grayish-green mudrock, all unfossiliferous
1 ft 4 inches	Unfossiliferous, medium-gray-green mudrock
4 ft 0 inches	Unfossiliferous mudrock, light-grayish-green in the lower and middle part of the unit, dark-green in the top 1 ft 6 inches. At the western end of the quarry, the basal 1 ft of this unit is light-greenish-gray shale, overlain by red shale

WINFIELD LIMESTONE

Luta Member

2 ft 8 inches	Medium-bedded, shaly dolomudstone, thinly layered, the basal 1 ft with thin laminae with finely comminuted skeletal debris (including recognizable crinoids), very light gray; small vugs filled with green shale
0 ft 9 inches	Unfossiliferous, green shale-mudrock, lower half calcitic and rooted
0 ft 7 inches	Bed of shaly, dolomitic limestone, mudstone, cryptalgal-laminated, desiccation cracks, very light gray
2 ft 9 inches	Basal 1 ft 1 inches bed of very light gray, shaly calcitic dolomudstone, cryptalgal-laminated, with abundant calcite-quartz-anhydrite nodules; upper 1 ft 8 inches-thick bed of very light gray, shaly calcitic dolomudstone, cryptalgal-laminated and with prominent desiccation cracks, in the top 8 inches. Some bedding planes with trace fossils and wisps of green shale (crinoids, gastropods)
5 ft 0 inches	Medium-bedded, shaly limestone, mudstone, light-gray, some small, light-gray to white chert nodules (heavily calcitized); scattered crinoids

Measured Section Number: 104

Location: Composite of the following closely spaced roadcuts: (1) along Union Road, in SE NE sec. 22, T. 15 S., R. 4 E.; (2) along K–4 in SW SE sec. 35, T. 15 S., R. 4 E. and in NE sec. 2, T. 16 S., R. 4 E.; and (3) along Vane Road, in NE sec. 26, and adjoining NW sec. 25, T. 15 S., R. 4 E., north of Herington, Dickinson County, Kansas

WINFIELD LIMESTONE

Luta Member

4 ft 0 inches	Thin-bedded, shaly limestone, mudstone, cryptalgal-laminated, light-gray
2 ft 0 inches	Bed of limestone, mudstone, with abundant pea- to golfball-size, calcite-anhydrite nodules, light-gray
1 ft 8 inches	Thin-bedded, shaly limestone, mudstone, wavy laminated and bioturbated (partly cryptalgal), light-gray, scattered small light-gray chert nodules; crinoids, Derbyia, echinoid fragments
3 ft 4 inches	Medium-bedded, shaly limestone, mudstone with thin (<1 inch) layers of biowackestone, the most prominent one at 1 ft above the base, light-gray; discontinuous, 1.5-inches-thick layer of chert at 2 inches above the base, and scattered small, oval chert nodules (light-gray) in the basal 10 inches of this unit. Rocks contain echinoid fragments, crinoids, scattered Derbyia, Composita, Permophorus

Cresswell Limestone Member

3 ft 2 inches	Bed of limestone, crudely layered mudstone and biowackestone, bioturbated, light-yellow; scattered dark-gray chert nodules, some following burrows, and chert nodules along the top bedding plane. Rocks contain crinoids, ramose bryozoans, Derbyia, echinoid fragments, Composita, high-spired gastropods

Grant Shale Member

9 ft 0 inches	Fossiliferous, light-yellow-gray mudrock, abundant calcite nodules in the top 2 ft; Composita, Derbyia, fenestrate bryozoans, crinoids

Stovall Limestone Member

1 ft 0 inches	Bed of limestone, mudstone to sparse biowackestone, yellow-gray, scattered chert nodules; crinoids, brachiopod fragments

DOYLE SHALE

Gage Shale Member

3 ft 0 inches	Fossiliferous, greenish-yellow-brown mudrock; Derbyia, fenestrate bryozoans, Edmondia, pectinid casts, echinoid fragments, Composita

Measured Section Number: 105

Location: Roadcut on Trail Road, east side, in sec. 3, T. 15 S., R. 4 E., Dickinson County, Kansas

Comment: This section complements the nearby cutbank exposures along Lyon Creek (measured section number 106)

WINFIELD LIMESTONE

Cresswell Limestone Member

2 ft 2 inches	Medium-bedded limestone, biowackestone with inclined lenses of, and burrows filled with, biopackstone, porous, yellow; crinoids, echinoid fragments, Derbyia

Grant Shale Member

9 ft 6 inches	Poorly exposed mudrock, fossiliferous and bioturbated in the top 5 ft 6 inches, light-yellow-gray; Derbyia, crinoids, echinoid fragments, Allorisma

Stovall Limestone Member

2 ft 6 inches	Bed of limestone, fines upward from biowackestone to shaly mudstone, light-yellow-gray, chert nodules; crinoids, bryozoans, brachiopod fragments

DOYLE SHALE

Gage Shale Member

8 ft 4 inches — Fossiliferous, light-yellow-gray, calcitic mudrock with lenses of shaly lime mudstone, bioturbated. The upper 5 inches is gradational with the Stovall and consists, in ascending order, of 4 inches of light-yellow, shaly biowackestone overlain by 1 inch of shale. Rocks contain Chonetes, Allorisma, large ramose bryozoans, Derbyia, Juresania, crinoids, fenestrate bryozoans, Composita

1 ft 4 inches — Two beds of shaly limestone: basal bed mudstone, mottled yellow-gray, upper bed intraclastic biowackestone-packstone, fine-grained, yellow. This unit has a gradational lower contact and a sharp upper contact; brachiopod fragments

6 ft 8 inches — Unfossiliferous, greenish-yellow mudrock

4 ft 0 inches — Poorly exposed, unfossiliferous red and green shale and mudrock, and some 3-inches-thick layers of red, shaly siltstone in the middle

5 ft 0 inches — Unfossiliferous, silty red mudrock, some thin layers of green shale. The top of this unit has been soft-sediment deformed into a diapir-like structure that passes laterally into deformed, green shale/mudrock

Measured Section Number: 106

Location: Cutbank on West Branch of Lyon Creek, in SW SE sec. 34, T. 14 S., R. 4 E., just north of 1300 Ave. near Woodbine, Dickinson County, Kansas

WINFIELD LIMESTONE

Luta Member

1 ft 4 inches — Thin-bedded, shaly limestone, mudstone, with laminae of porous biowackestone, very light yellow; foraminifers, crinoids

Cresswell Limestone Member

5 ft 6 inches — Thick- to medium-bedded, light-yellow limestone: basal 2–3 inches of shaly mudstone, overlain by 3 ft 3 inches of coarse-grained biowackestone with inclined lenses of, and burrows filled with, porous biopackstone. Overlain by 7 inches of porous biopackstone, and then 1 ft 4 inches of bioturbated mudstone with lenses of biowackestone, porous. Scattered chert nodules, and a thin layer of chert below the top. Many of the fossils are silicified; crinoids, fenestrate bryozoans, Derbyia, echinoid fragments

Grant Shale Member

9 ft 6 inches — Fossiliferous, yellow-gray mudrock, bioturbated, and lenses of shaly lime mudstone; abundant large, sub-horizontal, brown-weathering burrows in the top 5 ft 6 inches. Rocks contain Derbyia, Composita, Aviculopecten, echinoid fragments, crinoids, fenestrate bryozoans, Septimyalina

Stovall Limestone Member

2 ft 10 inches — Bed of limestone, fines upward from biowackestone to, in the top 8 inches, shaly mudstone, light-yellow, angular light-gray chert nodules; Reticulatia, Derbyia, echinoid fragments, crinoids

DOYLE SHALE

Gage Shale Member—several feet of poorly exposed shale down to river level

Measured Section Number: 107

Location: Roadcut on K–209 east of Woodbine, north side, in sec. 25, T. 14 S., R. 4 E., 1.0 mi west of the intersection of K–209 and US–77, Dickinson County, Kansas

Comment: This outcrop is the east-dipping limb of an anticline whose crest is to the immediate west; the Towanda reeks of hydrocarbons

WINFIELD LIMESTONE

Cresswell Limestone Member

2 ft 8 inches — Thin-bedded limestone, mudstone, light-yellow

Grant Shale Member

9 ft 6 inches — Poorly exposed, fossiliferous mudrock, light-gray and calcitic; Derbyia, crinoids, echinoid fragments

Stovall Limestone Member

2 ft 5 inches — Bed of limestone, fines upward from biowackestone to mudstone-sparse biowackestone, light-yellow, irregular and angular, light-gray chert nodules; Reticulatia, crinoids, echinoid fragments, Derbyia, fenestrate and ramose bryozoans

DOYLE SHALE

Gage Shale Member

14 ft 0 inches — Poorly exposed mudrock, light-gray, upper part sparsely fossiliferous; Derbyia, crinoids, echinoid fragments

4 ft 0 inches	Unfossiliferous, silty, green and red mudrock, and some layers of red, shaly siltstone: section is highly deformed
8 ft 0 inches	Unfossiliferous, silty, red and green mudrock, some layers of red, shaly siltstone: section is highly deformed
6 ft 8 inches	Basal 10 inches–1 ft 8 inches layer of hard, red mudrock that appears brecciated; overlain by 5 ft of silty, red mudrock with sporadic 1–2 inches thick layers of light-gray or red, shaly siltstone, hard, and some layers of green shale, all unfossiliferous: section is deformed
4 ft 0 inches	Unfossiliferous, red, silty mudrock, discontinuous 2-inches-thick layer of hard, yellow, mudrock with red shale streaks and cellular texture at 1 ft 5 inches above the base

Towanda Limestone Member

2 ft 4 inches	Basal 1 ft 1 inches of very light gray mudrock with thin (~1 inch) layers of calcitic mudrock with abundant biomolds; overlain by a 3-inches-thick bed of coarse-grained, intraclastic dolobiopackstone-wackestone, yellow-gray (clasts of dolomudstone); then 1 ft of very thin bedded, light-gray, hard mudrock and thin interbeds of light-gray, calcitic mudrock with abundant biomolds. Rocks contain biomolds and fragments of foraminifers, gastropods
1 ft 0 inches	Light-gray, silty mudrock, top few inches calcitic and with abundant biomolds of foraminifers and gastropods
3 ft 0 inches	Very light gray mudrock and thin (~1 inch) layers in the lower half of very light gray, shaly dolowackestone to dolomitic mudrock with abundant biomolds of foraminifers and gastropods, some pelecypods
2 ft 3 inches	Very light gray shale, unfossiliferous, thin hard layers of calcitic mudrock in the lower half
1 ft 11 inches	Bed of porous breccia, orange mudrock clasts in a matrix of dark-gray, porous biowackestone; foraminifers, other unidentifiable allochems
1 ft 10 inches	Thin-bedded, shaly limestone, mudstone, the top 9 inches laminated, light-gray (but locally weathers dark gray)
1 ft 9 inches	Thin-bedded, shaly limestone, fine-grained laminites of biowackestone and packstone, bioturbated, some intraclasts of lime mudstone, light-gray; foraminifers, crinoids

Holmesville Shale Member

1 ft 4 inches	Unfossiliferous, yellow-green mudrock

Measured Section Number: 108

Location: Roadcut, south side of I–70 immediately west of Exit 286, ~ 1 mi north of Chapman, in the S/2 sec. 19, T. 12 S., R. 4 E., Dickinson County, Kansas

Comment: There is no Cresswell at this locality
WINFIELD LIMESTONE

Luta Member

10 ft 3 inches	Medium- up to thin-bedded, shaly dolomudstone, light-yellow, scattered small, dark-gray chert nodules. At 4 ft 9 inches above the base is a 2-ft-thick bed of dolomitized, porous oolite grainstone with large foresets that dip to the west
2 ft 9 inches	Medium-bedded, shaly dolomudstone, secondary calcite veins, light-yellow

Grant Shale Member

9 ft 0 inches	Sparsely fossiliferous, yellow-gray mudrock, the upper 6 ft with abundant "cauliflower" chert nodules and laminae of palisades calcite, and lenses with some fossils; rare pectinids

Stovall Limestone Member

0 ft 8 inches	Bed of limestone, mudstone-sparse biowackestone, light-gray, with light-gray chert nodules; crinoids, bryozoans, brachiopod fragments

Measured Section Number: 109

Location: Roadcuts on 2800 Ave. in S/2 sec. 17 and N/2 sec. 20, and along Rain Road in NW SE sec. 17, T. 12 S., R. 4 E., Dickinson County, Kansas

NOLANS LIMESTONE

Herington Member

6 ft 0 inches	Thin-bedded, shaly dolomudstone, top 2 ft laminated (cryptalgal), light-yellow, scattered calcite-lined geodes
4 ft 0 inches	Medium- to thin-bedded (upsection), shaly dolomudstone, light-yellow, calcite geodes and fenestral fabric in the top 1 ft; some pectinid casts, crinoids, fenestrate bryozoans in middle strata of this unit
1 ft 0 inches	Thin-bedded, shaly dolomudstone, light-yellow; some bivalve fragments and crinoids
2 ft 0 inches	Platy-bedded, coarsening-upward section from shaly dolomudstone with abundant dark-gray chert nodules in the basal few inches, to noncherty, porous dolobiowackestone, light-yellow; pelecypod and gastropod molds and fragments, crinoids

Paddock Shale Member

15 ft 0 inches	Concealed

Krider Member

1 ft 4 inches	Thin-bedded, shaly and silty dolomite: coarsens upward from dolomudstone to intraclastic dolobiopackstone (clasts of desiccated dolomudstone), and then fines upward to similarly intraclastic dolomudstone with vertical roots, light-gray; pelecypod and gastropod molds, including abundant high-spired gastropods
2 ft 0 inches	Dark-green, unfossiliferous mudrock in the lower 8 inches, light-yellow, unfossiliferous siltstone in the upper 1 ft 4 inches

ODELL SHALE

14 ft 0 inches	Interbedded, unfossiliferous, red and light-green mudrocks (equal thicknesses of both), some red, shaly siltstones; the top 6 inches is a light-gray paleocaliche
2–3 ft	Concealed

WINFIELD LIMESTONE

Luta Member–few inches of light-gray lime mudstone exposed in the road ditch

Measured Section Number: 110A and 110B

Location: Composite of several roadcuts along US–77, both sides: measured section 110A—NW sec. 22 and SW sec. 15, T. 11 S., R. 5 E.; measured section 110B—SE sec. 3 and NE sec. 10, T. 13 S., R. 5 E., Geary County, Kansas

DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

4 ft 6 inches	Thin-bedded, shaly limestone, mudstone, pea-size vugs and fenestral fabric, light-yellow
1 ft 9 inches	Progressively thinner-bedded section of shaly lime mudstone, yellow; the basal bed is 6 inches of porous, intraclastic (clasts of desiccated lime mudstone) biowackestone-packstone, locally cross stratified, that thickens and thins along the length of the outcrop. Rocks contain crinoids, pelecypod fragments
1 ft 10 inches	Progressively thinner-bedded upsection: basal 6 inches of porous biopackstone-grainstone, overlain by biopackstone, light-grayish-yellow; high-spired and planispiral gastropods, foraminifers
1 ft 9 inches	Thin-bedded, very fine grained biopackstone (size of allochems increases upsection), laminated, porous, light-yellow-gray; foraminifers, pelecypod fragments, gastropod at the top
1 ft 10 inches	Bed of shaly mudstone, weathers platy, intraclastic at base (clasts of lime mudstone), light-yellow-gray; pelecypod fragments
1 ft 0 inches	Basal 4 inches shaly lime mudstone overlain by 8 inches of unfossiliferous, calcitic mudrock, yellow
0 ft 8 inches	Unfossiliferous, calcitic mudrock, yellow
1 ft 0 inches	Bed of limestone that fines upward from fine-grained biopackstone to shaly mudstone, light-yellow; crinoids

Holmesville Shale Member

1 ft 8 inches	Unfossiliferous, yellow mudrock, thin lense of red shale just below the top
4 ft 6 inches	Unfossiliferous, medium-gray shale, splintery
3 ft 0 inches	Unfossiliferous, deep red mudrock; along the outcrop it locally passes into red mudrock with lenses of dark-green shale
5 ft 8 inches	Unfossiliferous, medium-gray shale/mudrock, locally with splotches of red and yellow; most of this unit is replaced by white, soft paleocaliche, the top of which is highly irregular, and has what appears to be fractures or dikes filled with paleocaliche

FORT RILEY FORMATION

2 ft 0 inches	Thin-bedded, shaly and silty dolomudstone, laminated (cryptalgal?), with calcite-lined geodes, light-yellow
10 ft 6 inches	Medium-bedded, shaly and silty, calcitic dolomudstone and dolomudstone, porous, abundant calcite-lined geodes, weathers to a scoriaceous appearance, light-yellow; sparse crinoids, high-spired gastropods
2 ft 2 inches	Bed of calcitic dolomite, laminated, light-yellow, calcite-lined geodes: 5 inches below the top is a 1.5-inches-thick layer of porous mudstone-biowackestone. Rocks contain foraminifers and some crinoids at the top; Septimyalina, Permophorus, Aviculopecten and crinoids below
6 ft 2 inches	Laminated and fissile, shaly limestone, mudstone, some lenses of biowackestone, yellow to medium-gray (weathers dark-gray); pelecypod casts [Permophorus?] common in beds~5 ft above the base, and some foraminifers, crinoids, Derbyia
3 ft 7 inches	Thick-bedded limestone, two beds of biowackestone-packstone, shaly at the base, yellow; brachiopod and echinoid fragments, crinoids, foraminifers in the lower bed; crinoids, brachiopod fragments, fenestrate bryozoans, echinoid fragments, and Amphiscapha in the upper bed
5 ft 5 inches	Bed of limestone, fines upward from biowackestone-packstone, with some lenses of

porous biopackstone, to bioturbated biowackestone, light-yellow; crinoids, Aviculopecten, high-spired gastropods throughout; oncolites, crinoids, fenestrate and ramose bryozoans, high-spired gastropods, Reticulatia, and Composita in the basal few inches. This bed is the Fort Riley main ledge referred to in the text

