# Inferring Stratigraphic Position of Fossil Vertebrates from the Niobrara Chalk of Western Kansas

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## Abstract

The stratigraphy of the Smoky Hill Chalk Member of the Niobrara Chalk of western Kansas is well understood as a result of the work of Hattin (1982) and Stewart (1988). Marker units identified by Hattin (1982) allow quick determination of the stratigraphic position of a specific outcrop. This study demonstrates that it is now possible to determine the stratigraphic positions of specimens from locality data, thus permitting one to infer stratigraphic position of specimens collected long ago. This technique is particularly useful in the upper half of the Smoky Hill Chalk Member, where biostratigraphy is not informative. The stratigraphic distribution of the type skulls of the pterosaur *Pteranodon* is examined as an example of the procedure, which in turn demonstrates that the procedure can have the power to reject hypotheses. Inferring stratigraphic positions of fossil vertebrates may be useful in further studies of the large collections of fossil vertebrates from the Smoky Hill Chalk Member. In addition, examination of the stratigraphic distribution of outcrops of the Smoky Hill Chalk Member in western Kansas suggests that most of the fossil vertebrates collected from the member came from a rather restricted stratigraphic interval between Marker Units 15 and 20.

## Introduction

The Smoky Hill Chalk Member of the Niobrara Chalk of western Kansas is famous for the very large number of fossil vertebrates it has produced. The collection of fossil vertebrates from the Smoky Hill Chalk Member was begun in earnest by O. C. Marsh and the Yale College Scientific Expedition in 1870. That expedition and subsequent ones by Marsh and colleagues in 1871 and 1872 were so successful in the discovery of abundant remains of fish, mosasaurs, pterosaurs, birds, plesiosaurs, and turtles that Marsh hired professional collectors, including B. F. Mudge and S. W. Williston, to work the Niobrara Chalk for him each year through 1879. During this 10-year period, Marsh amassed the largest and one of the most important collections of Niobrara vertebrates. Since the 1870's, collecting of Niobrara vertebrates has been almost continuous. H. T. Martin of The University of Kansas collected many specimens, providing the core of the large collection at The University of Kansas, and selling specimens to many other museums. George F. Sternberg collected for many years and, like H. T. Martin, sold specimens widely but saved much of the best material for the Sternberg Memorial Museum [later renamed the Fort Hays State Museum (FHSM) and now called the Sternberg Museum of Natural History] in Hays, Kansas. In addition, many other individuals have made small but good collections.

The majority of fossil vertebrates were collected before the stratigraphy of the Niobrara Chalk was adequately understood, and their stratigraphic positions are unknown. The most that the collectors recorded was whether the specimen was from gray (or blue) shale or yellow chalk. The gray-yellow dichotomy is not particularly useful because it is largely a weathering phenomenon (Williston, 1897; Miller, 1968), and often the color change is found at different levels in the same outcrop.

Most studies of fossil vertebrates from the Smoky Hill Chalk Member have suffered from a lack of stratigraphic information, and authors have often had to rely on the fact that exposures along the eastern end of the outcrop area in Ellis County are low in the Smoky Hill Chalk Member, while those of the western end in Logan County are higher. Bardack (1965) located many of the old localities, but at the time the stratigraphy was not sufficiently well known to determine stratigraphic positions of those localities with any precision. The purpose of this report is to show that it is now possible to determine the stratigraphic positions of specimens from locality data. Although precise locality data are best, often even rather vague locality data are sufficient to determine the stratigraphic position of a specimen.

It is important to note that almost all of the Yale Peabody Museum (YPM) collection was collected in the 1870's, before the old Wallace County was divided into Wallace and St. John counties in 1881. St. John County was changed to Logan County in 1885 (Elias, 1931). Bardack (1965) noted that the present Logan County was formerly called St. John County, but did not mention that it was formerly a part of a larger Wallace County. The Niobrara Chalk is not widely exposed in the modern Wallace County. Many specimens in the YPM and other collections are listed as being collected in Wallace County, but almost all of them are from what is now Logan County, and a few are probably from Gove County (see below).

## Stratigraphy

The stratigraphy of the Smoky Hill Chalk Member of the Niobrara Chalk in western Kansas is now well understood. Hattin (1982) described the stratigraphy of the Smoky Hill Chalk Member and identified 23 marker units. Hattin's marker units are the completion and perfection of the pioneering work of Russell (1929), and they allow quick determination of the stratigraphic position of an outcrop in the field. The invertebrate biostratigraphy of the Smoky Hill Chalk Member was examined by Miller (1968) and Hattin (1982). Stewart (1988) showed that vertebrates can also be useful for biostratigraphy in the Smoky Hill Chalk Member. Biostratigraphic zonations based on inoceramids and species of the fish *Protosphyraena* divide the Smoky Hill Chalk Member into four zones, but biostratigraphic zonations do not allow subdivision of the upper half of the Smoky Hill Chalk Member. This is unfortunate because the upper half of the Smoky Hill Chalk Member has produced the majority of fossil vertebrates. Stewart (1988) noted that this is not because the lower half is unfossiliferous (fossils may actually be more common in the lower parts), but rather that fossils from the upper parts were more intensively collected. Letters sent to O. C. Marsh by his collectors S. W. Williston and E. W. Guild (alias E. S. Field) indicate that they concentrated on the upper part because they believed the hunting better, particularly in regard to the birds and pterosaurs for which O. C. Marsh paid the most money. Whatever the reason, most fossil vertebrates have been collected from the upper part of the Smoky Hill Chalk Member, and biostratigraphy is of no use in determining the relative stratigraphic position of these specimens. Therefore, it is necessary to rely on the stratigraphic marker units.

Hattin (1982) and Russell (1929) both designated marker units that allow quick determination of stratigraphic position, and in some instances both authors used the same markers. Marker units identified by Russell (1929) are based almost entirely on bentonite sequences and are lettered, while those identified by Hattin (1982) also include units of unusual lithology and are numbered. In addition to the marker units, many other bentonites are readily recognizable and traceable in the field. These are particularly useful in correlating small outcrop areas with larger outcrops nearby. In this paper Hattin's marker units are used when possible, but Russell's Marker Unit H between Marker Units 17 and 18 also is used because it is readily identifiable and widely exposed.

If the exact locality of a specimen is known, one need only compare the exposure at the locality with the composite stratigraphic column of Hattin (1982). When the exact locality is not known or the exposure at the particular locality is of limited vertical extent and between marker units, a number of nearby outcrops are examined. Despite some regional variations, the bentonite sequences are remarkably uniform across the outcrop area in western Kansas. This uniformity makes possible the precise correlation of outcrops.

## *Pteranodon*

The utility of this method for inferring stratigraphic position from locality data was examined with the pterosaur *Pteranodon. Pteranodon* was a large pterosaur with a wingspan ranging from 3–6 m (9–20 ft). Known from roughly 1,200 specimens, it was an important part of the fauna of the Western Interior Seaway and was the most common tetrapod after the mosasaurs *Platecarpus, Clidastes,* and *Tylosaurus.* The postcranial skeleton is of no taxonomic value at the species level, and although *Pteranodon* occurs in two size classes, this reflects sexual dimorphism in size rather than specific differences (Bennett, 1991, 1992). The skull, on the other hand, has been used to distinguish species. Five nominal species of *Pteranodon* are based on skulls, and they differ in the size and shape of the cranial crest and the angle between the occiput and the palate. The type skulls of *Pteranodon longiceps, P. marshi,* and *P. eatoni* have a reclined occiput that is plesiomorphic for pterodactyloids, while those of *P. sternbergi* and *P. walkeri* have a more upright occiput. In the absence of stratigraphic information, it was hypothesized that the cranial morphology evolved from a reclined occiput to an upright occiput, and that a single species or lineage of *Pteranodon* was present in the Smoky Hill Chalk Member. If this were the case, one would not expect the two morphologies to co-occur, and skulls with reclined occiputs should be stratigraphically lower than those with upright occiputs.

To test this hypothesis, it was necessary to determine the stratigraphic positions of the type skulls. The localities of these specimens of *Pteranodon,* as well as nearby outcrops, were visited and stratigraphic columns measured. Localities in Logan and Gove counties are shown in fig. 1, and the stratigraphic columns are listed in the Appendix. These columns were then compared to the composite stratigraphic column of Hattin (1982), and stratigraphic positions of the outcrops were determined. Using the stratigraphic columns and any other available information about the position or locality of the specimens, it was possible to determine the stratigraphic position or