2 ft 6 inches — Medium- to thin-bedded (upsection), shaly limestone, coarse-grained biopackstone-wackestone, silty and bioturbated, more shaly upsection, light-yellow; oncolites, crinoids, fenestrate and ramose bryozoans, high-spired gastropods, Reticulatia and Composita

FLORENCE FORMATION

Oketo Shale Member

5 ft 6 inches — Fossiliferous mudrock, silty and calcitic, bioturbated, medium- to dark-gray (although some lenses are light yellow); a 2-inches-thick bed of medium-gray, shaly lime mudstone-biowackestone at 3 ft 2 inches above the base. Rocks contain Allorisma, Amphiscapha, Crurithyris, crinoids, bryozoans, echinoid fragments

Middle part of the formation

2 ft 8 inches — Medium- to thin-bedded (upsection) limestone, coarsens upward from mudstone to biowackestone, light-yellow, chert nodules in the lower half, and a thin layer of chert just above the base; fenestrate and ramose bryozoans, accessory crinoids, echinoid fragments, Reticulatia, Derbyia

1 ft 4 inches — Fossiliferous, yellow-brown, calcitic mudrock (increase in the amount of fossils upsection: fenestrate and ramose bryozoans, accessory crinoids, echinoid fragments, Reticulatia, Derbyia

2 ft 3 inches — Medium-bedded limestone, sparse biowackestone, light-yellow, chert nodules, and thin layers of chert in the lower half; fenestrate and ramose bryozoans, accessory crinoids, echinoid fragments, Reticulatia, Derbyia

1 ft 4 inches — Fossiliferous, yellow-brown, calcitic mudrock; Reticulatia, Composita, fenestrate and ramose bryozoans, crinoids, echinoid fragments

2 ft 8 inches — Bed of limestone, sparse biowackestone, light-yellow, chert nodules, many of them round; Derbyia, Allorisma, ramose and fenestrate bryozoans, crinoids, echinoid fragments

0 ft 10 inches — Fossiliferous, yellow-brown, calcitic mudrock; Reticulatia, crinoids, bryozoans

7 ft 0 inches — Bed of limestone, sparse biowackestone, basal 10 inches with biomoldic porosity, light-yellow; layers of chert in the upper half (the basal one laminated), and discontinuous layers of chert nodules throughout; basal 1 ft bed noncherty. Rocks contain fenestrate and ramose bryozoans, accessory crinoids, Reticulatia

3 ft 4 inches — Bed of limestone, sparse biowackestone with biomoldic porosity, light-yellow, chert nodules and discontinuous layers of nodules; fusulinids in the middle of the unit; fenestrate and ramose bryozoans, accessory crinoids and Reticulatia throughout

6 ft 8 inches — Medium- to thick-bedded limestone, fines upward from biopackstone at the base, with conspicuous red brachiopod and bryozoan fragments in the basal 4 inches; to biowackestone-packstone, to biowackestone, biomoldic porosity in the top 1 ft 4 inches, light-yellow; chert nodules in basal 1 ft 6 inches, which is capped by a stylolite, layers of chert from 1 ft 6 inches to 4 ft above the base, and chert nodules above that, with a thick layer of chert 1 ft 6 inches below the top. Rocks contain ramose bryozoans, accessory fenestrate bryozoans, Composita, Derbyia and crinoids in the basal beds; fenestrate and ramose bryozoans and accessory crinoids and brachiopod fragments above; fusulinids in the middle

1 ft 4 inches — Basal 9 inches of fossiliferous, light-yellow, calcitic mudrock overlain by 7 inches of biopackstone, with chert nodules and conspicuous red brachiopod and bryozoan fragments; fenestrate bryozoans, echinoid fragments, Derbyia, Composita

Cole Creek Member

1 ft 4 inches — Thin-bedded, shaly limestone, fines upward from intraclastic biopackstone to mudstone, bioturbated, intraclasts of lime mudstone, light-yellow; foraminifers, brachiopod fragments, crinoids, high-spired gastropods, Composita, Derbyia, ramose bryozoans, echinoid fragments

MATFIELD SHALE

Blue Springs Shale Member

2 ft 4 inches — Unfossiliferous, calcitic mudrock with lenses of shaly lime mudstone, mostly light-yellow-gray, fissile but jointed; 1-inch-thick layer of hard, light-yellow lime mudstone 6 inches below the top, and the top 3 inches of the unit is very dark gray shale

5 ft 8 inches — Unfossiliferous, alternating layers of compact, silty, light-green mudrock and recessive-weathering, soft, darker-green shale

1 ft 3 inches — Unfossiliferous red mudrock, with a layer of green shale in the middle

4 ft 4 inches — Unfossiliferous mudrock, mostly red but with a 2-inches-thick layer of green shale at the base, and an 8-inches-thick layer 1 ft 8 inches above the base

1 ft 5 inches — Bruno limestone bed: 3-inches-thick beds at the top and base of the unit of light-green, shaly lime mudstone with streaks of green shale; middle 11 inches of light-green shale overlain by red shale, unfossiliferous

0 ft 10 inches — Unfossiliferous, light-green shale

1 ft 10 inches	Unfossiliferous, grayish-green shale in the lower half, grayish-green mudrock in the upper half
1 ft 0 inches	Unfossiliferous, red shale
1 ft 3 inches	Unfossiliferous, green and dark-grayish-green shale
2 ft 2 inches	Unfossiliferous, dark-gray shale

Kinney Limestone Member

1 ft 3 inches	Basal thin-bedded, shaly limestone, biowackestone, light-yellow, overlain by 7 inches of fossiliferous shale, dark-gray with green splotches; Derbyia, Composita, crinoids, echinoid fragments, ramose and fenestrate bryozoans, Permophorus
4 ft 0 inches	Unfossiliferous, very dark gray shale, fissile
6 ft 0 inches	Generally unfossiliferous, fissile, black shale; juvenile Composita in the top few inches
1 ft 5 inches	Fossiliferous, calcitic mudrock to shaly lime mudstone, grading up to fossiliferous, calcitic mudrock, yellow-brown; Derbyia, curved spines, crinoids
2 ft 2 inches	Unfossiliferous, yellow-brown mudrock
1 ft 6 inches	Bed of shaly limestone, intraclastic (lime mudstone, yellow), partly oncolitic, light-yellow: graded layers of biowackestone-packstone and mudstone-biowackestone, platy-bedded in upper part. Rocks contain crinoids, Derbyia, Aviculopecten at the base; Derbyia-rich at the top

Wymore Shale Member

8 ft 8 inches	Fissile, yellow to light-gray, calcitic shale, weathers as a prominent vertical face

Measured Section Number: 111

Location: Roadcut and field exposure on and immediately around Wayne White Farm, NE SW, and center south, of sec. 28, T. 12 S., R. 5 E., Geary County, Kansas

FLORENCE FORMATION

4 ft 0 inches	Thick- to medium-bedded (upsection) limestone, mudstone to sparse biowackestone, layers of chert, some nodules at the base; crinoids, bryozoans, Reticulatia
0 ft 8 inches	Fossiliferous, yellow, calcitic mudrock; echinoid and brachiopod fragments, crinoids, bryozoans
1 ft 4 inches	Medium-bedded limestone, fines upward from intraclastic biopackstone to biowackestone, bioturbated, light-yellow, chert nodules; foraminifers, crinoids, fenestrate bryozoans, Reticulatia, echinoid fragments, Derbyia, ramose bryozoans

Cole Creek Member

2 ft 5 inches	Basal 1 ft 11 inches of calcitic, yellow mudrock and thin lenses of shaly lime mudstone with desiccation cracks, sheet cracks, incipient tepees, the basal bed with intraclasts of green shale and lime mudstone; top 6 inches of coarse-grained, fossiliferous, olive-green mudrock with red fossils, clasts of shale. Rocks contain brachiopod fragments, crinoids, high-spired gastropods

MATFIELD SHALE

Blue Springs Shale Member

5 ft 0 inches	Unfossiliferous mudrock, interbedded light and dark-green
0 ft 8 inches	Bruno equivalent: very silty dolomudstone with root traces, glaebules, light-yellow (paleocaliche)
5 ft 4 inches	Unfossiliferous, red mudrock, with a 3-inches-thick layer of green shale 1 ft 4 inches below the top and a 10-inch-thick layer of massive, red siltstone at the top
1 ft 3 inches	Unfossiliferous, light-yellow-green mudrock

Kinney Limestone Member

2 ft 10 inches	Thick-bedded carbonate: basal 1 ft 9 inches bed of white, calcitic dolomudstone with root traces, unfossiliferous. Overlying bed of porous, light-yellow, dolobiopackstone-grainstone with green shale in the matrix and clasts of silty, light-gray shale in the top 6 inches. Rocks contain pelecypod fragments, foraminifers, planispiral and high-spired gastropods
1 ft 5 inches	Unfossiliferous, light-yellow-green mudrock
0 ft 4 inches	Unfossiliferous, red mudrock
2 ft 5 inches	Sparsely fossiliferous (in the lower half), fissile, laminae of dark-gray and light-gray shale; Derbyia
2 ft 4 inches	Fossiliferous, light- to medium-gray, calcitic mudrock, with a prominent 2-inches-thick layer of coarse brachiopod hash at the base; Derbyia, accessory ramose bryozoans, curved spines, Composita, Juresania, Septimyalina
5 ft 8 inches	Unfossiliferous, medium-gray shale and mudrock
0 ft 8 inches	Thin-bedded, shaly limestone, biowackestone, bioturbated, medium-grayish-yellow; Derbyia, Septimyalina, pectinid casts, crinoids, gastropods
2 ft 0 inches	Medium-gray, fissile shale with splotches of yellow, fossiliferous in only the top 10 inches; Derbyia, Septimyalina, pectinid casts, crinoids, curved spines
1 ft 10 inches	Basal 1 ft 2 inches bed of intraclastic (orange, shaly lime mudstone) biowackestone-packstone, intraclasts as much as 8 inches in length. Overlain by 6.5 inches of fossiliferous, bioturbated, yellow, calcitic mudrock. Top 1 ft

of very coarse grained, intraclastic (lime mudstone) biopackstone, light-yellow. Rocks contain crinoids, pelecypod fragments, Allorisma, echinoid fragments, Derbyia, Myalina; top 1 inch also with some oncolites

Wymore Shale Member

2 ft 4 inches	Fissile shale, chocolate-brown grading up to brownish-yellow, unfossiliferous except for in the top few inches (brachiopod fragments)

Measured Section Number: 112

Location: Roadcut on Frank's Hill, N/2 sec. 9, T. 12 S., R. 6 E., Geary County, Texas

MATFIELD SHALE

Wymore Shale Member

2 ft 0 inches	Unfossiliferous, light-yellow, calcitic mudrock, weathers recessively
6 ft 2 inches	Sparsely fossiliferous, light-yellow, calcitic mudrock, weathers as a prominent cliff wall; rare pectinid casts, Permophorus in basal 2 ft
1 ft 4 inches	Unfossiliferous mudrock, light-yellow and calcitic, weathers as a minor ledge
5 ft 5 inches	Unfossiliferous mudrock, dark-grayish-green in the lower half, yellowish-green above
4 ft 0 inches	Unfossiliferous, red mudrock

WREFORD LIMESTONE

Schroyer Limestone Member

~1 ft 6 inches	Basal 1 ft bed of limestone, coarsens upward from biowackestone to packstone, and is overlain by float of biograinstone, light-gray; foraminifers
1 ft 8 inches	Sparsely fossiliferous, light-gray to yellow-gray mudrock; crinoids, brachiopod fragments
2 ft 6 inches	Thick-bedded, slightly shaly limestone, light-gray biowackestone, increase in size of skeletal particles upsection, chert nodules and a thick layer of chert below the middle; crinoids, brachiopod fragments, spicules, fenestrate bryozoans
0 ft 10 inches	Sparsely fossiliferous, yellow-brown mudrock; crinoids, brachiopod fragments
0 ft 3 inches	Lime mudstone, chert nodules, light-yellow

Measured Section Number: 113

Location: Roadcuts on I–70, in N/2 sec. 34 (south side of road) and extending into the SE sec. 27, (north side of the road), T. 11 S., R. 6 E., Geary County, Kansas

MATFIELD SHALE

Kinney Limestone Member

4 ft 1 inches	Basal 3 ft 1 inches bed of limestone, intraclastic (yellow, shaly lime mudstone) biopackstone; fines upward to top 1 ft of thin-bedded limestone, graded layers of mudstone and partly oncolitic biopackstone, green shale in vugs and fissures in the top 6 inches. The rocks are light-yellow-gray with dark spots; foraminifers, crinoids, brachiopod fragments; also echinoid fragments at the top
0 ft 5 inches	Unfossiliferous, yellow-brown, fissile, calcitic shale
2 ft 1 inches	Calcitic mudrock to shaly lime mudstone in the lower half, fossiliferous, yellow; and laminated, shaly limestone in the upper half, intraclastic and silty, fine-grained biopackstone with Skolithos, yellow. Rocks contain foraminifers, pelecypod fragments, Myalina

Wymore Shale Member

1 ft 9 inches	Unfossiliferous, yellow, calcitic mudrock
6 ft 2 inches	Sparsely fossiliferous, fissile, yellow, calcitic shale, weathers as a prominent vertical face; rare pectinid casts, Permophorus
3 ft 6 inches	Unfossiliferous mudrock, green in the lower half, yellow above
5 ft 10 inches	Unfossiliferous, red mudrock, calcite nodules in the lower two-thirds of the unit (paleocaliche)
4 ft 8 inches	Unfossiliferous, green mudrock

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 0 inches	Thin- to medium-bedded limestone, coarsens upward from mudstone to porous biopackstone, the top bed with green shale in interparticle pores, light-yellow-gray to light-gray; foraminifers
0 ft 7 inches	Basal 4 inches of cherty lime mudstone overlain by 3 inches of unfossiliferous, yellow-brown shale
2 ft 0 inches	Basal 3 inches of sparsely fossiliferous shale, greenish-yellow-brown, overlain by 1 ft 6 inches of fossiliferous, yellow-brown mudrock with anhydrite nodules; Derbyia, ramose bryozoans, Composita
0 ft 8 inches	Thin interbeds of limestone and layers of chert: the unit coarsens upward from mudstone to biopackstone; crinoids, ramose bryozoans, brachiopod fragments
4 ft 0 inches	Medium-bedded, shaly limestone, coarsens upward from mudstone to biowackestone, light-gray and yellow with dark spots; layers of chert 1 ft above the base and at the top of the unit, chert nodules near the top; a few inches of

yellow shale occurs 2 ft above the base. Rocks contain small Composita, echinoid fragments, crinoids, fenestrate bryozoans, rare rugose corals

Havensville Shale Member

4 ft 4 inches	Calcitic, yellow-brown mudrock, sparsely fossiliferous at the very top, 1 ft 3 inches thick zone 8 inches below the top with abundant anhydrite nodules; brachiopod fragments at the top
1 ft 2 inches	Bed of shaly limestone, mudstone, platy bedded at the top, light-brown; crinoids, Derbyia
1 ft 10 inches	Unfossiliferous, yellow-brown mudrock
2 ft 4 inches	Thin interbeds of fossiliferous, yellow, calcitic mudrock and shaly lime mudstone, yellow-gray to yellow-brown; the second limestone bed below the top contains abundant vertical rootcasts, and the topmost limestone bed is fine-grained biopackstone-grainstone. Rocks contain foraminifers, Derbyia, Myalina, pectinid casts
1 ft 7 inches	Sparsely fossiliferous, yellow-brown mudrock; pectinid casts, Myalina
4 ft 11 inches	Unfossiliferous shale, very dark gray, fissile
1 ft 8 inches	Sparsely fossiliferous, very dark gray, fissile shale, top 2-inches-thick layer of shaly lime mudstone-biowackestone, yellow-brown; crinoids, Derbyia

Threemile Limestone Member

0 ft 7 inches	Basal 5 inches of yellow, calcitic shale with chert nodules, top 2 inches of shaly lime mudstone with chert nodules
0 ft 9 inches	Thin-bedded limestone, shaly mudstone, yellow-gray, chert nodules
4 ft 0 inches	Bed of limestone, coarsens upward from mudstone with blade-shaped pores in basal 2–3 inches, to sparse biowackestone, very light yellow; scattered chert nodules, but top 1.5 ft of the section is a thick bed of chert. Rocks contain brachiopod fragments, crinoids, fenestrate bryozoans
2 ft 9 inches	Thick- to medium-bedded (upsection) limestone, mudstone, conspicuous blade-shaped pores, very light yellow; crinoids, brachiopod fragments, ramose bryozoans
0 ft 9 inches	Basal 7 inches of fossiliferous, yellow-gray mudrock, top 2 inches of biowackestone-packstone, yellow-gray; Chonetes, Derbyia, Reticulatia, Composita, fenestrate and ramose bryozoans in the limestone, fenestrate bryozoans in the shale, crinoids throughout
1 ft 0 inches	Bed of limestone, mudstone, very light gray, rare chert nodules, layer of chert at the base; crinoids, brachiopod fragments, ramose bryozoans
1 ft 8 inches	Bed of limestone, mudstone, very light gray, some chert nodules at the top; Composita, crinoids

SPEISER FORMATION

1 ft 8 inches	Fossiliferous, gray mudrock; crinoids, Derbyia, Composita, ramose and fenestrate bryozoans

Measured Section Number: 114

Location: Two closely spaced roadcuts on K–177, in NW SW and the center-west of sec. 9, T. 12 S., R. 8 E., 2.5–2.9 mi south of the intersection of KS–177 and I–70, Geary County, Kansas

FLORENCE FORMATION

Cole Creek Member

2 ft 0 inches	Yellow-gray, calcitic mudrock and lenses of shaly mudstone-biowackestone, intraclastic (lime mudstone) at base; crinoids, brachiopod fragments

MATFIELD SHALE

Blue Springs Shale Member

2 ft 8 inches	Basal 2 ft 4 inches of light-yellow mudrock with abundant calcite nodules (paleocaliche); top 4 inches dark-green shale, all unfossiliferous
5 ft 6 inches	Unfossiliferous, light-green shale and mudrock
7 ft 8 inches	Unfossiliferous mudrock, interbedded green and red (layers of red mudrock thicker than layers of green mudrock). Two prominent ledges of silty red mudrock (each 9 inches thick) 1 ft 8 inches below the top
3 ft 0 inches	Unfossiliferous, light-green mudrock
0 ft 9 inches	Basal 7 inches of unfossiliferous, light-green mudrock overlain by 2 inches of light-gray paleocaliche

Kinney Limestone Member

1 ft 8 inches	Bed of limestone, coarsens upward from basal few inches of light-gray biowackestone (weathers thin-bedded) to porous, white biopackstone, with green shale in the matrix; foraminifers, some high-spired and planispiral gastropods
1 ft 0 inches	Unfossiliferous, light-grayish-green to green shale
12 ft 0 inches	Poorly exposed: unfossiliferous, yellow-brown mudrock in the basal 8 ft, dark-greenish-gray mudrock in the top 4 ft
2 ft 2 inches	Medium-bedded limestone, porous biopackstone-wackestone, bioturbated, light-yellow-gray, coarsens upward in the top 4 inches to orange, very coarse grained biopackstone; brachiopod fragments, fenestrate

	bryozoans, crinoids
0 ft 7 inches	Fossiliferous, calcitic, yellow mudrock, bioturbated; Allorisma
0 ft 11 inches	Two beds of shaly limestone, intraclastic at base (orange, shaly lime mudstone), biopackstone, mottled medium-gray-yellow; crinoids, brachiopod fragments

Wymore Shale Member

2 ft 0 inches	Unfossiliferous, fissile shale, brownish-green grading up to yellow

Measured Section Number: 115

Location: Composite of several roadcuts in NE sec. 3, T. 12 S., R. 7 E. on and around Tully Hill Road and Meadowlark Lane, west of McDowell Creek Road (south of I–70), Geary County, Kansas

FLORENCE FORMATION

~3 ft 0 inches	Medium-bedded limestone, cherty (too high and steep to reach

Cole Creek Member

~3 ft 0 inches	Fossiliferous, calcitic mudrock and shaly limestone (too high and steep to reach)

MATFIELD SHALE

Blue Springs Shale Member

2 ft 10 inches	Unfossiliferous, yellow-green mudrock
1 ft 4 inches	Unfossiliferous, yellow-green mudrock with calcite nodules (paleocaliche)
5 ft 2 inches	Unfossiliferous, yellow-green mudrock and shale
6 ft 0 inches	Unfossiliferous, mainly red mudrock; layers of green shale and mudrock 2–4 inches thick at 1 ft 6 inches, 3 ft 4 inches, and 5 ft below the top
1 ft 6 inches	Unfossiliferous, green and red mudrock (green at top, red at the base)
0 ft 9 inches	Unfossiliferous, green shale

Kinney Limestone Member

3 ft 4 inches	Bed of shaly, calcitic dolomite, mudstone to biopackstone, porous 8 inches below the top, light-greenish-gray grading up to light-yellow with dark spots; foraminifers, gastropods, pelecypod fragments
4–5 ft	Concealed
1 ft 6 inches	Thin-bedded limestone, intraclastic (orange, shaly lime mudstone), oncolite biowackestone-packstone, light-yellow; Derbyia, crinoids, echinoid fragments

Wymore Shale Member

4 ft 0 inches	Unfossiliferous, yellow-brown mudrock
0 ft 3 inches	Layer of shaly lime mudstone with plant debris, light-yellow-green: lacustrine?
3 ft 4 inches	Unfossiliferous, yellow to brownish-green mudrock
3 ft 4 inches	Unfossiliferous, red shale and mudrock, abundant calcite nodules ~1 ft 4 inches above the base (paleocaliche)
0 ft 7 inches	Maximum thickness of a bed of shaly limestone, biowackestone, erosional top, light-greenish-brown; ostracodes: lacustrine?
3 ft 4 inches	Unfossiliferous shale and mudrock: light-green in basal 7 inches, darker-green grading up to lighter-green in overlying 2 ft, interbedded red and green in top 8 inches

WREFORD LIMESTONE

Schroyer Limestone Member

0 ft 9.5 inches	Basal 4 inches unfossiliferous, green shale, overlain by 1 inch of shaly lime mudstone; overlain by 2 inches of unfossiliferous, green shale; top 2.5 inches of shaly lime mudstone; limestones are light gray
2 ft 0 inches	Medium-bedded limestone, coarsens upward from biowackestone-packstone to grainstone, current-layered, some green shale in interparticle pores in the grainstone, light-yellow to light-gray, scattered chert nodules at the base; foraminifers, crinoids, brachiopod fragments
~1 ft 0 inches	Cherty lime mudstone, yellow-brown
6 ft 0 inches	Concealed Havensville–Schroyer contact

Basal Havensville

2 ft 0 inches	Unfossiliferous, grayish-yellow-brown mudrock

Threemile Limestone Member

0 ft 4 inches	Basal 3 inches of fossiliferous, yellow-brown mudrock overlain by 1 inch of cherty, light-gray lime mudstone; Reticulatia, echinoid fragments
1 ft 8 inches	Thin-bedded, very cherty limestone, mudstone-sparse biowackestone, light-gray, some of the chert is laminated; crinoids, echinoid and brachiopod fragments, ramose and fenestrate bryozoans
1 ft 5 inches	Bed of limestone, porous biowackestone, surface- dissolution vugs, almost white; ramose bryozoans, crinoids, spicules, brachiopod fragments, fenestrate bryozoans
2 ft 7 inches	Bed of limestone, coarsens upward from biowackestone to porous, coarse-grained biowackestone-packstone, yellow-gray to white, layers of chert; ramose bryozoans, crinoids, spicules, brachiopod fragments, fenestrate bryozoans
1 ft 0 inches	Fossiliferous, calcitic, yellow-brown mudrock; Reticulatia, Composita, crinoids, pelecypod

	fragments, Derbyia
1 ft 5 inches	Bed of limestone, coarsens upward from biowackestone to biowackestone-packstone, light-gray, chert nodules and layers of chert at top and base; crinoids, brachiopod fragments, spicules, echinoid fragments

SPEISER FORMATION

3 ft 0 inches	Mudrock, dark-gray-green and unfossiliferous in the basal 2 ft, fossiliferous and greenish-yellow-brown in the top 1 ft; a 1.5-inches-thick layer of shaly lime mudstone 1 inch below the top. Fossiliferous zones with crinoids, Derbyia
6 ft 0 inches	Unfossiliferous, red mudrock; 3 inches below the top is a 4-inches-thick layer of green shale
1 ft 7 inches	Basal 8 inches of reddish-green, unfossiliferous shale overlain by 11 inches of beige paleocaliche

Funston Limestone at the base of the exposure

Measured Section Number: 116

Location: Roadcut, east side of US–77, in SW NE sec. 29, T. 10 S., R. 5 E., ~1 mi southeast of the town of Milford, Geary County, Kansas
WINFIELD LIMESTONE

Cresswell Limestone Member

1 ft 0 inches	Thin-bedded limestone, mudstone to sparse biowackestone, light-yellow; echinoid fragments, crinoids

Grant Shale Member

8 ft 0 inches	Calcitic mudrock with lenses of shaly mudstone and biowackestone, bioturbated and fossiliferous, yellow-gray; Derbyia, Composita, crinoids, planispiral gastropods, ramose and fenestrate bryozoans

Stovall Limestone Member

1 ft 1 inch	Bed of limestone, mudstone, light-gray, with light-gray chert nodules; Derbyia, Reticulatia, fenestrate and ramose bryozoans

DOYLE SHALE

Gage Shale Member

8 ft 0 inches	Light-gray, unfossiliferous mudrock
9 ft 6 inches	Unfossiliferous, red mudrock and siltstone, some layers of green shale; sporadic 4-inches-thick lenses of light-greenish- gray, shaly lime mudstone at the top
6 ft 0 inches	Unfossiliferous, light-grayish-green mudrock, local aureoles of red shale

Towanda Limestone Member—exposed in the roadcut 0.25 mi to the south along US–77

Measured Section Number: 117

Location: Roadcuts, both sides of US–77, in SE NE sec. 7, T. 10 S., R. 5 E., Geary County, Kansas

Comment: There is no Cresswell at this locality

WINFIELD LIMESTONE

Luta Member
(probable top of the member)

2 ft 0 inches	Very thin bedded, shaly dolomudstone, light-gray
3 ft 0 inches	Thin-bedded, shaly dolomudstone, some calcite-quartz-anhydrite nodules and vugs from their dissolution; the rocks are laminated (cryptalgal) in the upper 1 ft 4 inches, with layers of foraminiferal-intraclastic dolopackstone, light-gray
6 ft 6 inches	Thick-bedded dolomudstone, cryptalgal-laminated, abundant calcite-quartz-anhydrite nodules and vugs from their dissolution, light-gray
6 ft 0 inches	Very thick bedded dolomudstone, the top 1 ft 4 inches with calcite-quartz-anhydrite nodules and vugs from their dissolution, light-gray; rare brachiopod fragments

Grant Shale Member

8 ft 0 inches	Sparsely fossiliferous (in the basal 2–3 ft) silty mudrock, light-yellow-gray with orange streaks, and the upper 5 ft contains abundant "cauliflower" quartz geodes and laminae of palisades calcite; pectinid casts

Stovall Limestone Member

1 ft 1 inches	Bed of limestone, mudstone-sparse biowackestone, light-gray, with light-gray chert nodules; Reticulatia, Derbyia, fenestrate bryozoans

Measured Section Number: 118

Location: Exposures along Illinois Creek on Bryce Hunt Farm, in NW NE sec. 35, T. 13 S., R. 9 E., Wabaunsee County, Kansas

Comment: In the slope above this outcrop is a few feet of concealed Havensville section (perhaps as much as 3–4 ft), and then rubble of cherty (Schroyer) limestone

WREFORD LIMESTONE

Threemile Limestone Member: "Reef facies" referred to in the text

2 ft 6 inches	Bed of limestone, porous, fine-grained biowackestone, soft and chalky, light-yellow; ramose bryozoans, lesser crinoids and brachiopod fragments
16 ft 0 inches	Bed of porous limestone that coarsens upward from fine-grained, sparse biowackestone in the basal to middle 12 ft, to fine-grained biowackestone-packstone in the top 4 ft; soft and chalky, light-yellow. Rocks contain fenestrate bryozoans and lesser ramose bryozoans, crinoids, foraminifers, brachiopod fragments
7 ft 0 inches	Bed of limestone, porous, fine-grained, sparse biowackestone, soft and chalky; light-yellow; appears to be syndepositionally brecciated at the top; the basal 4 ft weathers recessively along the creek bed. Rocks contain fenestrate and ramose bryozoans, lesser crinoids and brachiopod fragments
1 ft 0 inches	Bed of sparse biowackestone, porous, light-gray, chert nodules; brachiopod fragments, crinoids, bryozoans: nonreef facies

Measured Section Number: 119

Location: Roadcuts, SW SE sec. 24, T. 13 S., R. 9 E., near Bryce Hunt Farm, Wabaunsee County, Kansas

WREFORD LIMESTONE

Threemile Limestone Member

5 ft 6 inches	Bed of limestone, very porous and appears to be brecciated, fines upward from biowackestone at the base to mudstone in the middle, and then coarsens upward to sparse biowackestone, soft and chalky, light-yellow; fenestrate bryozoans, lesser crinoids, brachiopod fragments, ramose bryozoans, high-spired and planispiral gastropods. This bed is the "reef facies" referred to in the text
1 ft 4 inches	Bed of limestone, biowackestone to fine-grained packstone, porous, light-gray, chert nodules at the top and a thin layer of chert at the base; bryozoans, crinoids, brachiopod fragments
2 ft 0 inches	Bed of limestone, mudstone-sparse biowackestone, light-yellow, chert nodules; crinoids, brachiopod fragments, including juvenile Composita
1 ft 10 inches	Thin-bedded limestone, sparse biowackestone, light-yellow, layers of chert; crinoids and brachiopod fragments, lesser fenestrate and ramose bryozoans
1 ft 8 inches	Bed of limestone, porous biowackestone, brownish-yellow, slightly shaly; brachiopod fragments, crinoids, bryozoans
1 ft 2 inches	Thin-bedded limestone, biowackestone, light-yellow, layers of chert; crinoids, brachiopod fragments

SPEISER FORMATION

3 ft 8 inches	Fossiliferous, yellow mudrock; Derbyia, Reticulatia, crinoids, echinoid fragments, ramose and fenestrate bryozoans
2 ft 4 inches	Unfossiliferous, light-yellow-green mudrock
1 ft 2 inches	Unfossiliferous, green mudrock
3 ft 0 inches	Unfossiliferous, dark-red mudrock

Measured Section Number: 120

Location: Roadcut on I–70, north side, in sec. 29, T. 11 S., R. 10 E., 3.75 mi east of the Wabaunsee–Riley County line, Wabaunsee County, Kansas

WREFORD LIMESTONE

Havensville Shale Member

1 ft 4 inches	Platy-bedded, shaly limestone, biowackestone, splotchy yellow-gray; brachiopod fragments
16 ft 0 inches	Mostly concealed, silty mudrock and shale, not obviously fossiliferous but with narrow horizontal burrows on bedding planes in the basal 10 ft: dark-gray in the basal 10 ft, brownish-yellow in the top 6 ft
1 ft 4 inches	Basal 8 inches of dark-gray, fossiliferous mudrock, overlain by 8 inches of thin-bedded, shaly limestone, coarse-grained biopackstone, medium-yellow-gray; crinoids, Derbyia, high-spired gastropods, Septimyalina, Aviculopecten

Threemile Limestone Member

0 ft 8 inches	Thin-bedded, shaly limestone, coarse-grained biopackstone, yellowish-light-gray; crinoids, brachiopod fragments

2 ft 4 inches	Bed of limestone, sparse biowackestone, white, abundant spherical, angular and oval chert nodules, some laminated in the lower half of the unit; crinoids, brachiopod fragments
2 ft 2 inches	Thick-bedded limestone, porous mudstone-sparse biowackestone, white, abundant spherical chert nodules in the basal bed; crinoids, brachiopod fragments
1 ft 10 inches	Medium- to thin-bedded limestone, fines upward from coarse biopackstone in the basal few inches, to biowackestone above, white; chert nodules in the lower half, layers of chert in the upper half. Rocks contain crinoids, brachiopod fragments
0 ft 7 inches	Fossiliferous, light-gray mudrock; brachiopod fragments, crinoids, echinoid fragments, bryozoans
1 ft 11 inches	Bed of limestone, shaly biowackestone in basal 2 inches, light-yellow-gray, overlain by white, sparse biowackestone that coarsens upward to biowackestone-packstone; layers of chert nodules throughout the section. Rocks contain crinoids, bryozoans, brachiopod fragments

SPEISER FORMATION

1 ft 0 inches	Fossiliferous, gray mudrock; Derbyia, crinoids, bryozoans

Measured Section Number: 121

Location: Roadcut on Clay County Road 857, west side, in NE sec. 19, T. 10 S., R. 4 E., Clay County, Kansas

WINFIELD LIMESTONE

Cresswell Limestone Member

3 ft 4 inches	Basal 5 inches of thin-bedded limestone, sparse biowackestone, light-yellow, overlying bed of sparse biowackestone with lenses of biowackestone-packstone, bioturbated, light-yellow; crinoids, Derbyia, Composita, Reticulatia, echinoid fragments, fenestrate bryozoans

Grant Shale Member

6 ft 0 inches	Badly weathered, calcitic mudrock and shaly limestone, mudstone-biowackestone, fossiliferous, gray; Derbyia, pectinid casts, echinoid fragments, crinoids, Aviculopinna

Measured Section Number: 122

Location: Roadcuts on I–70, south side, in center of sec. 29, T. 11 S., R. 9 E. (5.7 mi east of the intersection of I–70 and K–177), Riley County, Kansas

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 0 inches	Thin-bedded, very cherty limestone, biowackestone, light-yellow-brown, layers of chert; crinoids, echinoid fragments, Chonetes, Composita
1 ft 3 inches	Thin-bedded limestone, sparse biowackestone, light-brown, silicified fossils, nodules of soft, white calcite and quartz; fenestrate bryozoans, Composita, Reticulatia, echinoid fragments
~3 ft 6 inches	Concealed Havensville–Schroyer contact