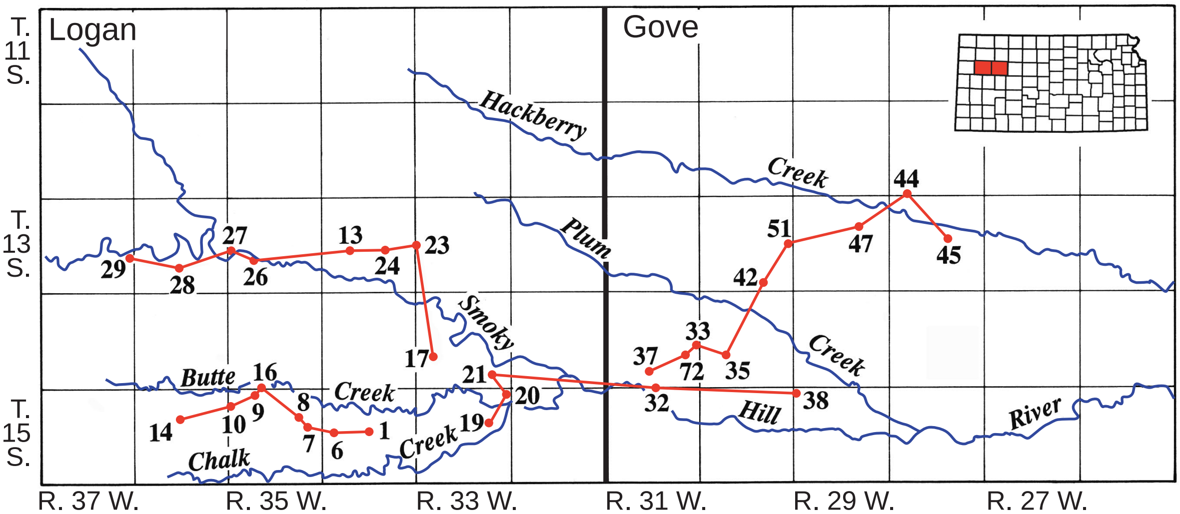


FIGURE 1. Map of Logan and Gove counties, Kansas, showing the localities where stratigraphic columns were measured. Red lines between localities show their order in figs. 2 and 5–7.

range for these type specimens of *Pteranodon.* The five nominal species are discussed below in the order in which they were named.

*Pteranodon longiceps* (YPM 1177)—According to the YPM catalog, this skull was collected May 2, 1876, by S. W. Williston from "near Smoky Hill River, Wallace Co." Williston's 1876 field notebook in the YPM archives lists the locality as "3 mi. NE of Monument Rocks in fine yellow chalk," and a map prepared by S. W. Williston (also in the YPM archives) shows that the specimen was collected on the west side of the first drainage east of Monument Rocks and about 3 mi. (4.8 km) north of the Smoky Hill River. This is in Gove County, not in Wallace or Logan, and is approximately Locality 72. Comparison of this locality with Locality 37 to the southwest and Localities 33 and 35 to the northeast shows that Locality 72 ranges from 4 m (13 ft) below Marker Unit 15 up almost to Marker Unit 16 (fig. 2). At Locality 72, the chalk is gray from 1.5 m (5 ft) above Marker Unit 15. The fact that the skull was collected in yellow chalk while the chalk in the lower parts of the exposure is gray suggests that the skull came from at least 2 m (6.5 ft) above Marker Unit 15 and below Marker Unit 16.

*Pteranodon sternbergi* (FHSM VP 339)—This skull was collected by G. F. Sternberg from sec. 12, T. 8 S., R. 22 W., Graham County, Kansas, about 1 mi (1.6 km) west of Bogue and between Highway 24 and the south fork of the Solomon River (Bardack, l965). An outcrop in the NE sec. 12, T. 8 S., R. 22 W., Graham County, is very small and difficult to measure, but it has abundant remains of *Inoceramus (Volviceramus) grandis.* The presence of *I. (V.) grandis* indicates that the specimen is from Stewart's (1988) Biostratigraphic Zone A or B and quite low in the Smoky Hill Chalk Member. Marker Unit 4 is visible near the top of the approximately 8 m (26 ft) of exposure and also is exposed in other nearby outcrops. Although the exact horizon of the type skull is unknown, it must have come from approximately Marker Unit 4 or a short distance below.

*Pteranodon marshi* (YPM 2594)—This skull was collected July 20, 1877, by S. W. Williston from "near Smoky Hill River, Wallace Co." (according to field labels and YPM catalog). A chronological listing of all specimens collected by the field party indicates that they had been moving east from Russell Springs for a number of weeks and collected a mosasaur on Plum Creek in western Gove County, also on July 20. The skull was presumably collected somewhere near there. Localities 33, 35, and 42 are on either side of Plum Creek and indicate that exposures on Plum Creek are between Marker Units 16 and 19 (fig. 2). Therefore, the skull was probably collected between those marker units.

*Pteranodon walkeri* (FHSM VP 221)—This skull was collected by G. F. Sternberg from 2 mi. (3.2 km) northeast of Penokee, Sec. 13, T. 8 S., R. 24 W., Graham County, Kansas (Bardack, 1965). Locality 55 in sec. 13, T. 8 S., R. 24 W. has Marker Unit 18 in the middle of a l0-m (32-ft) exposure, and Localities 54 and 60 to the southwest and northeast, respectively, are both a little lower (fig. 3). In this case the exact locality is known and, although the exact horizon is not known, the type skull must have come from within 5 m (16 ft) above or below Marker Unit 18.

*Pteranodon eatoni* (YPM 1179)—This skull was collected in 1875 by E. W. Guild (alias E. S. Field) from the "Smoky Hill River, near Castle Rock, Trego Co." (according to field labels and YPM catalog). In an earlier report of this work (Bennett, 1990), I took "near Castle Rock" to mean within a couple of miles and concluded

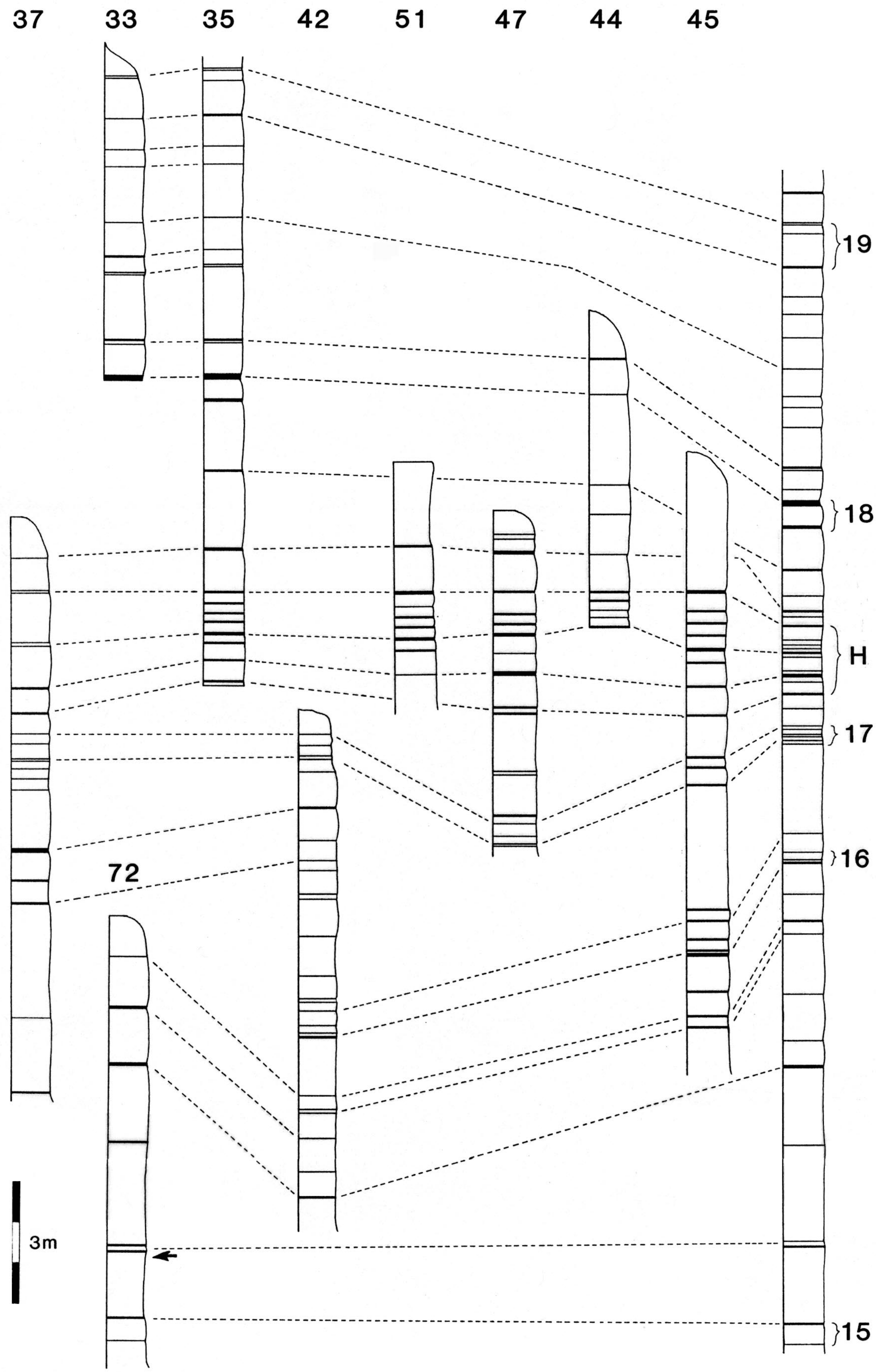


FIGURE 2. Correlation of stratigraphic columns of localities in western Gove County, Kansas. Black bands indicate bentonites, seams, and in a few instances a change in lithology; white indicates chalk. Localities are numbered across the top and arranged in order from west to east. The unnumbered column at right is the composite stratigraphic column from Hattin (1982). Hattin's marker units are identified by the numbers at right, and Russell's (1929) marker unit H is also indicated. The relative vertical position of different stratigraphic columns in the figure is not significant. The arrow by Locality 72 indicates the change from gray to yellow chalk.

that the skull was collected between Marker Units 8 and 13. However, the fact that it was collected in Trego County should have suggested a greater distance. Analysis of the calcareous nannofossils in the matrix adhering to the specimen indicates that it came from between Marker Unit 4 and 6 (D. Watkins, 1991, personal communication). Wildcat Canyon in western Trego County and near Castle Rock has exposures ranging from Marker Units 2 to 4, so the range between Marker Units 4 and 6 is reasonable.