Havensville Shale Member

1 ft 8 inches	Platy-bedded, shaly limestone, mudstone, silicified fossils, splotchy medium-gray and yellow; crinoids, brachiopod fragments
2 ft 0 inches–10 ft 8 inches	Thick-bedded, light-yellow limestone, porous biopackstone-grainstone, current-layered and locally low-angle cross stratified; some yellow shale in the matrix at the top of the unit, and a few inches of shaly biopackstone at the base. The unit thins to the west along the outcrop. Upper beds with Derbyia, Juresania, Chonetes, Reticulatia, Aviculopecten, Bellerophon; remainder of the unit with foraminifers, Reticulatia, Chonetes, Composita, crinoids, bryozoans, gastropods, fenestrate and ramose bryozoans, pelecypod molds
1 ft 11 inches	Fossiliferous mudrock, dark-gray in the lower few inches, grading up to splotchy yellow-gray to yellow shale; Derbyia and Composita at the base, Derbyia and crinoids in the middle, crinoids at the top

Threemile Limestone Member

3 ft 0 inches	Basal 2 ft 8 inches bed of sparse biowackestone, white, abundant spherical, angular and oval chert nodules, some of them laminated in the lower half of the unit; top 4 inches is shaly, thin-bedded mudstone. Rocks contain ramose bryozoans, crinoids, brachiopod and echinoid fragments
2 ft 2 inches	Thick-bedded limestone, porous mudstone-sparse biowackestone, white, chert nodules, spherical in the basal bed: crinoids, echinoid and brachiopod fragments, spicules, fenestrate bryozoans
1 ft 10 inches	Medium- to thin-bedded limestone, fines upward from coarse-grained biopackstone in the basal few inches, to biowackestone, white; chert nodules in the lower part, layers in the upper part. Rocks contain Juresania, Composita, crinoids, fenestrate bryozoans, echinoid fragments, spicules

0 ft 7 inches	Basal 4 inches of fossiliferous, gray shale, overlain by 3 inches of coarse-grained, shaly biopackstone, yellow-gray; ramose bryozoans and crinoids in the shale; Derbyia, Composita, Reticulatia, crinoids, and echinoid fragments in the limestone
1 ft 11 inches	Bed of limestone, fines upward from shaly biowackestone in the basal 2 inches to sparse biowackestone above, and then coarsens upward to fine-grained biopackstone, white, chert nodules; crinoids, Composita, bryozoans

SPEISER FORMATION

1 ft 0 inches	Fossiliferous, gray mudrock; Derbyia, crinoids, echinoid fragments, bryozoans

Measured Section Number: 123

Location: Roadcuts on I–70, north side, in center W/2 sec. 7, T. 11 S., R. 9 E., 0.85 mi west of the Riley–Wabaunsee County line, Riley County, Kansas

WREFORD LIMESTONE

Schroyer Limestone Member

0 ft 10 inches	Float of porous biopackstone, white; foraminifers
1 ft 2 inches	Thin-bedded limestone, biowackestone, bioturbated, yellow to white, chert nodules at the top replace burrows; echinoid fragments, lesser crinoids and brachiopod fragments
1 ft 4 inches	Fossiliferous, calcitic, light-yellow mudrock; crinoids, juvenile Composita
2 ft 2 inches	Thin- to medium-bedded (upsection) limestone, fines upward from biopackstone to biowackestone-packstone, light-yellow to white, layers of chert; fenestrate bryozoans, Composita, Derbyia, Reticulatia, echinoid fragments
0 ft 6 inches	Fossiliferous, light-gray shale; crinoids, Composita
1 ft 10 inches	Medium- to thin-bedded limestone, mudstone, white, layers of chert, porous above the first chert; crinoids, brachiopod fragments

Havensville Shale Member

0 ft 6 inches	Unfossiliferous, greenish-yellow shale

Measured Section Number: 124

Location: Roadcut on Kansas–177, east side, in SW sec. 21, T. 11 S., R. 8 E., Riley County, Kansas

FLORENCE FORMATION

4 ft 0 inches	Thick- to medium-bedded limestone, mudstone-sparse biowackestone, very porous in middle, light-yellow, discontinuous layers of chert; fenestrate bryozoans, crinoids, Reticulatia
1 ft 4 inches	Medium- to thin-bedded (upsection) limestone, fine-grained biowackestone, light-yellow, chert layers; crinoids, fusulinids, bryozoans, brachiopod fragments
2 ft 6 inches	Bed of limestone, porous mudstone-sparse biowackestone, light-yellow, chert nodules to discontinuous layers; crinoids, brachiopod fragments
1 ft 0 inches	Fossiliferous, calcitic, yellow-brown mudrock, chert nodules in the upper half; crinoids, Reticulatia, Derbyia, Composita

Cole Creek Member

1 ft 6 inches	Basal 1 ft 1 inches of fossiliferous, yellow, calcitic mudrock. Overlain by 5-inches-thick bed of shaly lime mudstone, light-yellow. Shale with Reticulatia, fenestrate bryozoans, Aviculopecten; limestone with rare crinoids and brachiopod fragments

MATFIELD SHALE

Blue Springs Shale Member

0 ft 8 inches	Fossiliferous, orange-green shale; Chonetes, planispiral and high-spired gastropods
1 ft 8 inches	Unfossiliferous, hard, light-gray mudrock with orange-stained roots, 4-inches-thick layer of green shale just above the base (paleosol)
4 ft 0 inches	Unfossiliferous, light-green mudrock; at 1 ft 6 inches above the base is a 7-inches-thick, prominent ledge of hard, compact, light-green mudrock with rootcasts (paleosol)
7 ft 5 inches	Unfossiliferous, red mudrock: 7-inches-thick layers of heavily rooted, silty red mudrock 1 ft, 2 ft 5 inches, and 3 ft above the base, separated by green shale; and a 1 ft 8 inches thick layer of the same at 5 ft above the base, with large rootcasts and glaebules (these are paleosols)
1 ft 1 inch	Unfossiliferous mudrock: 1-inch-thick ledge of hard, green mudrock at the base, and two 1-inch-thick ledges of green mudrock at the top, separated by red mudrock
1 ft 4 inches	Basal 9 inches of heavily rooted, red mudrock (paleosol) overlain by 7 inches of green mudrock with haloes of red, all unfossiliferous
2 ft 8 inches	Interbedded, unfossiliferous shale: basal layer is black, overlying layers are green, interspersed with layers of compact, light-green mudrock (paleosols)

1 ft 8 inches	Unfossiliferous, green mudrock with hard layers of palisades calcite
2 ft 2 inches	Unfossiliferous, yellow-green mudrock with laminae of palisades calcite
1 ft 4 inches	Unfossiliferous mudrock with laminae of palisades calcite, gray-green, the top 5 inches with a reddish tinge

Kinney Limestone Member

6 ft 6 inches	Dark-gray mudrock, abundantly fossiliferous in the basal 3 inches, less so above, to rare fossils at the top; basal 3 inches with Derbyia, Juresania, ramose bryozoans, curved spines, trilobite fragments, juvenile Composita; overlying beds with Aviculopecten, Septimyalina, top few inches with brachiopod fragments
4 ft 8 inches	Sparsely fossiliferous, dark-gray mudrock capped by a 3-inches-thick layer of shaly lime mudstone, medium-gray; scattered Derbyia
1 ft 8 inches	(maximum thickness): Basal 1 ft of light-yellow, calcitic, fossiliferous mudrock overlain by 0–8 inches lense of yellow-brown limestone that coarsens upward from intraclastic biopackstone to coarse-grained biograinstone; Allorisma, Edmondia in the mudrock; foraminifers and lesser crinoids, oncolites, and brachiopod fragments in the limestone
2 ft 10 inches	Basal 2 ft 4 inches bed of limestone, coarsens upward from intraclastic biopackstone (clasts of lime mudstone) to coarser-grained biowackestone-packstone, light-yellow- gray; the top 6 inches of this unit is flaggy-bedded, shaly biowackestone, light-yellow-gray. Brachiopod fragments, crinoids, Derbyia and Allorisma in the massive bed; top 6 inches with crinoids, Septimyalina

Wymore Shale Member

7 ft 0 inches	Unfossiliferous, laminated, silty mudrock, calcitic, light-yellow
3 ft 8 inches	Unfossiliferous, light-green mudrock
0 ft 6 inches	Basal 4 inches of unfossiliferous, red shale overlain by 2 inches of bright-green shale, unfossiliferous
	Very close to the base of the Wymore because the Schroyer is exposed a few hundred yards to the north

Measured Section Number: 125

Location: Roadcuts, both sides of K–408 along Scenic Drive, in SW SE sec. 15, T. 10 S., R. 7 E., Riley County, Kansas

MATFIELD SHALE

Wymore Shale Member

1 ft 0 inches	Unfossiliferous, light-green mudrock

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 11 inches	Thick-bedded limestone, very porous, very light gray, coarsens upward from basal few inches of mudstone up to biopackstone and then, at the top, bio-grainstone with green shale in interparticle pores; pelecypod and brachiopod fragments, ostracodes, crinoids; gastropod-rich at the top
1 ft 6 inches	Thin-bedded section: coarsens upward from mudstone to biopackstone, almost white, chert nodules, then fines upward to 4 inches of fossiliferous, greenish-yellow shale; brachiopod fragments, crinoids, ramose and fenestrate bryozoans
1 ft 1 inches	Fossiliferous, yellow, calcitic mudrock; Composita, crinoids, fenestrate and ramose bryozoans, Chonetes, Reticulatia, echinoid fragments
2 ft 8 inches	Bed of limestone, biopackstone, very light gray, thick layers of chert; brachiopod fragments, crinoids, ramose bryozoans
1 ft 2 inches	Recessive bed of limestone, mudstone-sparse biowackestone, light-gray, chert nodules; brachiopod fragments, crinoids, curved spines, ramose bryozoans

Havensville Shale Member

3 ft 6 inches	Varved light-yellow and dark-gray shale, sparsely fossiliferous in the lower half, scattered "cauliflower" quartz geodes throughout; lingulids
1 ft 0 inches	Unfossiliferous shale, varved dark-gray and yellow
1 ft 4 inches	Bed of shaly limestone, fines upward from biowackestone to mudstone, platy-bedded at top, yellow; brachiopod fragments, crinoids, ramose bryozoans, oncolites, ramose and fenestrate bryozoans, Derbyia
1 ft 10 inches	Basal 2 inches layer of sparse, shaly biowackestone, overlain by sparsely fossiliferous, medium- to light-gray mudrock; crinoids, lingulids
1 ft 7 inches	Sparsely fossiliferous, silty shale, grades upward from dark-greenish-gray to black; pelecypod molds
1 ft 2 inches	Thin-bedded limestone, fines upward from fine-grained biopackstone to mudstone, yellow-gray; brachiopod fragments, crinoids, Permophorus, pectinid casts
5 ft 0 inches	Unfossiliferous, light-yellowish-green mudrock, calcite nodules (paleocaliche); top 1 ft 8 inches contains thin layers of knobby, calcite-cemented shale (paleocaliche)
5 ft 0 inches	Very sparsely fossiliferous, very dark greenish gray to black shale to mudrock; Permophorus
0 ft 8 inches	Fossiliferous mudrock, mottled light- and dark-gray; unidentifiable skeletal fragments

Threemile Limestone Member

1 ft 3 inches	Bed of limestone, sparse biowackestone, light-gray, chert layers in lower half; ramose bryozoans, lesser crinoids, brachiopod and echinoid fragments
2 ft 0 inches	Medium-bedded limestone, very porous biowackestone, very light gray (orange-stained pores), scattered chert nodules in upper half; crinoids, brachiopod fragments, ramose bryozoans, echinoid fragments
2 ft 4 inches	Medium-bedded limestone, fines upward from biowackestone-packstone in basal few inches, to biowackestone, porous in the middle, very light gray, chert layer at top, discontinuous layers and nodules below; crinoids, Composita, fenestrate bryozoans, spicules
0 ft 10 inches	Basal 6.5 inches of unfossiliferous, yellow shale overlain by 3.5 inches of fossiliferous, calcitic, yellow mudrock, chert nodules; large samples of crinoids, Chonetes, Derbyia, Reticulatia, Composita
1 ft 8 inches	Bed of limestone, mudstone, very light gray, chert nodules in lower half, thick layer of chert toward the top; crinoids, brachiopod fragments, foraminifers, spicules

SPEISER FORMATION

2 ft 8 inches	Fossiliferous, calcitic, yellow-gray mudrock; Chonetes, Derbyia, Reticulatia, crinoids, ramose and fenestrate bryozoans, pectinid casts
0 ft 8 inches	Bed of shaly limestone, fine-grained biowackestone-packstone, bioturbated, light-yellow; brachiopods, crinoid fragments
3 ft 0 inches	Unfossiliferous, yellow-green and gray mudrock, abundant calcite nodules (paleocaliche)
9 ft 0 inches	Interbedded red and light-green mudrock, unfossiliferous

Measured Section Number: 126

Location: Roadcuts, "Top of the World," on K–113, west side, in SE NW sec. 35, T. 9 S., R. 7 E., Riley County, Kansas

Comment: The section continues up to include some cherty Florence limestone, which was fully described at measured section 127

FLORENCE FORMATION

Cole Creek Member

2 ft 0 inches	Poorly exposed, fossiliferous, calcitic mudrock and shaly mudstone-biowackestone; pelecypod fragments

MATFIELD SHALE

Blue Springs Shale Member

5 ft 8 inches	Unfossiliferous, green mudrock
11 ft 0 inches	Interbedded red and green mudrock

Kinney Limestone Member

1 ft 4 inches	Thin-bedded, shaly limestone, porous, coarsens upward from mudstone to biopackstone, very light gray, green shale in the matrix; foraminifers, pelecypod and gastropod fragments and molds
4 ft 0 inches	Unfossiliferous, light-yellow-green shale, locally varved; 1 ft below the top is a 2–3-inches-thick layer of porous, intraclastic biopackstone (clasts of shaly lime mudstone), yellow-gray (foraminifers)
6 ft 0 inches	Unfossiliferous, dark-gray mudrock and shale, some layers are tannish-yellow; at the base are 4-inches-thick lenses of very hard, shaly lime mudstone, yellow to medium-gray
3 ft 8 inches	Unfossiliferous, fissile, dark-gray shale
1 ft 1 inches	Thin-bedded, shaly limestone, intraclastic (orange, shaly lime mudstone) biopackstone, porous, light-yellow-gray; foraminifers, gastropods, pelecypod fragments
0 ft 8 inches	Unfossiliferous, medium-gray to yellow shale
2 ft 0 inches	Bed of shaly limestone, intraclastic mudstone (yellow, shaly lime mudstone), mottled light-yellow and gray; crinoids, brachiopod fragments

Wymore Shale Member

6 ft 2 inches	Basal 2 inches of brecciated, very porous, shaly lime mudstone, with calcite-lined vugs and secondary calcite veins; overlying 6 ft of poorly exposed, light-yellow, calcitic mudrock, unfossiliferous
1 ft 10 inches	Unfossiliferous, light-yellow-green shale, fissile to platy
1 ft 6 inches	Unfossiliferous, green mudrock
2 ft 10 inches	Basal 1 ft 6 inches unfossiliferous, green mudrock overlain by 1 ft 4 inches light-gray, vertic paleosol
1 ft 7 inches	Unfossiliferous, red mudrock and shale, paper-thin calcitic laminae in the basal half
1 ft 3 inches	Reddish-green-gray paleocaliche
4 ft 0 inches	Unfossiliferous mudrock, green, with some layers of red in the upper half

WREFORD LIMESTONE

Schroyer Limestone Member

1 ft 6 inches	Bed of limestone, porous biopackstone, yellow; gastropod-rich

Measured Section Number: 127

Location: Roadcut on US–24 (Tuttle Creek Boulevard), both sides, in NW SE sec. 21, T. 9 S., R. 7 E., Riley County, Kansas

DOYLE SHALE

Holmesville Shale Member

2 ft 10 inches	Bed of very porous limestone, coarse-recrystallized, calcite-filled and/or lined vugs, yellow-brown
1 ft 8 inches	Thin-bedded limestone, hard, coarse-recrystallized mudstone, calcite-filled and/or lined vugs, yellow-brown
5 ft 0 inches	Unfossiliferous, light-yellow, calcitic shale, laminated

FORT RILEY FORMATION

1 ft 7 inches	Thin-bedded, shaly calcitic dolomite, interbeds of dolomudstone with desiccation cracks and dolobiowackestone-packstone, fining upward to dolomudstone, porous, light-yellow; pelecypod molds and fragments, crinoids, gastropods, Permophorus
2 ft 4 inches	Thin-bedded, shaly dolomudstone, laminated and porous, celestite molds and calcite-lined vugs, yellow
1 ft 2 inches	Very thin bedded shaly limestone, mudstone, laminated, porous, light-yellow
1 ft 8 inches	Sparsely fossiliferous, medium-gray, calcitic shale, locally varved, fissile; lingulids
2 ft 0 inches	Bed of limestone, very porous biopackstone, orange; crinoids
2 ft 4 inches	Thin- to medium-bedded, shaly calcitic dolomudstone, porous (likely from the dissolution of evaporite nodules),intraclastic at base, highly jointed, light-yellow
2 ft 8 inches–3 ft 0 inches	Medium- to massive-bedded limestone, porous and jointed, bioturbated, fines upward from biopackstone to biowacke-stone, light-yellow; prominent stylolite at the base. Rocks contain foraminifers, crinoids, Composita, Derbyia, ramose bryozoans, echinoid fragments, Reticulatia. This bed is the Fort Riley main ledge referred to in the text
1 ft 7 inches	Fining-upward section from thin-bedded, shaly limestone, biowackestone, to fossiliferous, yellow, silty mudrock; Derbyia, Reticulatia, Composita, crinoids, echinoidfragments, ramose bryozoans
0 ft 8 inches	Sparsely fossiliferous, silty, yellow-brown mudrock; crinoids, brachiopod fragments
1 ft 4 inches	Thin- to medium-bedded, shaly limestone, fines upward from biopackstone to biowackestone, splotchy medium-gray and yellow; brachiopod fragments, crinoids

FLORENCE FORMATION

Oketo Shale Member

5 ft 8 inches	Very fossiliferous and silty mudrock, generally dark-gray although some lenses are yellow-gray; 4-inches-thick layer of shaly, silty biowackestone, yellow-gray, just below the middle. Rocks contain ramose bryozoans, crinoids, Reticulatia, high-spired gastropods, Derbyia, Meekella, Composita, Amphiscapha, Allorisma, Crurithyris

Middle part of the formation

1 ft 10 inches	Bed of limestone, biowackestone with large fossil fragments, weathers platy-bedded at top, light-yellow, chert nodules in the lower half; echinoid fragments, lesser crinoids and brachiopod fragments
2 ft 3 inches	Fossiliferous, calcitic, yellow mudrock; curved spines, echinoid fragments
3 ft 8 inches	Medium- to thick-bedded (upsection) limestone, bioturbated biowackestone-packstone, shaly at base, some vertical burrows in the middle bed (replaced by chert), yellow, chert nodules; brachiopod fragments and crinoids, lesser ramose bryozoans and echinoid fragments
1 ft 11 inches	Fossiliferous, calcitic mudrock to shaly lime mudstone in the lower half, all mudrock in the upper half, yellow; ramose bryozoans, crinoids, Composita, Derbyia, Reticulatia, fenestrate bryozoans
3 ft 6 inches	Bed of limestone, biowackestone, light-yellow, chert nodules; ramose bryozoans and crinoids, brachiopod fragments, fenestrate bryozoans
1 ft 6 inches	Very shaly lime mudstone in the basal half, calcitic mudrock in the upper half, bioturbated, yellow, fossiliferous; ramose bryozoans, brachiopod fragments, crinoids
4 ft 8 inches	Medium-bedded limestone, biowackestone, light-yellow, chert nodules and layers; crinoids, ramose bryozoans, brachiopod fragments
1 ft 6 inches	Medium- to thin-bedded (upsection) limestone, very porous mudstone, very light gray; crinoids, brachiopods, ramose bryozoans, rare rugose corals
5 ft 10 inches	Basal 2 inches of calcitic, yellow shale overlain by medium-bedded limestone, porous mudstone-sparse biowackestone, very light gray to yellow-gray, discontinuous layers of chert and chert nodules in the middle; ramose bryozoans, crinoids, brachiopod fragments, fenestrate bryozoans, spicules
4 ft 0 inches	Medium-bedded limestone, fines upward from biowackestone to mudstone, porous in basal half, very light gray to yellow-gray, discontinuous layers of chert, some chert nodules near the top; fenestrate bryozoans, echinoid fragments, crinoids, Derbyia, Reticulatia, Composita, ramose bryozoans; Chonetes and fusulinids at the top
1 ft 11 inches	Basal 7 inches and top 4 inches of coarse-grained biowackestone-packstone with red fossils, light-yellow, separated by 4 inches of fossiliferous, yellow, calcitic mudrock; Derbyia, Reticulatia, Composita, Chonetes, crinoids, fenestrate and ramose bryozoans

Cole Creek Member

1 ft 10 inches	Basal 5 inches of shaly limestone, intraclastic biowackestone, bioturbated, medium-grayish-yellow; overlain by 1 ft 5 inches fossiliferous calcitic mudrock to shaly lime mudstone, bioturbated, light-yellow. Rocks contain Derbyia,Reticulatia, Composita, crinoids, ramose and fenestrate bryozoans

MATFIELD SHALE

Blue Springs Formation

1 ft 8 inches	Basal 4 inches unfossiliferous, green shale overlain by 8 inches fossiliferous, calcitic, yellow-brown mudrock; pelecypod fragments

Measured Section Number: 128

Location: Roadcut on Union Road, east side, 0.6 mi north of Walsburg, in SW NW sec. 31, T. 7 S., R. 6 E., Riley County, Kansas

WINFIELD LIMESTONE

Luta Member

7 ft 6 inches	Medium- to thin-bedded (upsection) shaly limestone, mudstone, with vugs, light-yellow, thin lenses of biowackestone in the bed 2 ft below the top; crinoids, brachiopod fragments

Interbedded Cresswell and Luta

1 ft 10 inches	Bed of limestone, porous mudstone (Luta lithology) with lenses of biowackestone, bioturbated, light-yellow (Cresswell lithology); crinoids, lesser echinoid fragments, Composita, Derbyia
1 ft 0 inches	Bed of limestone, shaly mudstone, light-yellow-gray: Luta lithology; crinoids
2 ft 4 inches	Thick-bedded, shaly limestone: basal 1 ft 4 inches is Cresswell lithology—porous biowackestone-packstone, light-yellow; upper half is Luta lithology—light-yellow, shaly lime mudstone. Rocks contain crinoids, brachiopod fragments

Grant Shale Member

8 ft 0 inches	Fossiliferous, light-greenish-gray mudrock; crinoids, echinoid fragments, Composita, Derbyia, Reticulatia

Stovall Limestone Member

1 ft 3 inches	Bed of limestone, biowackestone, light-gray, chert nodules; ramose bryozoans, echinoid fragments, fenestratebryozoans, brachiopod fragments

DOYLE SHALE

Gage Shale Member

8 ft 0 inches	Mostly concealed, light-yellow-gray mudrock

Measured Section Number: 129

Location: Exposures along North Otter Creek, center E/2 SW sec. 17, T. 6 S., R. 6 E., Riley County, Kansas

MATFIELD SHALE

Kinney Limestone Member

2 ft 0 inches	Very thin bedded, shaly limestone, fines upward from lime mudstone to very shaly mudstone-calcitic shale, light-yellow-gray; crinoids, brachiopod fragments
2 ft 2 inches	Bed of shaly limestone, biowackestone-packstone, bioturbated, intraclastic at base (clasts are orange, shaly lime mudstone), light-yellow; crinoids, brachiopod fragments

Wymore Shale Member

7 ft 0 inches	Unfossiliferous mudrock, top 2 ft 8 inches yellow, dull-grayish-green below
7 ft 0 inches	Unfossiliferous, deep-red mudrock, some thin layers of green shale
1 ft 0 inches	Unfossiliferous, green shale

WREFORD LIMESTONE

Schroyer Limestone Member

2 ft 4 inches	Medium-bedded limestone, porous, coarsens upward from biopackstone in basal 1 ft 8 inches, to biograinstone with green shale in interparticle pores and vugs, yellow to light-gray; foraminifers, crinoids
2 ft 4 inches	Unfossilferous, dolomitic mudrock, the basal 1 ft 1 inch dark-gray and the top 1 ft 3 inches is light-gray; calcite-quartz-anhydrite nodules throughout
1 ft 2 inches	Thin-bedded limestone, biowackestone-packstone, light-gray, chert nodules; crinoids, fenestrate and ramose bryozoans, echinoid fragments, Composita, Reticulatia, Derbyia
0 ft 10 inches	Fossiliferous, medium-gray shale; Chonetes, crinoids, Derbyia, Composita, echinoid fragments
1 ft 3 inches	Layers of chert at top and base, limestone in the middle, biopackstone, light-gray; crinoids, brachiopod fragments

Measured Section Number: 130

Location: Streambank exposures along Swede Creek, on the Nelson Farm, in W/2 sec. 6, T. 6 S., R. 7 E., due south of Toburen Road and due west of Flat Rock Road, Riley County, Kansas

FLORENCE FORMATION

7 ft 9 inches	Thick- to medium-bedded (upsection) limestone, sparse biowackestone, light-yellow, basal 3 inches with angular nodules of brecciated-appearing chert, overlying section with large chert nodules; ramose bryozoans, brachiopods
4 ft 3 inches	Thick-bedded limestone, sparse biowackestone, light-yellow, discontinuous layers and nodules of chert; ramose bryozoans, brachiopod fragments, fusulinids in the middle

Cole Creek Member

0 ft 10 inches	Fossiliferous, light-yellow, bioturbated mudrock, rare small chert nodules at the top (extending down from overlying limestones); crinoids, ramose and fenestrate bryozoans, Chonetes
3 ft 8 inches	Basal 1 ft 2 inches bed of intraclastic biowackestone-packstone (clasts of yellow shale and gray mudstone-foraminiferal wackestone), vugs, yellow. Overlying thick bed of shaly lime mudstone, light-yellow-gray. Rocks contain Allorisma, crinoids, Reticulatia

MATFIELD SHALE

Blue Springs Shale Member

1 ft 5 inches	Unfossiliferous mudrock, basal 1 ft very coarse blocky, light-greenish-gray, top 4–5 inches black paleosol
6 ft 4 inches	Unfossiliferous, green mudrock and shale; prominent 8-inches-thick layer of light-greenish-gray, calcitic mudrock with coarse blocky texture, the top of which is 32 inches below the base of the Florence (paleosol)
1 ft 0 inches	Unfossiliferous mudrock, basal 3–4 inches green, silty and red above
0 ft 8 inches	Unfossiliferous, light-grayish-red, silty mudrock with glaebules, green shale-filled rootcasts (paleosol)
2 ft 11 inches	Unfossiliferous mudrock, basal 3 inches soft, green; overlying 2 ft 8 inches is a ledge-forming bed of red, silty mudrock, the top 2–3 inches of which is oxidized to light gray and with rootcasts. Green shale-filled rootcasts throughout the section (paleosol)
1 ft 6 inches	Unfossiliferous, red, silty mudrock, ledge-former, breaks into large blocks, fines upward to shale; green shale-filled rootcasts throughout (paleosol)
1 ft 0 inches	Unfossiliferous, green mudrock, coarse blocky texture
1 ft 8 inches	Unfossiliferous red, silty mudrock, ledge-former, coarse blocky texture

Measured Section Number: 131

Location: Cutbank exposures on Swede Spring, on Nelson Farm, in center N/2 S/2 sec. 1, T. 6 S., R. 6 E., due north of Toburen Road, Riley County, Kansas

FORT RILEY FORMATION

0 ft 4 inches	Bed of porous limestone, biopackstone-grainstone, orange; foraminifers, crinoids, brachiopod fragments
4 ft 0 inches	Thick-bedded, very porous limestone, biowackestone, bioturbated, light-yellow in lower half, light-yellow-gray in upper half; crinoids, foraminifers, Derbyia, echinoid fragments. This bed is the Fort Riley main ledge referred to in the text
1 ft 6 inches	Basal 8 inches platy-bedded, sparse biowackestone, yellow-brown, bioturbated; top 10 inches is fossiliferous, yellow-brown, calcitic mudrock to shaly biowackestone. Rocks contain crinoids, Reticulatia, Derbyia, echinoid fragments, Amphiscapha

FLORENCE FORMATION

Oketo Shale Member

4 ft 5 inches	Fossiliferous, yellow-brown mudrock with lenses of shaly lime mudstone to sparse biowackestone, mottled medium-gray and yellow-brown; the mudrocks are fossiliferous in only the upper half of the unit. Rocks contain crinoids, pectinid casts, Reticulatia, Derbyia
0 ft 8 inches	Black, silty mudrock; rare crinoids
1 ft 5 inches	Fossiliferous (except in basal few inches), calcitic mudrock to shaly biowackestone, medium-gray; crinoids, echinoid fragments, Meekella, ramose bryozoans, Derbyia

Middle part of the formation

1 ft 5 inches	Bed of limestone, coarsens upward from shaly mudstone in basal 6 inches, to coarse biowackestone-packstone above, medium-gray, scattered chert nodules; echinoid fragments, crinoids, fenestrate and ramose bryozoans, some oncolites, Derbyia, Reticulatia, Myalina
1 ft 8 inches	Unfossiliferous, very dark gray to black, silty shale, top 7 inches with thin layers of skeletal debris; crinoids,brachiopod fragments, fenestrate and ramose bryozoans
1 ft 1 inches	Basal 10 inches of fossiliferous, yellow-brown, calcitic mudrock. Overlain by 3 inches shaly lime mudstone, dark-gray. Rocks contain crinoids, brachiopod fragments
2 ft 9 inches	Platy-bedded, shaly limestone, biowackestone, light-gray, scattered chert nodules; top 6 inches fairly hard and compact, and mottled gray-yellow. Rocks contain crinoids,

Derbyia,Reticulatia, echinoid fragments, ramose and fenestrate bryozoans

0 ft 6 inches — Almost pervasively silicified limestone, mudstone

Measured Section Number: 132

Location: Hillsides due east of private road along Swede Creek, in E/2 sec. 4, T. 7 S., R. 7 E., two closely spaced outcrops, Pottawatomie County, Kansas

WREFORD LIMESTONE

Schroyer Limestone Member

3–4 ft	Thin- to thick-bedded (upsection) limestone, coarse-grained biograinstone, very porous, light-yellow; crinoids and pelecypod fragments, foraminifers
4 ft 6 inches	Thin-bedded limestone, mudstone, light-gray, chert nodules; thin calcitic shale near the base; brachiopod fragments, crinoids, bryozoans

Havensville Shale Member

4 ft 6 inches	Thick-bedded limestone, porous oolite grainstone, herringbone cross stratification, light-yellow; some lenses silicified
5 ft 0 inches	Thin-bedded, shaly limestone, mudstone, wavy to lenticular bedded, light-yellow; rare Composita and Derbyia in upper half
5 ft 0 inches	Unfossiliferous mudrock, very dark gray to black in basal 1 ft (shale), yellow-green and silty above
2 ft 4 inches	Medium- to thin-bedded (upsection), shaly limestone, biowackestone with a lense of biowackestone-grainstone at 4–10 inches above the base, above which it fines to mudstone, bioturbated, brownish-yellow-gray; foraminifers, pelecypod and brachiopod fragments, crinoids, curved spines
3 ft 6 inches	Basal 2 inches light-gray, shaly lime mudstone; overlain by 3 ft 4 inches unfossiliferous, silty mudrock with a 6-inches-thick layer of silty biopackstone 1 ft 4 inches below the top; the mudrock below this limestone layer is yellow-medium-gray with orange streaks, above this layer it is very dark gray to black
3 ft 0 inches	Sparsely fossiliferous mudrock to shale, dark-gray with yellow-orange mottles in the lower half, very dark in the upper half; Derbyia, Chonetes, fenestrate bryozoans

Threemile Limestone Member

0 ft 4 inches	Essentially a layer of dark chert, minor lime mudstone
0 ft 9 inches	Basal 4 inches of lime mudstone, overlain by 5 inches of fossiliferous, calcitic, light-gray to yellow mudrock; fenestrate and ramose bryozoans, Derbyia
3 ft 4 inches	Two beds of limestone, porous mudstone-sparsebiowacke-stone, white, thin chert layer at the top and separating the two limestone beds; brachiopod fragments
0 ft 5 inches	Lower half lime mudstone, white, upper half a layer of chert
0 ft 8 inches	Basal 5 inches limestone, sparse biowackestone, gray, chert nodules, overlain by 3 inches of fossiliferous, calcitic, yellow shale; Amphiscapha
0 ft 5 inches	Fossiliferous, calcitic, yellow shale; Reticulatia, crinoids, ramose bryozoans, Composita
1 ft 0 inches	Bed of limestone, sparse biowackestone, white, chert nodules; crinoids, brachiopod fragments

SPEISER FORMATION

2 ft 0 inches	Fossiliferous, calcitic, yellow-gray mudrock; echinoid fragments, crinoids, Derbyia

Measured Section Number: 133

Location: Quarry at intersection of Case Ravine Road and Booth Creek Road, SE SE sec. 10, T. 7 S., R. 7 E., Pottawatomie County, Kansas

DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

1 ft 0 inches	Thin-bedded, shaly limestone, mudstone, yellow
2 ft 4 inches	Medium-bedded limestone, relatively thick interbeds of porous biowackestone and packstone in the lower half, and biowackestone and grainstone in the upper half, the beds arranged in large foresets that dip to the east, yellow; foraminifers, and at the top, planispiral and high-spired gastropods and lesser pelecypod fragments, foraminifers, brachiopod fragments, crinoids
0 ft 10 inches	Bed of porous limestone, biowackestone-packstone, yellow; foraminifers, and lesser crinoids, brachiopod and pelecypod fragments
6 ft 8 inches	Thin-bedded, shaly lime mudstone, light-yellow

Measured Section Number: 134

Location: Roadcuts, both sides of K–99, 1.8 mi south of the intersection of K–16 and K–99, in SW SW sec. 3, T. 7 S., R. 9 E., south of Blaine, Pottawatomie County, Kansas

WREFORD LIMESTONE

Schroyer Limestone Member

0 ft 3 inches — Poorly exposed, cherty limestone

Havensville Shale Member

15 ft 0 inches — Top 4 ft of light-yellow mudrock with lenses of shaly, recrystallized limestone, unfossiliferous except for the top few inches (pelecypod and brachiopod fragments), calcite nodules throughout. Underlying 2 ft 8 inches of light-yellow, unfossiliferous mudrock with calcite nodules at the top, lenses of fossiliferous, shaly dolobiowackestone in the middle (porous due to abundant pelecypod and gastropod molds), and orange shale at the bottom; underlying section is yellow-greenish-brown, unfossiliferous mudrock with lenses of recrystallized limestone