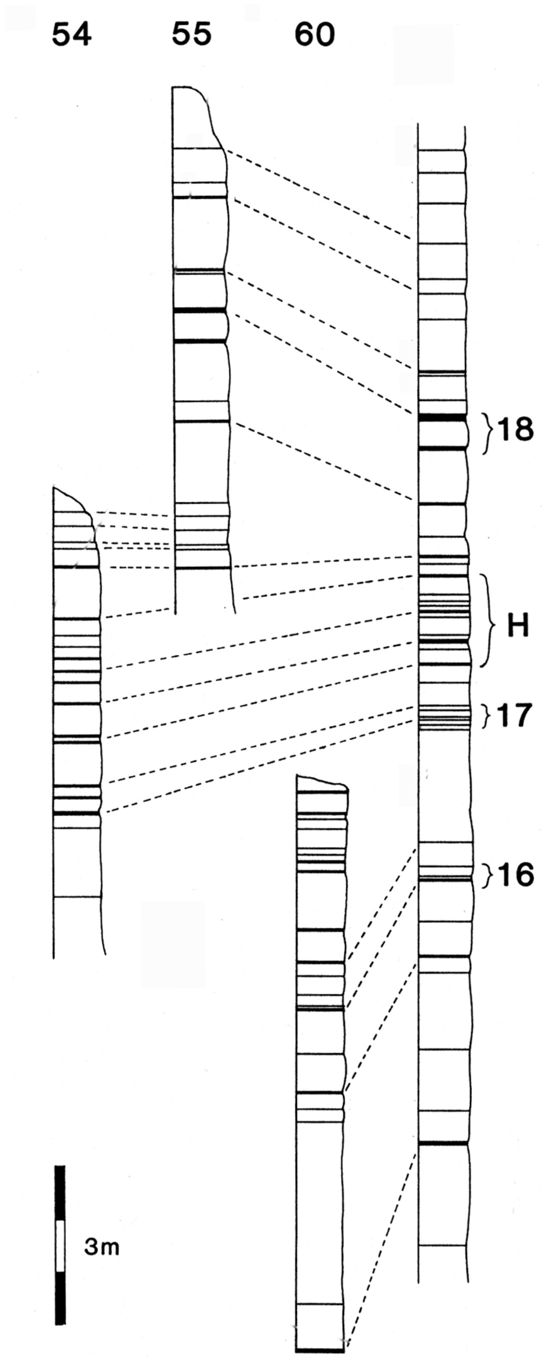


FIGURE 3. Correlation of stratigraphic columns of localities in Graham County, Kansas. Black bands indicate bentonites, seams, and in a few instances a change in lithology; white indicates chalk. Localities are numbered across the top and arranged in order from west to east. The unnumbered column at right is the composite stratigraphic column from Hattin (1982). Hattin's marker units are identified by the numbers at right, and Russell's (1929) marker unit H is also indicated. The relative vertical position of different stratigraphic columns in the figure is not significant.

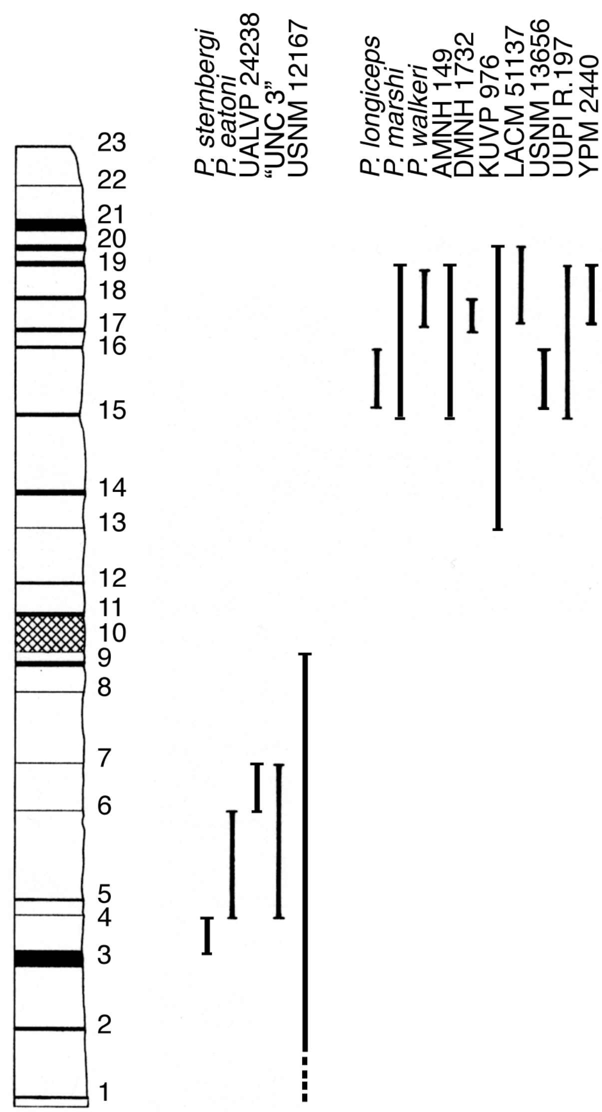


FIGURE 4. Inferred stratigraphic positions or ranges of type and other important specimens of *Pteranodon* plotted against the composite stratigraphic column from Hattin (1982). Marker units are indicated by black lines or bands, or in the case of Marker Unit 10, the prominent caprock, by cross-hatching. Institutional abbreviations: AMNH, American Museum of Natural History, New York; DMNH, Denver Museum of Natural History; KUVP, Natural History Museum, University of Kansas, Lawrence; LACM, Los Angeles County Museum of Natural History; UALVP, Geology Museum, University of Alberta, Edmonton; "UNC", Uncatalogued specimen (see Bennett, 1991); USNM, U.S. National Museum, Washington, D.C; UUPI, Palaeontological Institute, University of Uppsala, Uppsala, Sweden; YPM, Yale Peabody Museum, New Haven.

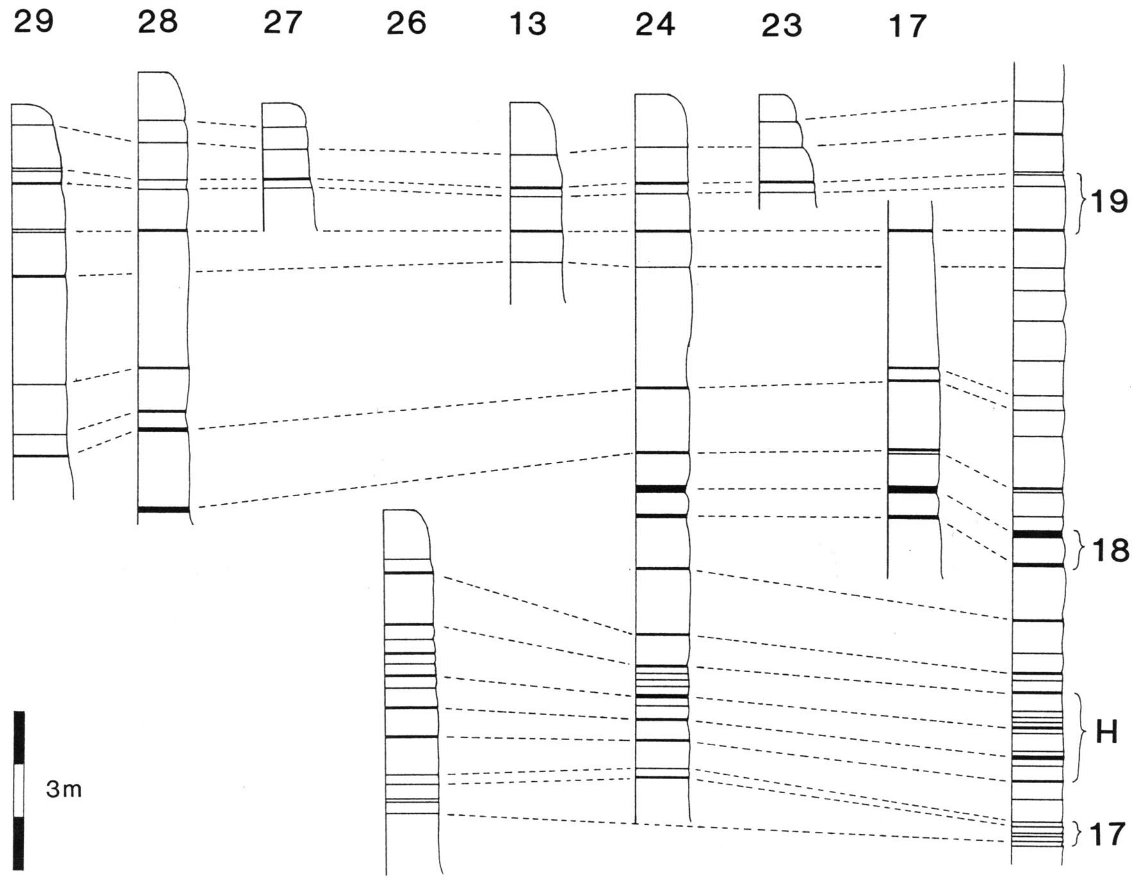


FIGURE 5. Correlation of stratigraphic columns of localities along the Smoky Hill River in Logan County, Kansas. Black bands indicate bentonites, seams, and in a few instances a change in lithology; white indicates chalk. Localities are numbered across the top and arranged in order from west to east. The unnumbered column at right is the composite stratigraphic column from Hattin (1982). Hattin's marker units are identified by the numbers at right, and Russell's (1929) marker unit H is also indicated. The relative vertical position of different stratigraphic columns in the figure is not significant.

A plot of the stratigraphic positions of the type skulls as well as other important specimens (fig. 4) shows that skulls with upright occiputs are found from Marker Unit 3 up to Marker Unit 7 or perhaps 10, while skulls with reclined occiputs occur between Marker Units 13 and 20. Therefore, the two morphologies do not co-occur.

## Discussion

The stratigraphic distribution shows that skulls with upright occiputs occurred only in the lower part of the Smoky Hill Chalk Member and that skulls with reclined occiputs occurred only in the upper part of the Smoky Hill Chalk Member. Because the two morphs do not co-occur, they could be early and late forms of a single evolving species or lineage, but the hypothesis is falsified because the polarity of the crest shape change is the opposite of that which was expected. The two morphs are probably chronospecies of an anagenetically evolving single species lineage that continued throughout the time of deposition of the Smoky Hill Chalk Member.

This study shows that it is possible to determine the stratigraphic positions of specimens from the Smoky Hill Chalk Member from locality data even if they were collected more than 100 years ago. When applied to even a small number of specimens, the procedure can have the power to reject hypotheses.

While determining the stratigraphic positions of other specimens not discussed in this paper, I visited many other localities and measured stratigraphic columns. Additional measured sections covering much of Logan County and part of Gove County are included in figs. 2 and 5–7. The pattern of the exposures is interesting. In the northwestern part of the exposures in Gove County (fig. 2) and much of

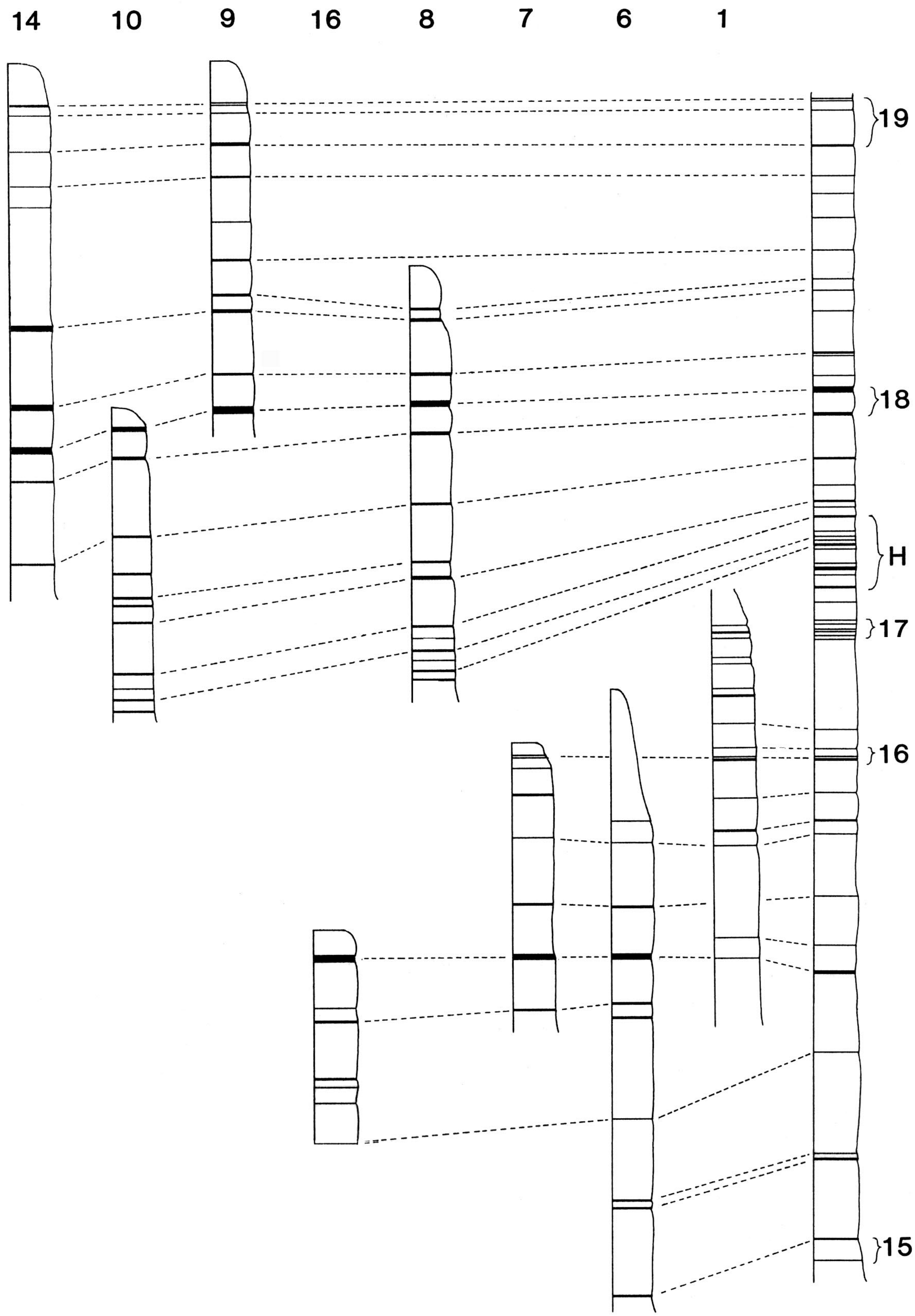


FIGURE 6. Correlation of stratigraphic columns of localities along Twin Butte Creek in Logan County, Kansas. Black bands indicate bentonites, seams, and in a few instances a change in lithology; white indicates chalk. Localities are numbered across the top and arranged in order from west to east. The unnumbered column at right is the composite stratigraphic column from Hattin (1982). Hattin's marker units are identified by the numbers at right, and Russell's (1929) marker unit H is also indicated. The relative vertical position of different stratigraphic columns in the figure is not significant.

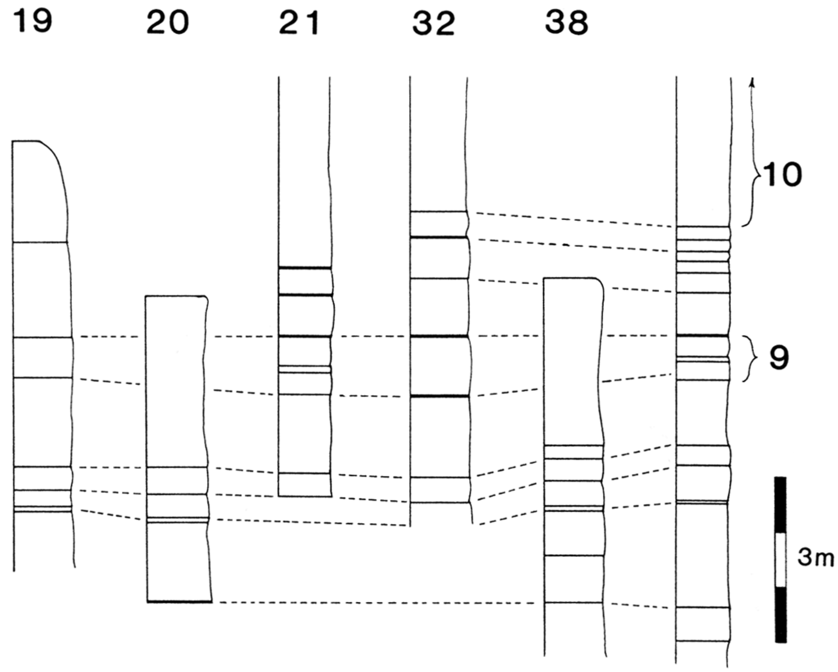


FIGURE 7. Correlation of stratigraphic columns of localities in southeastern Logan and southwestern Gove counties, Kansas. Black bands indicate bentonites, seams, and in a few instances a change in lithology; white indicates chalk. Localities are numbered across the top and arranged in order from west to east. The unnumbered column at right is the composite stratigraphic column from Hattin (1982). Hattin's marker units are identified by the numbers at right. The relative vertical position of different stratigraphic columns in the figure is not significant.

Logan County (figs. 5 and 6) as well as in western Graham County (fig. 3), the interval between Marker Units 15 and 20 is almost exclusively exposed. The interval between Marker Units 10 and 15 is exposed in places in eastern Logan and western Gove counties (Locality 18, Hattin's localities 22 and 23), but the caprock (Marker Unit 10) and the chalk below appear to be more widely exposed in those areas (fig. 7). This may be a result of a bias on my part toward outcrops that are larger and easier to measure; other parts of the Smoky Hill Chalk Member may be extensively exposed but in outcrops that are small in area or thickness and difficult to measure. On the other hand, it is possible that the chalk between Marker Units 10 and 15 and above Marker Unit 20 erodes more easily and is not widely exposed. More study of this question is needed. The apparently biased distribution of exposures suggests that most of the fossil vertebrates collected from the Smoky Hill Chalk Member came from a rather restricted stratigraphic interval between Marker Units 15 and 20. This may have important implications for future studies of fossil vertebrates from the Smoky Hill Chalk Member.