0 ft 4 inches — Bed of limestone that coarsens upward from greenish-gray mudstone to brownish-yellow biopackstone; Derbyia, Reticulatia, foraminifers, crinoids

2 ft 0 inches — Unfossiliferous, orange-brown and yellow-green mudrock

Threemile Limestone Member

1 ft 8 inches — Thin-bedded limestone, coarsens upward from white mudstone to yellow-brown biopackstone, chert layers; crinoids, brachiopod fragments

1 ft 0 inches — Bed of limestone, porous mudstone, white

2 ft 8 inches — Medium-bedded limestone, porous mudstone, white, scattered nodules and layers of chert; brachiopod fragments, crinoids

1 ft 0 inches — Basal 5 inches of fossiliferous, calcitic, yellow mudrock, overlain by 7 inches bed of biowackestone, yellow, chert nodules ; crinoids, brachiopod fragments; some rugose corals in the limestone

0 ft 9 inches — Bed of limestone, biowackestone-packstone, medium-gray, layer of chert in the middle; crinoids, brachiopod fragments

SPEISER FORMATION

1 ft 0 inches — Fossiliferous mudrock, yellow; crinoids, brachiopod fragments

Measured Section Number: 135

Location: Roadcuts along K–63, in NW SW sec. 35, T. 6 S., R. 12 E., and field exposures due west of K–63 in NE SE sec. 3, T. 7 S., R. 12 E., Pottawatomie County, Kansas

Comment: The roadcut in sec. 35 is Condra and Upp's (1931) type locality of the Havensville, where only the Schroyer is exposed now. The field outcrops in sec. 3 expose the Speiser to basal Havensville

WREFORD LIMESTONE

Schroyer Formation

1 ft 0 inches — Basal 7-inches-thick layer of chert overlain by 5 inches of thin-bedded limestone, sparse biowackestone, light-yellow-gray; fenestrate bryozoans, brachiopod and echinoid fragments, crinoids

1 ft 0 inches — Fossiliferous, calcitic, yellow mudrock; crinoids, Derbyia

2 ft 0 inches — Bed of heavily silicified limestone (thick band of chert in lower to middle part of the unit), fines upward from fine-grained biopackstone to biowackestone-packstone, light-yellow, some chert nodules; ramose bryozoans, Derbyia, Composita, Reticulatia, crinoids, fenestrate bryozoans, spicules

0 ft 7 inches — Basal few inches of yellow shale overlain by bed of biowackestone, light-yellow; Reticulatia, Composita, crinoids, fenestrate and ramose bryozoans, echinoid fragments, Amphiscapha

1 ft 10 inches — Medium-bedded limestone, coarsens upward from mudstone with lenses of biowackestone, to biowackestone, porous in the middle, light-gray, layer of chert in the middle and chert nodules above; brachiopod fragments, crinoids, spicules, echinoid fragments, bryozoans, high-spired gastropods

1 ft 10 inches — Yellow-brown mudrock and 3-inches-thick lenses of calcitic mudrock to shaly lime mudstone, "cauliflower" chert nodules; the mudrocks are fossiliferous in only the upper 8 inches (brachiopod fragments, crinoids)

1 ft 0 inches — Bed of shaly limestone, biowackestone, medium-gray, small chert nodules; ramose bryozoans, brachiopod fragments, crinoids

Havensville Shale Member

~14 ft 0 inches — Concealed: in the field exposures in sec. 3, there are float blocks ~3 ft of thick-bedded, porous limestone (biopackstone-grainstone, with foraminifers, crinoids, pelecypod fragments) that lie stratigraphically somewhere within the Havensville Member. We could not locate outcrops where this unit was exposed in its proper stratigraphic context, and Condra and Upp (1931) did not mention this unit. These strata likely are equivalent to the limestones in the Havensville elsewhere in northern Kansas

0 ft 4 inches — Bed of limestone that coarsens upward from light-greenish- gray mudstone to very coarse

	grained, brownish-yellow, intraclastic biopackstone; Derbyia, Reticulatia, pectinid casts, Permophorus, crinoids, spicules, high-spired gastropods, fenestrate bryozoans, foraminifers
2 ft 0 inches	Sparsely fossiliferous, green shale; pectinid casts

Threemile Limestone Member

0 ft 7 inches	Thin interbeds of chert and light-gray limestone, fine-grained biopackstone; brachiopod fragments, crinoids, ramose and fenestrate bryozoans, echinoid fragments, some Composita
2 ft 8 inches	Medium-bedded limestone, mudstone-sparse biowackestone, very light gray, chert nodules; brachiopod fragments, including Composita, crinoids, ramose and fenestrate bryozoans, echinoid fragments
2 ft 1 inches	Medium-bedded limestone, fines upward from relatively coarse-grained biopackstone to sparse biowackestone, light-yellow-gray, chert nodules; the top 2 inches of this unit is yellow, fossiliferous, calcitic shale. Rocks contain crinoids, spicules, fenestrate bryozoans, echinoid fragments, Derbyia, Composita

SPEISER FORMATION

0 ft 4 inches	Fossiliferous, orange-brown shale; crinoids, brachiopod and echinoid fragments, pectinid casts, Amphiscapha
3 ft 8 inches	Concealed
4 ft 0 inches	Unfossiliferous mudrock, dark-gray grading up to light-gray; the top 2 inches is a bed of fine-grained biowackestone, light-gray

Measured Section Number: 136

Location: Roadcuts on US–77, southern outskirts of Waterville, in NW sec. 27, T. 4 S., R. 6 E., Marshall County, Kansas

DOYLE SHALE

Holmesville Shale Member

1 ft 4 inches	Basal 1 ft of unfossiliferous, dolomitic mudrock, light-yellow-gray, overlain by a 4-inches-thick bed of porous, coarse-recrystallized limestone, yellow-brown

FORT RILEY FORMATION

4 ft 0 inches	Laminated, very shaly dolomudstone, light-yellow-gray
1 ft 10 inches	Thin-bedded to laminated, shaly dolomudstone, light-yellow-gray; a 4-inches-thick bed at the top of dolomudstone with vugs, light-yellow-gray
0 ft 10 inches	Bed of shaly dolomudstone with calcite-lined vugs, light-yellow-gray
1 ft 11 inches	Very thin bedded, shaly dolomudstone, light-yellow-gray; some Permophorus at the top
1 ft 1 inch	Thin-bedded, porous dolobiopackstone that grades upward to shaly dolomudstone, light-yellow-brown; foraminifers, lesser brachiopod fragments, crinoids, pectinid casts, gastropods
2 ft 8 inches	Bed of porous dolomite, coarsens upward from dolomudstone-sparse biowackestone to dolobiopackstone to fine-grained dolobiograinstone, bioturbated, yellow-brown; foraminifers, lesser brachiopod fragments and gastropods. This bed likely is the Fort Riley main ledge referred to in the text
2 ft 4 inches	Medium-bedded dolomite, coarsens upward from dolomudstone with vugs to porous, fine-grained dolobiopackstone, light-yellow; some pelecypod molds and casts
0 ft 6 inches	Unfossiliferous, yellow, dolomitic mudrock
1 ft 8 inches	Thin-bedded, shaly dolomudstone, light-brownish-yellow

FLORENCE FORMATION

Oketo Shale Member

2 ft 0 inches	Unfossiliferous, calcitic mudrock, grades upward from mottled dark-gray and brown to light-brownish-yellow
4 ft 0 inches	Unfossiliferous, black to very dark gray, silty mudrock

Middle part of the formation

1 ft 6 inches	Platy-bedded, shaly dolomudstone, earthy-brown
5 ft 0 inches	Poorly exposed, unfossiliferous mudrock: top 2 ft 8 inches very dark gray to black, silty; underlying section earthy-brown, dolomitic, with lenses of shaly dolomudstone
1 ft 4 inches	Thin- to medium-bedded dolomudstone, light-yellow, quartz-filled geodes (coarse crystals of opaque, white quartz)
4 ft 0 inches	Unfossiliferous, calcitic mudrock, yellow-gray
1 ft 10 inches	Thin- to thick-bedded dolomudstone, light-yellow-gray, small chert nodules and quartz-filled geodes (coarse crystals of opaque, white quartz) in the lower third of the section; Meekella, some Reticulatia
0 ft 10 inches	Bed of porous dolomudstone, light-yellow, some chert nodules and quartz-filled geodes (coarse crystals of opaque, white quartz); ramose and fenestrate bryozoans, Reticulatia, Derbyia
3 ft 0 inches	Basal 2 ft 4 inches thick bed of shaly dolomudstone with laminae of bioclastic debris (crinoids and brachiopod fragments), light-yellow, some chert nodules; top 8 inches is a

	layer of chert
1 ft 11 inches	Thin-bedded, shaly dolomudstone, porous, chert layers and nodules; crinoids, fenestrate and ramose bryozoans
0 ft 10 inches	Bed of chert with a thin layer of porous, shaly dolomudstone at the base
4 ft 7 inches	Basal 3 ft 10 inches thick bed of porous dolowackestone with some thin lenses of dolopackstone (Reticulatia, fenestrate and ramose bryozoans, crinoids), light-yellow, discontinuous layers of chert and a thick layer of chert just below the top. Overlying 9 inches is shaly, bioturbated dolomudstone, light-yellow, with laminae of skeletal debris (crinoids, Derbyia)
4 ft 7 inches	Thick-bedded, mostly porous dolobiowackestone-packstone, but the top 1 ft 4 inches is calcitic dolomite, light-yellow; large fronds of fenestrate bryozoans at the base; chert layers and angular, brecciated-appearing chert nodules. Rocks contain Reticulatia, fenestrate and ramose bryozoans; abundant crinoids at the top
4 ft 0 inches	Medium-bedded dolobiopackstone, porous, light-yellow, chert nodules and thin layers to discontinuous layers; Reticulatia, fenestrate and ramose bryozoans; fusulinids in the second bed from the top

Cole Creek Member

1 ft 10 inches	Medium-bedded, shaly dolomudstone, bioturbated, light-yellow; crinoids and brachiopod fragments

This bed likely is the base of the Florence Formation; the Blue Springs is concealed in the grass-covered slope here

Measured Section Number: 137

Location: Roadcut along East River Road in SE sec. 6, and quarry in adjoining sec. 5 to the immediate east, T. 4 S., R. 7 E., just south of the Alcove Spring parking lot (which was Condra and Upp's [1931] type locality of the Schroyer), Marshall County, Kansas (east bank of the Big Blue River)

Comment: The Funston to basal Schroyer section is exposed along the road, and the section up to the basal Kinney is exposed in the quarry. An outcrop of the upper Havensville is also exposed at Alcove Springs Park, which is a no-hammer stop because it is a protected, historical site
MATFIELD SHALE

Kinney Limestone Member

0 ft 6 inches	Thin-bedded, shaly lime mudstone, light-yellow

Wymore Shale Member

0 ft 8 inches	Beige paleocaliche
4 ft 6 inches	Unfossiliferous, red mudrock, scattered calcite (paleocaliche) nodules
5 ft 10 inches	Unfossiliferous, red mudrock: the basal 8 inches are light-yellow paleocaliche, and the top 1 ft 5 inches contain abundant light-yellow calcite nodules (incipient paleocaliche) and green shale-filled rootcasts. There is 1 inch of green shale directly above the basal paleocaliche

WREFORD LIMESTONE

Schroyer Limestone Member

1 ft 5 inches	Along the east wall of the quarry: medium-bedded limestone, coarsens upward from intraclastic biopackstone-grainstone (clasts of lime mudstone) to sparsely intraclastic biograinstone, with green shale in interparticle pores, yellow-orange; foraminifers, some crinoids, brachiopod fragments, high-spired gastropods
3 ft 0 inches	Shaly dolomudstone to dolomitic mudrock, very light gray, top 2 inches is light-green shale; sparsely fossiliferous: pelecypod molds, crinoids, brachiopod fragments
4 ft 0 inches	Unfossiliferous mudrock: basal 1 ft 4 inches is black, overlying section is greenish-yellow-brown; the entire unit contains calcite-anhydrite-quartz nodules
1 ft 0 inches	Two beds: basal shaly biowackestone, dark-gray, upper bed is chert; ramose bryozoans, crinoids, brachiopod fragments
1 ft 3 inches	Fossiliferous mudrock, dark-gray with yellow splotches, upper few inches calcitic; Composita, crinoids, ramose bryozoans, Chonetes, Reticulatia
0 ft 9 inches	Two beds: basal bed mudstone-biowackestone, light-yellow, upper bed chert; crinoids, brachiopod fragments
1 ft 8 inches	Thin-bedded limestone, relatively coarse-grained biowackestone, white, chert layers, and nodules in the top bed; brachiopod fragments, crinoids, ramose bryozoans
1 ft 3 inches	Bed of limestone, sparse biowackestone, white, chert nodules; brachiopod fragments, crinoids, fenestrate bryozoans
1 ft 3 inches	Fossiliferous, yellow, calcitic mudrock; Reticulatia, crinoids, Composita, ramose bryozoans
0 ft 10 inches	Bed of limestone, relatively coarse-grained biopackstone, porous, light-yellow-gray, chert nodules; crinoids, brachiopod fragments, high-spired gastropods

Havensville Shale Member

3 ft 8 inches	In the roadcuts: bed of limestone, biopackstone-grainstone, some cross stratification, porous, light-gray, basal 11 inches bioturbated. Along

	the east wall of the quarry: medium-bedded, light-gray biowackestone to packstone and lenses of porous biograinstone. AT both localities the rocks contain foraminifers, brachiopod and pelecypod fragments
3 ft 2 inches	Thin-bedded, shaly limestone, light-yellow: the basal 5 inches fines upward from fine-grained biopackstone to mudstone and is overlain by 2 inches of bioturbated biowackestone. The remainder of the unit is shaly and silty mudstone. Rocks contain pectinid casts, foraminifers, Permophorus, Edmondia, Aviculopecten
6 ft 5 inches	Very thin bedded, calcitic shale, silty, sparsely fossiliferous at the top (pectinid casts), yellow
4 ft 0 inches	Fossiliferous, yellow mudrock; 1 ft 5 inches below the top is a 5-inches-thick layer of limestone that fines upward from orange-brown biopackstone to shaly and silty mudstone. Septimyalina and Aviculopecten in the mudrock, Edmondia in the limestone

Threemile Limestone Member

4 ft 10 inches	Basal 3 inches of fossiliferous, gray shale (crinoids, Composita, echinoid fragments, fenestrate and ramose bryozoans). Overlain by medium- to thin-bedded (upsection) limestone that coarsens upward from white, sparse biowackestone in the basal 3 ft 4 inches, to yellow-gray, shaly biowackestone above, layers of chert (fenestrate and ramose bryozoans, crinoids, spicules, juvenile Composita)
1 ft 4 inches	Basal 4 inches of fossiliferous, gray shale, overlain by a bed of limestone that fines upward from biowackestone to sparse biowackestone, yellow-gray, chert layers; Chonetes, crinoids, Composita and Derbyia in the shale; Composita, Derbyia, Reticulatia, crinoids, fenestrate and ramose bryozoans in the limestone
1 ft 0 inches	Thin-bedded limestone, biowackestone, light-gray, thick layer of chert in the middle; brachiopod fragments, crinoids, foraminifers, high-spired gastropods

SPEISER FORMATION

3 ft 0 inches	Poorly exposed mudrock, yellow-brown and fossiliferous in the top 1 ft; Derbyia, crinoids, Composita
2 ft 0 inches	Light-gray paleosol with rootcasts
2 ft 4 inches	Unfossiliferous green mudrock, thin layer of red mudrock just below the top
5 ft 6 inches	Unfossiliferous, deep red mudrock

The Funston is exposed at the base of this outcrop along the road

Measured Section Number: 137A

Location: At Alcove Spring, in the exposures along the creek bank immediately west of the spring, the roadcuts along East River Road where the creek crosses the road, and the creek bank cliffs in the field due west of the road: E/2 sec. 31, T. 3 S., R. 7 E., Marshall County, Kansas

WREFORD LIMESTONE

Schroyer Limestone Member

1 ft 3 inches	Bed of limestone, biowackestone, light-yellow, the top 3 inches of which is a layer of fossiliferous, dark-gray chert; Reticulatia, fenestrate bryozoans, and large ramose bryozoans
2 ft 5 inches	Recessive unit of yellow, calcitic shale; abundant Reticulatia, lesser crinoids, ramose bryozoans, and rare Composita
1 ft 11 inches	Thin-bedded, shaly limestone, fines upward from dense biowackestone to less-dense biowackestone, light-yellow; ramose bryozoans, brachiopod fragments