## Conclusions

Hattin (1982) stated that the composite column and marker units make it possible to determine precisely the stratigraphic positions of Smoky Hill Chalk Member outcrops. This paper shows that it is possible to determine the stratigraphic positions of specimens collected long ago. This technique should be useful in studies of other taxa from the Smoky Hill Chalk Member. In addition, this study demonstrates that the marker units of Hattin (1982) make it possible for collectors to determine the strati- graphic positions of specimens. One hundred years ago, Williston (1897, p. 245) wrote, "I need not call the attention of future collectors to the importance of locating the horizon of specimens more accurately than has been done heretofore." For many years after that statement was made, the stratigraphy of the Smoky Hill Chalk Member was only poorly understood. We now have the means to do as Williston suggested, and all future collectors should record horizon and locality as accurately as possible.

## Acknowledgments

J. D. Stewart and O. W. Bonner shared their extensive knowledge of the Smoky Hill Chalk Member. D. Watkins kindly determined the age of samples using calcareous nannoplankton biostratigraphy. D. E. Hattin, J. D. Stewart, and R. L. Kaesler reviewed the manuscript and provided constructive criticism. This work would not have been possible without the generous funding of NSF Dissertation Improvement Grant BSR-700547.

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# Appendix: Measured stratigraphic sections at localities in figs. 2, 3, and 5–7.

**Locality 1**—W/2 of SW sec. 15, T. 15 S., R. 34 W., Logan County, Kansas. Base at 3,020 ft (920 m). Units 12–16 are Marker Unit 16.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 33 | Yellow chalk to top of the outcrop | ~100 |
| 32 | Ferruginous seam | 0.2 |
| 31 | Yellow chalk | 15 |
| 30 | Ferruginous seam | 0.2 |
| 29 | Pale chalk | 3.8 |
| 28 | Ferruginous seam | 0.3 |
| 27 | Yellow chalk | 12 |
| 26 | Ferruginous seam | 0.2 |
| 25 | Yellow chalk | 46 |
| 24 | Massive white chalk—forms resistant ledge | 15 |
| 23 | Yellow chalk | 56 |
| 22 | Massive white chalk—forms slight ledge | 16 |
| 21 | Tan silty chalk seam | 0.8 |
| 20 | Massive white chalk | 2 |
| 19 | Yellow chalk | 63.5 |
| 18 | Ferruginous seam | 0.8 |
| 17 | Yellow chalk | 56 |
| 16 | Ferruginous seam | 0.3 |
| 15 | Yellow chalk | 21.5 |
| 14 | Ferruginous seam | 0.2 |
| 13 | Yellow chalk | 7 |
| 12 | Ferruginous seam | 1.5 |
| 11 | Yellow chalk | 86 |
| 10 | Ferruginous seam | 0.3 |
| 9 | Yellow chalk | 76 |
| 8 | Ferruginous seam—forms prominent reentrant | 1.5 |
| 7 | Yellow chalk | 34 |
| 6 | Ferruginous seam | 0.2 |
| 5 | Yellow chalk | 213 |
| 4 | Ferruginous seam | 0.3 |
| 3 | Yellow chalk | 48 |
| 2 | Ferruginous/gypsiferous seam | 0.8 |
| 1 | Massive yellow chalk | 167 |

Total thickness of measured section 1,045.4 cm

**Locality 6**—S/2 of line between sec. 17 and 18, T. 15 S., R. 34 W., Logan County, Kansas. Base at 3,010 ft (917 m). Units 1–2 are Marker Unit 15.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 21 | Yellow chalk to top of outcrop | 305 |
| 20 | Bentonite | 0.6 |
| 19 | Massive chalk | 51 |
| 18 | Ferruginous seam—locally expanded to 2.5 cm by selenite | 0.6 |
| 17 | Yellow chalk | 147 |
| 16 | Gypsiferous seam—locally altered to selenite and may have local limonitic inclusions | 3 |
| 15 | Chalk | 109 |
| 14 | Bentonite unit—2.5 cm of orange to red-brown clay expanded by gypsum and iron oxide | 12.7 |
| 13 | Chalk | 102 |
| 12 | Bentonite | 3.8 |
| 11 | Chalk | 29 |
| 10 | Bentonite | 3 |
| 9 | Gray chalk | 235 |
| 8 | Ferruginous seam—locally expanded to 1 cm by selenite | 0.1 |
| 7 | Tan chalk | 185 |
| 6 | Gypsiferous seam | 2 |
| 5 | Tan chalk | 14 |
| 4 | Bentonite—locally expanded by selenite | 2.5 |
| 3 | Gray chalk | 201 |
| 2 | Bentonite unit—1 cm of white clay surrounded by iron oxide | 3 |
| 1 | Light-gray chalk | 46 |

Total thickness of measured section 1,455.3 cm

**Locality 7**—NW sec. 13, T. 15 S., R. 35 W., Logan County, Kansas. Base at 3,050 ft (930 m). Units 13–14 are part of Marker Unit 16.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 15 | Yellow chalk to top of outcrop | 30.5 |
| 14 | Pale-cream-colored chalk—in fresh chalk it is an indistinct 2.5-cm seam of powdery gypsum | 6.4 |
| 13 | Yellow chalk | 23 |
| 12 | Unit—two ferruginous/gypsiferous seams separated by 0.8-cm gray chalk | 1.4 |
| 11 | Gray chalk | 60 |
| 10 | Ferruginous seam—locally produces large limonitic inclusions up to 6.5 cm thick | 1.5 |
| 9 | Gray chalk | 100 |
| 8 | Ferruginous/gypsiferous seam | 0.8 |
| 7 | Gray chalk | 153 |
| 6 | Bentonite | 2.5 |
| 5 | Gray chalk | 114 |
| 4 | Bentonite unit—6 cm of gray, yellow, and orange clay expanded by iron oxide and gypsum | 12.7 |
| 3 | Gray chalk | 117 |
| 2 | Ferruginous/gypsiferous seam | 1.8 |
| 1 | Gray chalk | 61 |

Total thickness of measured section 685.6 cm

**Locality 8**—Butte in NE SE sec. 11, T. 15 S., R. 34 W., Logan County, Kansas, on the north or up side of a fault. Base at 3,100 ft (945 m). Units 20–22 are Marker Unit 18.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 31 | Yellow chalk to the top of the outcrop | ~ |
| 30 | Ferruginous/gypsiferous seam | 3.2 |
| 29 | Yellow chalk | 21 |
| 28 | Bentonite | 6.4 |
| 27 | Massive yellow chalk | 119 |
| 26 | Ferruginous/gypsiferous seam | 2.5 |
| 25 | Tan chalk | 2.9 |
| 24 | Seam | 0.6 |
| 23 | Yellow chalk | 61 |
| 22 | Bentonite unit—8.5 cm of silty chalk expanded by gypsum and iron oxide, forms a major reentrant | 11.4 |
| 21 | Chalk | 61 |
| 20 | Bentonite | 6.4 |
| 19 | Tan chalk | 160 |
| 18 | Ferruginous/gypsiferous seam | 2.5 |
| 17 | Massive gray chalk | 132 |
| 16 | Ferruginous/gypsiferous seam—crops out as selenite | 2.5 |
| 15 | Gray chalk | 32 |
| 14 | Bentonite | 6.7 |
| 13 | Gray chalk—forms a rounded cap on outcrop | 109 |
| 12 | Bentonite | 4.4 |
| 11 | Pale-tan chalk | 28 |
| 10 | Seam | 0.6 |
| 9 | Gray chalk | 26 |
| 8 | Ferruginous/gypsiferous seam | 1.8 |
| 7 | Gray chalk | 21 |
| 6 | Ferruginous seam | 1.4 |
| 5 | Gray chalk | 23 |
| 4 | Bentonite | 4.4 |
| 3 | Gray chalk | 18 |
| 2 | Ferruginous seam | 2 |
| 1 | Gray chalk | 61 |

Total thickness of measured section 931.7 cm

**Locality 9**—Small butte in NE NE sec. 5, T. 15 S., R. 35 W., Logan County, Kansas. Base at 3,090 ft (942 m). Units 1–2 are part of Marker Unit 18 and units 18–22 are Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 23 | Yellow chalk to top of bluff | ~ |
| 22 | Bentonite | 7 |
| 21 | Yellow chalk | 16.5 |

| | | |
|---|---|---|
| 20 | Ferruginous seam | 0.6 |
| 19 | Yellow chalk—a seam cropping out as selenite lies 44 cm above bottom | 70 |
| 18 | Ferruginous/gypsiferous seam | 4.4 |
| 17 | Tan chalk | 2.5 |
| 16 | Gypsiferous seam—with iron oxide film at bottom | 1 |
| 15 | Massive yellow chalk | 71 |
| 14 | Bentonite—crops out as a selenite | 3.8 |
| 13 | Massive yellow chalk | 105 |
| 12 | Ferruginous seam | 0.5 |
| 11 | Yellow chalk—a seam lies 21 cm above bottom | 86 |
| 10 | Ferruginous/gypsiferous seam—crops out as a selenite ledge | 2.5 |
| 9 | Yellow chalk | 79 |
| 8 | Ferruginous/gypsiferous seam | 2.5 |
| 7 | Yellow chalk | 32 |
| 6 | Bentonite unit—1.1 cm of waxy gray clay expanded by gypsum and iron oxide | 5.1 |
| 5 | Yellow chalk | 142 |
| 4 | Bentonite unit—1.2 cm of gray clay expanded by gypsum and iron oxide | 2.5 |
| 3 | Yellow chalk | 76 |
| 2 | Bentonite unit—gray, olive, and tan clays, expanded by iron oxide | 14 |
| 1 | Chalk | 91 |

Total thickness of measured section 841.9 cm

**Locality 10**—W/2 of line between sec. 6 and 7, T. 15 S., R. 35 W., Logan County, Kansas. Base at 3,150 ft (960 m). Units 20–22 are Marker Unit 18.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 23 | Chalk to top of the outcrop | ~ |
| 22 | Bentonite unit—7.5 cm of gray clay, expanded by iron oxide and gypsum | 10 |
| 21 | Chalk | 61 |
| 20 | Bentonite unit—4.3 cm of red-brown clay between powdery gypsum | 5.7 |
| 19 | Gray chalk | 178 |
| 18 | Ferruginous/gypsiferous seam | 3.2 |
| 17 | Massive yellow chalk | 85 |
| 16 | Seam—crops out as selenite | 2 |
| 15 | Massive yellow chalk | 55 |
| 14 | Seam—crops out as selenite | 2 |
| 13 | Massive yellow chalk | 14 |
| 12 | Seam—crops out as selenite | 2 |
| 11 | Massive yellow chalk | 36 |
| 10 | Ferruginous/gypsiferous seam | 3.8 |
| 9 | Yellow chalk—a 1-cm gypsiferous seam lies 25 cm above the bottom | 117 |
| 8 | Ferruginous/gypsiferous seam | 3.8 |
| 7 | Gray chalk | 32 |
| 6 | Ferruginous/gypsiferous seam | 1.4 |
| 5 | Gray chalk | 25 |
| 4 | Ferruginous/gypsiferous seam | 2 |
| 3 | Gray chalk | 23 |
| 2 | Ferruginous seam | 2 |
| 1 | Gray chalk | 30 |

Total thickness of measured section 693.9 cm

**Locality 13**—North end of line between sec. 20 and 21, T. 13 S., R. 34 W., Logan County, Kansas. Base at 2,920 ft (890 m). Units 4–8 are Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 11 | Yellow chalk to top of the outcrop | ~ |
| 10 | Seam | 0.3 |
| 9 | Yellow chalk | 60 |
| 8 | Bentonite | 3.4 |
| 7 | Yellow chalk | 14 |
| 6 | Seam | 0.5 |
| 5 | Yellow chalk | 63.5 |
| 4 | Unit—two ferruginous seams, the lower 0.2 cm and upper 0.5 cm thick, separated by chalk | 2.2 |

| | | |
|---|---|---|
| 3 | Yellow chalk | 58 |
| 2 | Ferruginous seam | 0.3 |
| 1 | Yellow chalk | 89 |

Total thickness of measured section 291.2 cm

**Locality 14**—SE SW sec. 10, T. 15 S., R. 36 W., Logan County, Kansas. Base at 3,210 ft (979 m). Units 18–24 are Marker Unit 19 and units 4–6 are Marker Unit 18.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 25 | Yellow chalk to top of the outcrop | ~ |
| 24 | Ferruginous seam | 1 |
| 23 | Yellow chalk | 3.8 |
| 22 | Ferruginous seam | 1 |
| 21 | Yellow chalk | 20 |
| 20 | Ferruginous seam | 0.8 |
| 19 | Yellow chalk | 84 |
| 18 | Ferruginous seam | 0.5 |
| 17 | Yellow chalk | 81 |
| 16 | Ferruginous seam | 0.5 |
| 15 | Yellow chalk | 48 |
| 14 | Ferruginous seam | 0.5 |
| 13 | Yellow chalk | 277 |
| 12 | Bentonite unit—4.4 cm of dark-gray to brown silty chalk that weathers shaly, expanded by gypsum and iron oxide—forms a reentrant | 13 |
| 11 | Gray chalk | 170 |
| 10 | Bentonite unit—1.7 cm of gray clay and flaky waxy gray material, expanded by gypsum—forms a reentrant | 11 |
| 9 | Gray chalk | 86 |
| 8 | Dark-gray seam | 0.6 |
| 7 | Chalk | 3.8 |
| 6 | Bentonite unit—10.2 cm of dark-gray to red-brown clay, expanded by gypsum, produces a major reentrant | 11.4 |
| 5 | Gray chalk | 63.5 |
| 4 | Ferruginous/gypsiferous seam | 3.2 |
| 3 | Gray chalk—a 10 cm thick band of darker gray chalk lies 94 cm above bottom | 190 |
| 2 | Bentonite | 2 |
| 1 | Gray chalk | 91 |

Total thickness of measured section 1,163.6 cm

**Locality 16—**Small exposure just south of Twin Butte Creek on line between SE and SW sec. 33, T. 14 S., R. 35 W., Logan County, Kansas. Base at 3,040 ft (927 m).

| Unit | Description | Thickness (cm) |
|---|---|---|
| 11 | Yellow chalk to top of the outcrop | 61 |
| 10 | Bentonite unit—2 cm gray clay, expanded by iron oxide and gypsum | 14 |
| 9 | Yellow chalk | 109 |
| 8 | Seam—crops out as a selenite seam with a few limonitic inclusions | 1 |
| 7 | Yellow chalk | 31 |
| 6 | Ferruginous/gypsiferous seam—crops out as limonitic ledges | 2 |
| 5 | Yellow chalk | 132 |
| 4 | Ferruginous/gypsiferous seam | 1.7 |
| 3 | Yellow chalk | 16.5 |
| 2 | Darker gray chalk—weathers slightly shaly | 37 |
| 1 | Gray chalk | 91 |

Total thickness of measured section 496.2 cm

**Locality 17**—SW sec. 20, T. 14 S., R. 33 W., Logan County, Kansas. Base at 2,880 ft (878 m). Units 2–4 are Marker Unit 18.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 15 | Chalk to top of the outcrop | ~ |
| 14 | Gypsiferous seam—with gray inclusions, crops out as selenite ledge | 2.5 |
| 13 | Yellow chalk | 256 |
| 12 | Gypsiferous seam—crops out as selenite ledge | 3.8 |
| 11 | Yellow chalk | 22 |
| 10 | Gypsiferous seam—crops out as selenite ledge | 3.8 |
| 9 | Yellow chalk | 125 |
| 8 | Bentonite | 3.2 |
| 7 | Chalk | 5.1 |
| 6 | Seam—produces a minor reentrant | 0.2 |
| 5 | Yellow chalk | 61 |
| 4 | Bentonite unit—8.9 cm of pale-gray clay expanded by iron oxide and gypsum | 11.4 |
| 3 | Yellow chalk | 41 |
| 2 | Bentonite unit—gray clay expanded by gypsum and iron oxide | 6.7 |
| 1 | Yellow chalk | 122 |

Total thickness of measured section 663.7 cm

**Locality 18**—Small outcrop south of Twin Butte Creek in E/2 of SW sec. 13, T. 15 S., R. 34 W., Logan County, Kansas. Base at 2,950 ft (899 m). Unit 8 is Marker Unit 13. (Not illustrated).

| Unit | Description | Thickness (cm) |
|---|---|---|
| 11 | Yellow chalk to top of the outcrop | ~ |
| 10 | Seam—with a few limonitic inclusions | 0.2 |
| 9 | Yellow chalk—with a few limonitic inclusions, commonly around inoceramids | 103 |
| 8 | Unit—two ferruginous seams, the upper 0.4 cm and the lower 0.7 cm separated by chalk, produces a reentrant | 5 |
| 7 | Yellow chalk | 184 |
| 6 | Ferruginous seam—locally thickens to 1 cm or includes selenite, produces small limonitic inclusions | 0.3 |
| 5 | Yellow chalk—with numerous *Inoceramus balticus* shells | 109 |
| 4 | Ferruginous seam—produces many small limonitic inclusions | 2 |
| 3 | Yellow chalk | 30.5 |
| 2 | Seam—invisible in fresh chalk, but produces limonitic inclusions where weathered | 0.0 |
| 1 | Yellow chalk | 152 |

Total thickness of measured section 585.9 cm

**Locality 19**—Little Pyramids, at east end of line between sec. 11 and 14, T. 15 S, R. 33 W., Logan County, Kansas. Base at 2,780 ft (848 m). Units 8–9 are probably Marker Unit 9.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 12 | Yellow chalk to the top of the outcrop | 183 |
| 11 | Seam—visible as a fine line on outcrop | 0.0 |
| 10 | Yellow chalk | 170 |
| 9 | Seam—crops out as a selenite seam with a few limonitic inclusions | 0.4 |
| 8 | Yellow chalk | 71 |
| 7 | Gray chalk | 158 |
| 6 | Ferruginous/gypsiferous seam | 1 |

| | | |
|---|---|---|
| 5 | Gray chalk | 43 |
| 4 | Bentonite | 1 |
| 3 | Gray chalk | 31 |
| 2 | Paler, poorly laminated band | 10 |
| 1 | Gray chalk | 120 |