Havensville Shale Member

4 ft 4 inches	As measured along the road: basal 1 ft 4 inches bed of bioturbated, very coarse grained limestone, biograinstone, fines upward to coarse-grained biopackstone, medium-gray with splotches of yellow. Overlying 2-ft bed of porous limestone, biograinstone, faint low-angle cross strata, very light gray. Upper 1-ft bed of limestone, fines upward from coarse-grained biograinstone to coarse-grained biopackstone, light-yellow, with abundant orange-colored ramose bryozoans. All of these rocks contain brachiopod fragments, foraminifers, high-spired gastropods, and pelecypod fragments, and at the top, ramose bryozoans. At the spring: 4 ft 4 inches bed of porous limestone, coarse-grained biograinstone, low-angle cross strata, light-gray or yellow (same fossils)
7 ft 0 inches	At the spring and in creek bank exposures to the immediate west: basal 2 ft 11 inches of thin-bedded to fissile, shaly limestone, mudstone, medium-gray, few foraminifers at the top, which is laminated. Overlying 2 ft 4 inches of thin-bedded limestone, shaly mudstone, light-gray, some partings of black shale, some foraminifers; there is a 2-inches-thick lens at the base of round- and flat-pebble conglomerate (clasts from below) in a matrix of foraminiferal packstone—this unit thickens to 8 inches farther west along the creek bank, where the conglomerate is overlain by cross stratified foraminiferal packstone-grainstone; the top 6-inches-thick bed in this unit varies along the outcrop at the spring from mudstone to foraminiferal packstone, and is disrupted into fairly large, truncated, curled desiccation polygons—farther downcreek, this disrupted unit consists of thin

interlayers of desiccated mudstone and foraminiferal packstone. Top 1 ft 9 inches of thin-bedded limestone, shaly and bioturbated foraminiferal wackestone-packstone, mottled light-yellow and medium-gray, with high-spired gastropods, pelecypod fragments, and small Composita.
At the roadcut the upper 3 ft of this 7 ft 0 inches thick unit has changed facies to, in ascending order: (a) basal 1 ft 6 inches of medium-bedded, fine-grained foraminiferal wackestone, bioturbated, mottled light-gray and medium-gray; and (b) 1 ft 6 inches bed of bioturbated to syndepositionally deformed layers of mudstone-wackestone and foraminiferal packstone, light- and medium-gray

1 ft 8 inches	Along the creek bank downstream of the spring: blocky, light-yellow, shaly lime mudstone to calcitic shale, unfossiliferous
1 ft 4 inches	Along the creek bank downstream of the spring and in west-facing cliff to the west of the road: two beds of hard limestone, shaly mudstone, splotches of light and medium-gray, unfossiliferous
5 ft 9 inches	At west-facing cliff to the west of the road: concealed
1 ft 7 inches	At west-facing cliff to the west of the road: fissile black shale, the basal 3 inches of which are mottled light-yellow and black, unfossiliferous

Threemile Limestone Member

3 ft 1 inches	At west-facing cliff to the west of the road: medium- up to thin-bedded limestone, very light yellow mudstone, with layers and nodules of black chert; a thin, yellow shale occurs just below the top 2–3-inches-thick bed of cherty limestone at the top of the section

Measured Section Number: 138

Location: Roadcut and field exposures along East River Road, NE SE sec. 31, T. 3 S., R. 7 E., Marshall County, Kansas (east bank of the Big Blue River)

MATFIELD SHALE

Blue Springs Shale Member

1 ft 6 inches	Badly weathered, unfossiliferous, yellow mudrock
1 ft 2 inches	Unfossiliferous, yellow-green mudrock
11 ft 6 inches	Unfossiliferous mudrock, mostly red but with some layers of green; prominent 1-ft-thick ledge of red siltstone in the middle, with incipient pisolites, glaebules, and green shale-filled vertical rootlets (paleocaliche)
7 ft 0 inches	Unfossiliferous, light-greenish-gray mudrock, bright-green in the top 2 ft

Kinney Limestone Member

2 ft 4 inches	Fossiliferous, light-brownish-yellow, calcitic mudrock; Derbyia, curved spines, high-spired gastropods, echinoid fragments, crinoids
0 ft 10 inches	Ledge of indurated, fossiliferous, light-brownish-yellow mudrock; Derbyia, curved spines, high-spired gastropods, echinoid fragments, crinoids
7 ft 4 inches	Fossiliferous, light-brownish-yellow, calcitic mudrock; Derbyia, curved spines, high-spired gastropods, echinoid fragments, crinoids
1 ft 6 inches	Bed of limestone, coarsens upward from shaly, intraclastic mudstone (clasts of orange, shaly lime mudstone) to sparse biowackestone, bioturbated, light-yellow; Septimyalina, crinoids, brachiopod fragments, foram-encrusted grains

Wymore Shale Member

1 ft 6 inches	Unfossiliferous, yellow mudrock at base grading up to calcitic and fissile yellow shale in the top 6 inches
1 ft 4 inches	Unfossiliferous, dark-grayish-green mudrock
1 ft 1 inches	Light-tan paleosol
5 ft 0 inches	Unfossiliferous, red mudrock

Measured Section Number: 139

Location: Roadcuts on US–77 in NE sec. 16 and N/2 sec. 21, T. 3 S., R. 7 E., Marshall County, Kansas (south of Marysville)

FORT RILEY FORMATION

1 ft 6 inches	Thin-bedded, shaly dolomite, coarsens upward from dolomudstone to porous, intraclastic (clasts of dolomudstone) dolobiowackestone, then fines upward to dolomudstone with anhydrite nodules, light-yellow, calcite-lined geodes; pelecypod fragments, foraminifers
2 ft 2 inches	Thin-bedded, shaly dolomudstone, very light yellow, calcite-lined vugs
0 ft 8 inches	Ledge of vuggy, shaly dolomudstone, fenestral fabric, light-yellow
1 ft 10 inches	Thin-bedded, shaly dolomudstone, calcite-lined vugs, very light yellow
2 ft 7 inches	Two beds of dolomite, fines upward from intraclastic (clasts of lime mudstone) dolobiopackstone with prominent vertical burrows in the basal bed, to finer-grained, porous dolobiopackstone in the upper bed, yellow-orange; foraminifers, some Aviculopecten, gastropods. This unit likely is the Fort Riley main ledge referred to in the text

3 ft 3 inches	Medium- to thick-bedded, porous, silty and shaly, sparse dolobiowackestone, vugs, light-yellow-gray; Aviculopecten, Meekella, Reticulatia, Edmondia, crinoids, fenestrate and ramose bryozoans

FLORENCE FORMATION

Oketo Shale Member

1 ft 8 inches	Fossiliferous, silty, light-yellow mudrock; pelecypod molds, crinoids, echinoid fragments, ramose and fenestrate bryozoans, Derbyia, Composita, Reticulatia
4 ft 0 inches	Dolomitic mudrock to shaly dolomudstone silty, wavy laminae, bioturbated, fossiliferous, light-yellow; crinoids, echinoid fragments, ramose and fenestrate bryozoans, Derbyia, Composita, Reticulatia
2 ft 8 inches	Recessive unit of sparsely fossiliferous, calcitic, yellow, silty mudrock, gradational top; crinoids, fenestrate and ramose bryozoans, brachiopod fragments

Middle part of the formation

5 ft 0 inches	Very thin bedded to laminated, medium-gray, silty and calcitic, fossiliferous shale, scattered chert nodules; crinoids, brachiopod fragments
3 ft 4 inches	Fossiliferous, calcitic mudrock, light- to medium-gray; the size and number of skeletal fragments decreases upsection, where the mudrocks become silty; ramose bryozoans, crinoids, brachiopod and echinoid fragments
3 ft 6 inches	Two thin beds of dolomitic limestone at the top and bottom separated by a thick bed of dolomite: silty mudstone, light-yellow, the middle bed with abundant chert nodules, some of which follow short, vertical burrows; crinoids, brachiopod fragments
1 ft 4 inches	Thin-bedded limestone, sparse biowackestone, light-yellow- gray, chert nodules at the base, 3-inches-thick layer of chert at the top; crinoids, brachiopod fragments
1 ft 11 inches	Bed of dolomitic limestone, biowackestone wherein particle size decreases upsection, light-yellow, discontinuous layers of chert, a layer at the base; crinoids, some fenestrate bryozoans and brachiopod fragments
4 ft 3 inches	Bed of limestone, coarse-grained biowackestone, orange; thin, discontinuous layers of chert at the base, thick layers in the middle, nodules at the top; fenestrate and ramose bryozoans, crinoids, brachiopod fragments
3 ft 4 inches	Medium-bedded, dolomitic limestone, biowackestone, light-gray, biomoldic pores in basal two beds; thin layers of chert in lower half, nodules and discontinuous layers above. Rocks contain crinoids, ramose bryozoans, Reticulatia
0 ft 10 inches	Bed of dolobiowackestone, yellow, chert nodules and a thin layer of chert at the top; crinoids, brachiopod fragments, ramose bryozoans

Cole Creek Member

4 ft 2 inches	Bed of limestone, coarsens upward from shaly mudstone, orange-yellow (with Septimyalina and ramose bryozoans); to crudely layered and bioturbated, porous, shaly biowackestone, orange-yellow, with calcite-quartz-anhydrite nodules (with pelecypod fragments, ramose bryozoans, Reticulatia). 1 ft 6 inches below the top is a 3-inches-thick layer of bioturbated crinoid packstone. This unit weathers in exfoliating fashion

MATFIELD SHALE

Blue Springs Shale Member

4 ft 0 inches	Unfossiliferous, dark- to medium-grayish-green mudrock
1 ft 0 inches	Unfossiliferous, red mudrock

Measured Section Number: 140

Location: Streamcut on Roemer Creek and adjoining roadcuts (both sides) to the immediate south, in N/2 SW sec. 10 and SE sec. 9, T. 2 S., R. 6 E., Marshall County, Kansas

Comment: There is no Cresswell at this locality

ODELL SHALE

10 ft 0 inches	Unfossiliferous, red shale and mudrock
4 ft 0 inches	Unfossiliferous, yellow-green and yellow mudrock, some layers of red shale in the middle

Note: total thickness of the Odell in this area is about 30–40 ft

WINFIELD LIMESTONE

Luta Member

3 ft 2 inches	Thin-bedded, shaly dolomudstone: basal 1 ft 2 inches very light gray, with pea- to marble-size calcite-anhydrite-quartz nodules and vugs from their dissolution. Overlying 4-inches bed of dolomudstone, in turn overlain by 6-inches mudstone with golf-ball-size, calcite-lined geodes. The top 1-ft bed fines upward from gastropod dolopackstone to dolomudstone (high-spired and planispiral gastropods),
2 ft 6 inches	Medium-bedded, yellow dolomudstone, shaly, with abundant pea- to marble-size calcite-

anhydrite-quartz nodules and vugs from their dissolution; top 1-inch- to 8-inches-thick lense of porous dolobiopackstone (with Myalina, Aviculopecten, Edmondia) on the west side of the road

Grant Shale Member

7 ft 8 inches	Light-yellow, calcitic mudrock, lower half fossiliferous, with small gray chert nodules at the base (Allorisma, Derbyia, ramose bryozoans, crinoids, Reticulatia, echinoid fragments, Composita, pectinid casts). Upper half unfossiliferous (but bioturbated in the top 2–3 inches) and silty, with abundant pea- to marble-size nodules of calcite-anhydrite-quartz
1 ft 8 inches	Fossiliferous, fissile, dark-gray shale; ramose and fenestrate bryozoans, crinoids, Derbyia
4 ft 0 inches	Sparsely fossiliferous, light-gray mudrock; pelecypod fragments, crinoids
2 ft 0 inches	Fossiliferous, very dark gray shale mudrock; crinoids, Derbyia, Reticulatia

Stovall Limestone Member

0 ft 10 inches	Bed of limestone, mudstone-sparse biowackestone, light-yellow-gray, dark- and light-gray chert nodules; Derbyia, fenestrate and ramose bryozoans, Reticulatia

DOYLE SHALE

Gage Shale Member

2 ft 4 inches	Fossiliferous mudrock, dark- to medium-gray grading up to light-gray; Derbyia, crinoids
1 ft 0 inches	Bed of shaly limestone, biopackstone, yellow; Derbyia, crinoids
2 ft 6 inches	Fossiliferous, medium- to dark-gray mudrock, interbeds of fossiliferous, yellow mudrock in the middle; crinoids, echinoid fragments, ramose bryozoans, oncolites, Derbyia, Reticulatia
2 ft 6 inches	Unfossiliferous, light-yellow-gray, calcitic and silty mudrock
1 ft 0 inches	Unfossiliferous, red, silty mudrock

Measured Section Number: 141

Location: Roadcut, edge of Horseshoe Creek, center west line of sec. 6, T. 2 S., R. 7 E., Marshall County, Kansas

DOYLE SHALE

Towanda Limestone Member

3 ft 0 inches	Thick-bedded, porous, recrystallized limestone, the top 8 inches foraminiferal biograinstone, yellow

Holmesville Shale Member

6 ft 0 inches	Poorly exposed mudrock, red at the base, yellow-green in the middle, yellow at the top, unfossiliferous

Measured Section Number: 142

Location: Two closely spaced exposures: in the ravine immediately west of the road in a tributary to Mission Creek, and roadside outcrops to the immediate north, in E/2 sec. 4, T. 1 S., R. 8 E., Marshall County, Kansas
DOYLE SHALE

Towanda Limestone Member
(probable top of the member)

12 ft 0 inches	Thin- to medium-bedded, shaly, coarse-recrystallized limestone, porous, secondary calcite laminae and veins, highly distorted, orange-yellow
2 ft 3 inches	Unfossiliferous, greenish-gray mudrock
1 ft 0 inches	Bed of shaly dolobiopackstone, light-yellow; crinoids, foraminifers, pelecypod and gastropod fragments

Holmesville Shale Member

1 ft 2 inches	Unfossiliferous, greenish-tan mudrock
0 ft 10 inches	Unfossiliferous, fissile, calcitic, light-tan shale
2 ft 4 inches	Unfossiliferous, dolomitic mudrock, calcite-lined vugs, yellow-brown

FORT RILEY FORMATION

3 ft 8 inches	Very thin bedded, shaly dolomudstone, light-gray, abundant calcite-lined vugs, biomolds of bivalves in the basal few inches
0 ft 7 inches	Thin-bedded, shaly dolomudstone, light-gray
1 ft 5 inches	Thin-bedded, shaly dolomite: basal 3 inches porous, light-gray, dolobiowackestone-packstone. Overlain by 5 inches of coarse-grained dolobiopackstone, yellow-orange. Overlain by 4 inches dolomudstone with lenses of dolobiopackstone, light-gray. Top 5 inches shaly dolomudstone with calcite-lined vugs, light-gray. Rocks contain gastropod and pelecypod fragments
5 ft 0 inches	Thick-bedded, shaly limestone, mudstone, abundant calcite-lined vugs; a 4-inches-thick recessive zone in the middle of the unit, more shaly than the surrounding rock

Measured Section Number: 143

Location: High cutbank on Mission Creek, south side, in NE SE sec. 3, T. 1 S., R. 8 E., Marshall County, Kansas

Comment: We could not measure any higher than we did because of the steepness and inaccessibility of this cutbank exposure. We correlate the top bed here with the basal bed at measured section number 142

FORT RILEY FORMATION

5 ft 0 inches	Bed of shaly limestone, mudstone, calcite-lined vugs; a 4-inches-thick recessive unit in the middle, shalier than the surrounding rock
1 ft 10 inches	Unfossiliferous, light- to medium-gray mudrock
2 ft 0 inches	Thick- to thin-bedded (upsection), shaly dolomudstone, porous, yellow-brown
4 ft 6 inches	Basal 1 ft 4 inches of thin-bedded section that coarsens upward from shaly dolomudstone to fine-grained dolobiopackstone, porous, yellow; middle thicker-bedded section that fines upward from porous, fine-grained dolobiopackstone to grainstone to sparse dolobiowackestone, yellow; upper thin-bedded section that fines upward from porous, sparse dolobiowackestone to dolomudstone, yellow. Rocks contain pelecypod molds

FLORENCE FORMATION

Oketo Shale Member

7 ft 3 inches	Thin-bedded, light- to medium- and dark-gray, dolomitic mudrock, sparsely fossiliferous, bioturbated, vugs (some filled with coarse, opaque white calcite spar); partings of unfossiliferous, black shale. Rocks contain rare Derbyia, pectinid casts

Measured Section Number: 144

Location: Small roadcut (of the Luta), and hillside exposures (of the Odell) in NW SE sec. 5, T. 2 S., R. 5 E., Washington County, Kansas

Comment: The top of the exposed Odell section here is the base of the Nolans as indicated by poorly exposed Krider limestone on the hillside

ODELL SHALE

~21 ft 0 inches	Mostly concealed section: unfossiliferous and red mudrock exposed a few feet below the top Note: see the equivalent section at measured section number 145
4 ft 0 inches	Unfossiliferous, medium-gray mudrock, light-green at the top

WINFIELD LIMESTONE

Luta Member

2 ft 0 inches	Medium-bedded, shaly limestone with abundant pea- and marble-size nodules of calcite-anhydrite-quartz and vugs from their dissolution, light-yellow

Measured Section Number: 145

Location: Roadcut, SE NE sec. 31, T. 1 S., R. 5 E., north of Hanover, Washington County, Kansas

NOLANS LIMESTONE

Herington Member

2 ft 7 inches	Thin-bedded, shaly dolomudstone, the top 1 ft 4 inches with pea- to golf-ball-size vugs; thin shale with ostracodes a few inches above the base, and thin laminae of biowackestone-packstone sporadically in the lower half of the section, yellow. Carbonates contain rare Permophorus, Bellerophon, Myalina, Aviculopecten

Paddock Shale Member

9 ft 6 inches	Mudrock, dark-gray with yellow splotches in the lower half, which is sparsely fossiliferous (pectinid casts, fenestrate bryozoans); and mottled light-brown and yellow in the upper half, which is seemingly unfossiliferous