Total thickness of measured section 788.4 cm

**Locality 20**—SE NE sec. 1, T. 15 S., R. 33 W., Logan County, Kansas. Base at 2,730 ft (832 m).

| Unit | Description | Thickness (cm) |
|---|---|---|
| 8 | Gray chalk to top of the outcrop | 305 |
| 7 | Ferruginous/gypsiferous seam—produces limonitic inclusions | 1 |
| 6 | Gray chalk | 47 |
| 5 | Bentonite unit—0.4 cm of gray clay expanded by iron oxide and gypsum | 1.3 |
| 4 | Gray chalk | 41 |
| 3 | Harder, pale-gray band | 7.6 |
| 2 | Gray chalk | 141 |
| 1 | Ferruginous seam | 1.5 |

Total thickness of measured section 545.4 cm

**Locality 21—**East end of line between sec. 26 and 35, T. 14 S., R. 33 W., Logan County, Kansas. Base at 2,750 ft (838 m). Units 5–9 are Marker Unit 9.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 14 | Yellow chalk to top of outcrop | 610 |
| 13 | Ferruginous/gypsiferous seam | 2 |
| 12 | Yellow chalk | 46 |
| 11 | Gypsiferous seam | 2 |
| 10 | Gray to yellow chalk | 71 |
| 9 | Selenite seam—between thin films of iron oxide | 1.5 |
| 8 | Gray chalk | 51 |
| 7 | Paler, poorly laminated chalk | 13 |
| 6 | Gray chalk | 38 |
| 5 | Bentonite unit—pale-gray clay expanded by iron oxide | 1.3 |
| 4 | Gray chalk | 140 |
| 3 | Bentonite | 0.3 |
| 2 | Gray chalk | 41 |
| 1 | Ferruginous/gypsiferous seam—produces limonitic inclusions | 0.3 |

Total thickness of measured section 1,018.4 cm

**Locality 23**—Tiny outcrop just north of road on W/2 of line between sec. 18 and 19, T. 13 S., R. 33 W., Logan County, Kansas. Base at 2,900 ft (884 m). Units 1–4 are part of Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 9 | Massive yellow chalk to top of the outcrop | 51 |
| 8 | Ferruginous seam | 0.5 |
| 7 | Massive yellow chalk | 48 |
| 6 | Ferruginous seam | 0.5 |
| 5 | Massive yellow chalk | 62 |
| 4 | Unit—two 0.5 cm ferruginous seams separated by chalk | 3.5 |
| 3 | Massive yellow chalk | 18 |
| 2 | Seam | 0.0 |
| 1 | Massive yellow chalk | 38 |

Total thickness of measured section 221.5 cm

**Locality 24**—Six-Mile Creek just north of two small buttes in W/2 NW sec. 23, T. 13 S., R. 34 W., Logan County, Kansas. Base at 2,940 ft (896 m). Units 1–4 are part of Marker Unit 17, units 26–28 are Marker Unit 18, and units 36–40 are Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 43 | Yellow chalk to top of the outcrop | ~ |
| 42 | Ferruginous seam | 0.5 |
| 41 | Massive yellow chalk | 66 |

| | | |
|---|---|---|
| 40 | Unit—two 0.5 cm iron oxide seams separated by chalk | 3.8 |
| 39 | Yellow massive chalk | 18 |
| 38 | Seam | 0.4 |
| 37 | Yellow massive chalk | 68 |
| 36 | Unit—two ferruginous seams, the upper 0.5 cm and the lower 0.3 cm, separated by chalk | 2.5 |
| 35 | Massive yellow chalk—seams lie at 79, 140, and 185 cm above the bottom | 66 |
| 34 | Seam | 0.4 |
| 33 | Massive yellow chalk | 224 |
| 32 | Ferruginous seam—produces a sharp reentrant | 3.2 |
| 31 | Yellow chalk | 117 |
| 30 | Seam | 2 |
| 29 | Yellow chalk | 61 |
| 28 | Bentonite unit—4 cm of tan clay and silty chalk, expanded by gypsum and iron oxide | 12 |
| 27 | Gray chalk | 41 |
| 26 | Ferruginous/gypsiferous seam | 5.2 |
| 25 | Gray chalk | 94 |
| 24 | Bentonite | 2.9 |
| 23 | Gray chalk | 119 |
| 22 | Ferruginous/gypsiferous seam | 4.4 |
| 21 | Gray chalk | 58 |
| 20 | Bentonite unit—crops out as two closely spaced limonitic ledges | 4.1 |
| 19 | Gray chalk | 13 |
| 18 | Seam | 0.2 |
| 17 | Gray chalk | 13 |
| 16 | Seam | 0.2 |
| 15 | Gray chalk | 13 |
| 14 | Seam | 0.2 |
| 13 | Gray chalk | 14 |
| 12 | Bentonite unit—4.2 cm of orange material, expanded by iron oxide | 5.2 |
| 11 | Gray chalk | 15 |
| 10 | Ferruginous seam | 1 |
| 9 | Gray chalk | 25 |
| 8 | Bentonite unit—3.5 cm of mixed yellow and gray clay, expanded by iron oxide | 4.4 |
| 7 | Gray chalk | 36 |
| 6 | Bentonite | 2.5 |
| 5 | Gray chalk | 52 |
| 4 | Ferruginous seam | 0.5 |
| 3 | Gray chalk | 14 |
| 2 | Bentonite | 1.5 |
| 1 | Gray chalk | 91 |

Total thickness of measured section 1,275.1 cm

**Locality 26**—Small area just west of road in NE SE sec. 20, T. 13 S., R. 35 W., Logan County, Kansas. Base at 2,930 ft (893 m). Units 2–10 are Marker Unit 17 and units 12–28 are Marker Unit H.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 31 | Gray chalk | 92 |
| 30 | Tan clay seam—crops out as a 1.5 cm selenite ledge | 0.5 |
| 29 | Gray chalk | 25 |
| 28 | Bentonite | 3.2 |
| 27 | Gray chalk | 93 |
| 26 | Bentonite unit—0.9 cm of gray clay expanded by iron oxide | 3.5 |
| 25 | Gray chalk | 28 |
| 24 | Ferruginous seam | 0.6 |
| 23 | Gray chalk | 23 |
| 22 | Ferruginous/gypsiferous seam | 1.5 |
| 21 | Gray chalk | 19 |
| 20 | Ferruginous seam | 0.6 |
| 19 | Gray chalk | 20 |
| 18 | Bentonite unit—2.8 cm of orange clay expanded by iron oxide | 4.4 |
| 17 | Gray chalk | 20 |
| 16 | Bentonite | 1.3 |
| 15 | Gray chalk | 37 |

| | | |
|---|---|---|
| 14 | Bentonite | 3.8 |
| 13 | Gray chalk | 52 |
| 12 | Bentonite | 2 |
| 11 | Gray chalk | 69 |
| 10 | Gypsiferous seam—locally may contain iron oxide | 0.5 |
| 9 | Gray chalk | 19 |
| 8 | Ferruginous seam—with a few limonitic inclusions | 0.5 |
| 7 | Gray chalk | 27 |
| 6 | Ferruginous seam—with limonitic inclusions | 0.8 |
| 5 | Gray chalk | 6.4 |
| 4 | Ferruginous seam—with limonitic inclusions | 0.5 |
| 3 | Gray chalk | 22 |
| 2 | Ferruginous seam | 0.5 |
| 1 | Gray chalk | 122 |

Total thickness of measured section 698.6 cm

**Locality 27**—W/2 of NW sec. 19, T. 13 S., R. 35 W., Logan County, Kansas. Base at 2,980 ft (909 m). Units 1–4 are part of Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 9 | Yellow chalk to top of the outcrop | 46 |
| 8 | Seam | 0.5 |
| 7 | Massive yellow chalk | 41 |
| 6 | Seam | 0.5 |
| 5 | Massive yellow chalk | 53 |
| 4 | Unit—two ferruginous seams, the upper 0.5 cm and the lower 0.3 cm thick, separated by chalk | 3.3 |
| 3 | Yellow chalk | 15 |
| 2 | Seam—crops out as a 1-cm-thick selenite ledge | 0.5 |
| 1 | Yellow chalk | 91 |

Total thickness of measured section 250.8 cm

**Locality 28**—Just south of K-25 on line between sec. 27 and 28, T. 13 S., R. 36 W., Logan County, Kansas. Base at 3,070 ft (936 m). Units 14–18 are Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 23 | Yellow chalk to top of the outcrop | 91 |
| 22 | Tan seam—crops out as selenite ledge 5 cm thick | 1 |
| 21 | Massive yellow chalk | 43 |
| 20 | Tan clay seam—crops out as selenite ledge | 1 |
| 19 | Yellow chalk | 69 |
| 18 | Dark-tan silty seam—crops out as selenite ledge 2.5 cm thick | 1 |
| 17 | Yellow chalk | 16.5 |
| 16 | Gypsiferous seam—crops out as selenite ledge 2.5 cm thick | 0.8 |
| 15 | Yellow chalk | 75 |
| 14 | Ferruginous/gypsiferous seam—crops out as thick selenite ledge | 3.8 |
| 13 | Yellow chalk | 254 |
| 12 | Selenite seam | 2.5 |
| 11 | Yellow chalk | 79 |
| 10 | Selenite seam | 2.5 |
| 9 | Chalk—bottom half gray and top half yellow | 29 |
| 8 | Bentonite unit—2.1 cm of pale-gray silty, clay, expanded by iron oxide and gypsum | 7 |
| 7 | Yellow and gray chalk | 142 |
| 6 | Gypsiferous seam | 2.5 |
| 5 | Chalk | 4 |
| 4 | Seam | 0.5 |
| 3 | Chalk | 1.2 |
| 2 | Seam | 2 |
| 1 | Gray and yellow chalk | 31 |