Krider Member

2 ft 6 inches	Medium-bedded, shaly dolomudstone, bioturbated and slightly porous, somewhat gradational top, light-yellow with orange wisps; Aviculopecten, Septimyalina
2 ft 2 inches	Sparsely fossiliferous mudrock, dark-gray with splotches of yellow; rare pectinid casts
0 ft 11 inches	Thin-bedded, shaly dolomudstone, gradational top, yellow with orange wisps; pectinid casts

ODELL SHALE

3 ft 2 inches	Unfossiliferous mudrock, grades upward from basal few inches of gray-green to reddish-yellow to yellow-brown, then greenish-yellow at the top; the top 3 inches is notably hard and blocky
6 ft 10 inches	Unfossiliferous mudrock, mostly red but with ~8-inches-thick layers of light-gray shale throughout

Measured Section Number: 146

Location: Roadcut in E/2 NW sec. 31, T. 1 S., R. 5 E., north of Hanover; with a supplemental section of the uppermost Herington along K–148, east side, in NW NW sec. 10, T. 3 S., R. 5 E., Washington County, Kansas

NOLANS LIMESTONE

Herington Member

9 ft 8 inches	Thin-bedded, shaly dolomudstone, yellow, abundant vugs above the basal 1 ft 3 inches, thin shale with ostracodes above the base; basal few feet of the unit contain some Aviculopecten, Bellerophon and Myalina

Paddock Shale Member

3 ft 0 inches	Unfossiliferous, yellow-brown mudrock

Measured Section Number: 147

Location: High cutbank on Plum Creek, NE NE sec. 30, T. 1 N., R. 8 E., Gage County, Nebraska

FLORENCE FORMATION

3 ft 6 inches	Thin- to medium-bedded, porous dolobiowackestone-packstone, light-yellow-gray, chert nodules; brachiopod fragments, ramose bryozoans

Cole Creek Member

1 ft 9 inches	Fossiliferous, calcitic, yellow mudrock; brachiopod fragments, crinoids, ramose bryozoans
1 ft 5 inches	Thin-bedded, shaly dolomudstone, medium-gray; crinoids, brachiopod fragments

MATFIELD SHALE

Blue Springs Shale Member

1 ft 4 inches	Unfossiliferous, yellow mudrock
5 ft 8 inches	Unfossiliferous, light-green mudrock
4 ft 0 inches	Interbedded red and green mudrock, unfossiliferous
2 ft 0 inches	Ledge of unfossiliferous, dull-red, shaly siltstone
0 ft 8 inches	Unfossiliferous, light-green shale
1 ft 3 inches	Ledge of unfossiliferous, dull-red, shaly siltstone
0 ft 9 inches	Ledge of unfossiliferous, blocky, dull-green, silty mudrock
1 ft 4 inches	Unfossiliferous, green mudrock
3 ft 6 inches	Unfossiliferous, red mudrock
0 ft 9 inches	Unfossiliferous, light-green shale
0 ft 8 inches	Unfossiliferous, red shale
2 ft 0 inches	Unfossiliferous, dark-grayish-green mudrock grading up to bright-green mudrock, with a thin stringer of red shale a few inches above the base
0 ft 10 inches	Basal 3 inches of red shale overlain by 7 inches of light-gray, compact paleocaliche with green shale in vugs/fissures, and glaebules

Measured Section Number: 148

Location: High cutbank along Plum Creek, NW sec. 15, T. 1 N., R. 8 E., Gage County, Nebraska

FLORENCE FORMATION

~4 ft 0 inches	Cherty limestone (too high to reach)

Cole Creek Member

~2 ft 0 inches	Fossiliferous, calcitic, yellow mudrock (too high to reach)
1 ft 6 inches	Shaly, thin-bedded dolomudstone (too high to reach)

MATFIELD SHALE

Blue Springs Shale Member

1 ft 4 inches	Unfossiliferous, yellow mudrock
5 ft 8 inches	Unfossiliferous, light-green mudrock
5 ft 4 inches	Unfossiliferous, red mudrock, band of green shale ~8 inches above the base
3 ft 4 inches	Ledge of red, silty shale to shaly siltstone, unfossiliferous, abundant green shale-filled rootcasts in the upper half (paleosol)
3 ft 2 inches	Unfossiliferous mudrock; basal 9 inches and top 4 inches are green, the remainder of the unit is red and silty
5 ft 8 inches	Unfossiliferous mudrock, mostly red but with thin bands of green; top 1 ft 8 inches is silty
1 ft 10 inches	Unfossiliferous mudrock: basal 1 inch hard, pale-green paleosol overlain by 4 inches dark-green mudrock, then light-green mudrock up to the top of the unit
2 ft 1 inches	Unfossiliferous, pale-green mudrock

Kinney Limestone Member

3 ft 8 inches	Fissile, unfossiliferous shale: basal 1 inch green, overlain by ~1 ft black shale with green

shale partings, the remainder of the section is black shale

2 ft 6 inches — Thin-bedded, shaly limestone, mudstone, medium-gray with yellow splotches; crinoids, brachiopod fragments, Aviculopecten, Septimyalina

2 ft 8 inches — Fossiliferous, calcitic mudrock, bioturbated, medium- gray with yellow splotches; fenestrate bryozoans, Derbyia, Reticulatia, Allorisma

2 ft 6 inches — Progressively thinner-bedded upsection: fines upward from porous, yellow, dolomitic limestone, oncolite biowackestone-packstone in the basal 7 inches, to layered (locally bioturbated), medium-gray and yellow, shaly dolomitic lime mudstone; crinoids, brachiopod fragments, Aviculo-pecten, Septimyalina, foraminifers

Wymore Shale Member

4 ft 0 inches — Unfossiliferous, mostly green mudrock: top 4 inches is a minor ledge of fissile, pale-yellowish-green mudrock beneath which is 1 ft 8 inches dark-green mudrock, the upper half of which is laminated (shale)

6 ft 9 inches — Unfossiliferous, red mudrock, some streaks of green shale

0 ft 8 inches — Unfossiliferous, red mudrock overlain by green shale

11 ft 0 inches — Unfossiliferous mudrock: basal 7 ft interbedded red and green, top 4 inches red shale; ~3-inches-thick paleosols at the top and ~3.5 ft below the top

2 ft 0 inches — Unfossiliferous, pale-green mudrock with conchoidal fracture

Measured Section Number: 149

Location: Roadcut, NW sec. 11 and adjoining NE sec. 10, T. 1 N., R. 7 E., Gage County, Nebraska

DOYLE SHALE

Towanda Limestone Member

4 ft 0 inches — Thick-bedded, coarse-recrystallized limestone, orange, porous; basal bed with a lense of fine-grained biowackestone (foraminifers), laminated, which passes laterally to ~1 ft 6 inches of breccia (clasts of recrystallized limestone in a matrix of with red shale)

3 ft 0 inches — Thick-bedded, very porous, coarse-recrystallized limestone, orange, calcite-lined vugs and secondary calcite laminae and veins; 6 inches below the top is a 4–5-inches-thick lense of gray, peloid grainstone

1 ft 0 inches — Bed of porous, coarse-recrystallized limestone, orange

0 ft 2 inches — Unfossiliferous, yellow shale (Holmesville?)

Measured Section Number: 150

Location: Roadcuts in W/2 SW sec. 29 and E/2 SE sec. 30, T. 2 N., R. 8 E., Gage County, Nebraska

FLORENCE FORMATION

3 ft 0 inches — Thin-bedded, porous (biomoldic) dolo-wackestone, light-yellow; brachiopod fragments, ramose bryozoans

Cole Creek Member

1 ft 7 inches — Fossiliferous, calcitic, yellow mudrock; brachiopod fragments, ramose bryozoans, crinoids

1 ft 3 inches — Very thin bedded, shaly dolomudstone, dark-gray; crinoids, brachiopod fragments

MATFIELD SHALE

Blue Springs Shale Member

10 ft 0 inches — Poorly exposed, unfossiliferous mudrock: red with layers of gray-green in the basal 7 ft, yellow-green grading up to yellow in the top 3 ft

Measured Section Number: 151

Location: Quarry on Marple Farm, in SW NE sec. 27, T. 2 N., R. 7 E., immediately east of the railroad tracks and the Big Blue River (to the northwest of the farmhouse), Gage County, Nebraska

Comment: This general locality is Condra and Upp's (1931) type locality for the Wymore and Blue Springs Members

FORT RILEY FORMATION

2 ft 0 inches — Poorly exposed, calcitic mudrock, light-yellow

0 ft 10 inches — Thin-bedded, silty dolomudstone, calcite-lined geodes, light-yellow; pectinid casts, Derbyia

FLORENCE FORMATION

Oketo Shale Member

4 ft 0 inches — Progressively thinner-bedded, silty and shaly dolomudstone in the lower half, grades upward into fossiliferous, dolomitic mudrock in the top 2 ft 2 inches, with nodules filled with coarse crystalline calcite; light-yellow; Aviculopecten, crinoids, fenestrate bryozoans, Derbyia, Meekella

1 ft 6 inches — Sparsely fossiliferous, silty mudrock, mottled dark-gray and yellow-brown; Aviculopecten

Middle part of the formation

2 ft 0 inches	Progressively thinner-bedded, silty and shaly dolomudstone, gradational top, light-yellow; pelecypod molds, lingulids, Aviculopecten
3 ft 4 inches	Thick-bedded, shaly dolomudstone: basal 2 ft 4 inches medium- to dark-gray with abundant (dark-gray) chert nodules, some of which have replaced short, vertical burrows; top 1 ft light-yellow, with small chert nodules and a few white chert geodes. Rocks contain brachiopod fragments, crinoids
2 ft 8 inches	Medium-gray, unfossiliferous, calcitic mudrock
2 ft 6 inches	Thin-bedded dolomudstone, light-yellow, chert layers; brachiopod fragments, crinoids
1 ft 2 inches	Basal 7 inches of unfossiliferous, calcitic, dark-gray shale; overlying 7 inches dolomudstone, yellow, thin chert layer at the base
0 ft 9 inches	Bed of dolomudstone, yellow with orange bands
3 ft 0 inches	Thick-bedded dolomite, sparse biowackestone: very dark gray and porous in the basal 8 inches, light-yellow and nonporous in the overlying 7 inches, medium-gray and nonporous above that; chert layers at the base and top. Rocks contain brachiopod fragments, crinoids, spicules
4 ft 8 inches	Medium-bedded, porous dolomite, sparse biowackestone, yellow-gray, chert layers and nodules; crinoids, ramose and fenestrate bryozoans, high-spired gastropods, Derbyia
1 ft 9 inches	Bed of very porous dolomudstone, light-yellow-gray, chert layers; crinoids, spicules, fenestrate and ramose bryozoans
1 ft 8 inches	Medium-bedded dolomudstone, medium-gray grading up to yellow-gray, chert nodules at the top; rare crinoids, brachiopod fragments, pelecypod molds

Measured Section Number: 152

Location: Roadcuts along N–112, 0.3–0.45 mi south of the Krider railroad siding, Condra and Upp's (1931) type locality for the Krider and Paddock Members: W/2 sec. 10 and E/2 sec. 9, T. 1 N., R. 6 E., Gage County, Nebraska

NOLANS LIMESTONE

Herington Member

4 ft 4 inches	Basal 4 inches ledge of yellow, shaly dolomudstone, overlain by badly weathered, thin-bedded, yellow dolomudstone, calcite geodes

Paddock Shale Member

11 ft 0 inches	Badly weathered mudrock: basal 4 ft sparsely fossiliferous and medium-gray with yellow splotches (rare pectinid casts); upper 7 ft unfossiliferous, yellow

Krider Member

1 ft 3 inches	Thin-bedded, shaly dolomudstone, light-yellow, gradational top; Myalina, some Aviculopecten
2 ft 1 inches	Unfossiliferous, grayish-yellow mudrock
1 ft 6 inches	Thin-bedded, shaly dolomudstone, light-yellow; lingulids

ODELL SHALE

3 ft 4 inches	Unfossiliferous, silty mudrock, grades upward from gray-green to yellow
1 ft 8 inches	Unfossiliferous, red mudrock
5 ft 10 inches	Unfossiliferous, red mudrock, few inches of green shale at the top, base, and above the middle
8 ft 0 inches	Poorly exposed, unfossiliferous mudrock and shale, mostly red with thin layers of bright green
0 ft 8 inches	Basal 2 inches of yellow, unfossiliferous shale overlain by 4 inches of yellow-gray mudrock, and then, 2 inches of green-gray shale; unfossiliferous

Measured Section Number: 153

Location: Cutbank along Big Indian Creek, SW sec. 36 and east edge of SE sec. 35, T. 2 N., R. 6 E., Gage County, Nebraska

Comment: We have tentatively identified this section as the Gage to Luta based on field relationships

QUATERNARY

3 ft 0 inches	Indurated gravelly sandstone, cross stratified (glacial drift)

WINFIELD LIMESTONE

Luta Member

5 ft 0 inches	Very thin bedded, dolomitic mudrock to shaly dolomudstone, calcite-lined geodes and smaller vugs, some paper-thin laminae of palisades calcite, unfossiliferous, light-yellow

Grant Shale Member

2 ft 4 inches	Unfossiliferous, black shale

Stovall Limestone Member

1 ft 2 inches	Basal bed of shaly, porous dolobiowackestone, overlain by fossiliferous, light-gray mudrock; top 5-inches-thick bed of shaly, porous dolobiowackestone, the top 2 inches of which is black and intraclastic; foraminifers, Permophorus, Aviculopecten, gastropods, Septimyalina
0 ft 10 inches	Recrystallized dolomite, yellow-gray, contorted, becomes shalier upsection

DOYLE SHALE

Gage Shale Member

0 ft 11 inches	Basal 4 inches of laminated, light-gray, unfossiliferous shale, overlain by 7 inches of medium-gray-green shale, unfossiliferous
5 ft 4 inches	Unfossiliferous, medium-gray-green, silty mudrock
1 ft 0 inches	Unfossiliferous, red mudrock

Measured Section Number: 154

Location: Creekbed and adjoining roadcut, SW sec. 13, T. 3 N., R. 6 E., west of Holmesville, Gage County, Nebraska

Comment: This outcrop may be Condra and Upp's (1931) type locality of the Holmesville

DOYLE SHALE

Holmesville Shale Member

10 ft 0 inches	Unfossiliferous mudrock and shale, mostly red, with ~1 inch of green shale at the base, and some 1–2-inches-thick layers of yellow-green shale in the top 6 ft of the unit
2 ft 0 inches	Laminated, dolomitic shale, unfossiliferous, light-yellow with red laminae, brecciated in upper beds

FORT RILEY FORMATION

3 ft 2 inches	Very thin bedded to laminated, very shaly dolomudstone to dolomitic shale, unfossiliferous, vugs, mostly light-yellow, some red laminae
3 ft 0 inches	Medium- to thin-bedded (upsection), shaly dolomudstone, medium-gray, small calcite-lined vugs, red stains along bedding planes

Measured Section Number: 155

Location: Churchill oil field, north of the town of Oxford, along the west bank of the Arkansas River, E/2 NW sec. 36, T. 31 S., R. 2 E., Sumner County, Kansas

QUATERNARY

Eolian sand

ODELL SHALE

5 ft 0 inches	Unfossiliferous, light-gray, locally calcitic, silty shale and mudrock

WINFIELD LIMESTONE

Luta Member

9 ft 6 inches	Thin-bedded, shaly limestone: basal 1 ft 3 inches dark-gray and unfossiliferous lime mudstone, locally mechanically laminated with quartz silt; overlying 1 ft 6 inches light-gray, possibly silty lime mudstone, small chert nodules (light- to medium-gray), scattered Lingula, thin partings of light-gray shale; overlying remainder of the section very shaly, light-gray, unfossiliferous lime mudstone, progressively more shaly upsection
1 ft 8 inches	Ledge-forming bed of shaly limestone, sparse biowackestone, medium-gray, with scattered small chert nodules (light- and dark-gray); Derbyia, Composita, crinoids, fenestrate and ramose bryozoans
1 ft 10 inches	Recessive unit of thin-bedded, shaly limestone, mudstone, bioturbated, medium-gray; crinoids, Derbyia; local concentrations of Reticulatia ~5 inches above the base
4 ft 7 inches	Thin-bedded, shaly limestone, light-gray: basal 9 inches is mudstone (crinoids, Derbyia); section from 9 to 22 inches above base is mudstone to biowackestone (crinoids, Derbyia, Composita, ramose bryozoans); overlying 2 ft 5 inches is apparently unfossiliferous mudstone; upper 4 inches is sparse biowackestone (crinoids, Derbyia, Composita, ramose bryozoans)

Cresswell Limestone Member

2 ft 8 inches	Bed of porous limestone, light-yellow, fines upward from oncolitic biowackestone-packstone to nononcolitic mudstone-biowackestone; foraminifers, crinoids
1 ft 6 inches	Bed of vertically burrowed limestone, porous, dense oncolite biopackstone to grainstone, light-yellow; crinoids
4 ft 8 inches	Bed of porous limestone, light-yellow, its top picked as the top of a prominently vertically burrowed zone that extends downward ~1 ft 5 inches; section coarsens upward from mud-stone-biowackestone to biopackstone; crinoids, echinoid fragments, ramose bryozoans, Composita, Derbyia, rare oncolites

Grant Shale Member

2 ft 8 inches	Thin-bedded, shaly limestone, bioturbated, light-gray; basal 8 inches is biopackstone (crinoids, bivalve fragments); overlying section is the "concretionary zone" which contains large oncolites, especially in the section 11–19 inches below the top

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