Total thickness of measured section 859.3 cm

**Locality 29**—Small outcrop on south side of the Smoky Hill River in N/2 of SE sec. 24, T. 13 S., R. 37 W., Logan County, Kansas. Base at 3,050 ft (930 m). Units 10–14 are Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 17 | Yellow chalk to top of the outcrop | 39 |
| 16 | Ferruginous seam—crops out as selenite | 1 |
| 15 | Yellow chalk | 80 |
| 14 | Unit—two 2 cm ferruginous seams separated by chalk | 7 |
| 13 | Gray chalk | 22 |
| 12 | Bentonite | 2.9 |
| 11 | Gray chalk | 84 |
| 10 | Unit—two 1.5 cm ferruginous seams separated by chalk | 5.1 |
| 9 | Gray chalk | 81 |
| 8 | Ferruginous/gypsiferous seam—crops out as a selenite ledge | 2.5 |
| 7 | Gray chalk | 201 |
| 6 | Seam—crops out as a 2-cm selenite ledge | 0.5 |
| 5 | Gray chalk | 94 |
| 4 | Ferruginous seam | 0.8 |
| 3 | Gray chalk | 38 |
| 2 | Bentonite unit—2.8 cm of orange clay expanded by iron oxide | 3.8 |
| 1 | Gray chalk | 91 |

Total thickness of measured section 753.6 cm

**Locality 32**—Monument Rocks. NW SW sec. 34, T. 15 S., R. 31 W., Gove County, Kansas. Base at 2,650 ft (808 m). Units 6–8 are Marker Unit 9.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 16 | Chalk to top | ~ |
| 15 | Gray and tan chalk—with a few bands of paler, poorly laminated chalk | 510 |
| 14 | Ferruginous/gypsiferous seam | 0.5 |
| 13 | Gray chalk | 46 |
| 12 | Ferruginous/gypsiferous seam | 2 |
| 11 | Gray chalk—a paler band 10 cm thick lies 29 cm above bottom | 72 |
| 10 | Ferruginous/gypsiferous seam | 0.4 |
| 9 | Gray chalk | 102 |
| 8 | Bentonite unit—1.2 cm of gray clay, expanded by gypsum and iron oxide | 2.6 |
| 7 | Gray chalk—a paler, poorly laminated chalk band 13 cm thick lies 40 cm above the bottom | 105 |
| 6 | Ferruginous/gypsiferous seam | 2.5 |
| 5 | Gray chalk | 144 |
| 4 | Ferruginous/gypsiferous seam | 0.7 |
| 3 | Gray chalk | 45 |
| 2 | Gypsiferous seam—with 0.1 cm iron oxide in the middle | 0.5 |
| 1 | Gray chalk | 52 |

Total thickness of measured section 1,185.2 cm

**Locality 33**—Middle of NE sec. 24, T. 14 S., R. 31 W., Gove County, Kansas. Base at 2,820 ft (860 m). Unit 1 is part of Marker Unit 18 and units 17–19 are Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 20 | Chalk to top of the outcrop | ~ |
| 19 | Unit—two ferruginous seams, the upper 0.8 cm and the lower 0.2 cm thick, separated by chalk, forms a reentrant | 4.5 |
| 18 | Yellow chalk | 97 |

| | | |
|---|---|---|
| 17 | Ferruginous seam | 0.5 |
| 16 | Yellow chalk | 75 |
| 15 | Ferruginous seam | 0.5 |
| 14 | Yellow chalk | 42 |
| 13 | Ferruginous seam | 0.5 |
| 12 | Yellow chalk | 135 |
| 11 | Hard white chalk seam | 0.5 |
| 10 | Yellow chalk | 81 |
| 9 | Selenite seam | 3 |
| 8 | Yellow chalk | 36 |
| 7 | Bentonite | 5.1 |
| 6 | Yellow chalk | 157 |
| 5 | Seam—crops out as selenite | 1.5 |
| 4 | Yellow chalk | 9 |
| 3 | Seam—crops out as selenite | 0.4 |
| 2 | Yellow chalk | 76 |
| 1 | Bentonite unit—12 cm of mixed tan, gray, and very pale gray clays, expanded by iron oxide | 13 |

Total thickness of measured section 737.5 cm

**Locality 35**—Steep south facing cliff in SW SE sec. 20, T. 14 S., R. 30 W., Gove County, Kansas. Base at 2,810 ft (857 m). Units 3–19 are Marker Unit H, units 23–25 are Marker Unit 18, and units 42–45 are Marker Unit 19.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 52 | Yellow chalk to top of the outcrop | ~ |
| 51 | Unit—two ferruginous seams, the upper 2.5 cm and the lower 0.5 cm, separated by chalk | 5.6 |
| 50 | Massive yellow chalk | 71 |
| 49 | Seam | 0.1 |
| 48 | Massive yellow chalk | 53 |
| 47 | Seam | 0.1 |
| 46 | Massive yellow chalk | 71 |
| 45 | Unit—two seams, the upper tan clay 0.7 cm and the lower 0.3 thick, separated by chalk, produces a reentrant | 4.8 |
| 44 | Yellow chalk | 24 |
| 43 | Seam | 0.0 |
| 42 | Yellow chalk | 80 |
| 41 | White chalk seam | 2 |
| 40 | Yellow chalk | 72 |
| 39 | Seam | 0.1 |
| 38 | Yellow chalk | 46 |
| 37 | Gypsiferous seam | 0.2 |
| 36 | Yellow chalk—a seam lies 76 cm above the bottom | 130 |
| 35 | Seam | 0.1 |
| 34 | Massive yellow chalk | 78 |
| 33 | Ferruginous seam | 0.5 |
| 32 | Massive yellow chalk | 37 |
| 31 | Dark-brown clay seam—produces a reentrant | 5.1 |
| 30 | Massive yellow chalk | 173 |
| 29 | Ferruginous seam | 2 |
| 28 | Massive yellow chalk | 7 |
| 27 | Seam | 0.1 |
| 26 | Massive yellow chalk | 75 |
| 25 | Tan clay seam—produces a reentrant | 11 |
| 24 | Yellow chalk | 49 |
| 23 | Tan clay seam | 6.4 |
| 22 | Yellow chalk—weathers orange | 165 |
| 21 | Bentonite unit—2 cm of gray clay, expanded by iron oxide and gypsum | 3.6 |
| 20 | Massive yellow chalk—a 0.8-cm ferruginous seam lies 108 cm above the bottom | 182 |
| 19 | Ferruginous/gypsiferous seam | 4.9 |
| 18 | Yellow chalk | 98 |
| 17 | Bentonite unit—1.5 cm of gray clay expanded by iron oxide and gypsum | 4.2 |
| 16 | Yellow chalk | 24 |
| 15 | Bentonite unit—0.5 cm of gray clay expanded by gypsum | 3.5 |
| 14 | Yellow chalk | 20 |

| | | |
|---|---|---|
| 13 | Ferruginous/gypsiferous seam | 3.2 |
| 12 | Yellow chalk | 19 |
| 11 | Ferruginous/gypsiferous seam | 2 |
| 10 | Yellow chalk | 25 |
| 9 | Bentonite unit—2 cm of pale-gray clay, expanded by iron oxide and gypsum | 6 |
| 8 | Yellow chalk | 18 |
| 7 | Ferruginous/gypsiferous seam | 3 |
| 6 | Yellow chalk | 38 |
| 5 | Bentonite | 2.8 |
| 4 | Yellow chalk | 47 |
| 3 | Ferruginous/gypsiferous seam | 2.5 |
| 2 | Yellow chalk | 10 |
| 1 | Ferruginous seam | 0.6 |

Total thickness of measured section 1,686.4 cm

**Locality 37**—Outcrop north of and higher than Monument Rocks in NW SE sec. 28, T. 14 S., R. 31 W., Gove County, Kansas. Base at 2,710 ft (826 m). Units 13–23 are Marker Unit 17.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 34 | Massive yellow chalk to top of the outcrop | ~100 |
| 33 | Seam | 0.5 |
| 32 | Massive yellow chalk—seams lie at 10, 36, and 52 cm above the bottom | 78 |
| 31 | Unit—two, 1-cm ferruginous/gypsiferous seams separated by chalk, forms a reentrant | 6 |
| 30 | Massive yellow chalk | 119 |
| 29 | Unit—two, 2.5-cm brown, silty seams separated by soft, dark-tan chalk, produces a reentrant | 7.5 |
| 28 | Massive yellow chalk | 100 |
| 27 | Selenite seam | 2.9 |
| 26 | Massive yellow chalk | 57 |
| 25 | Selenite seam | 2.9 |
| 24 | Massive yellow chalk | 47 |
| 23 | Seam | 0.4 |
| 22 | Massive yellow chalk | 25 |
| 21 | Seam | 0.4 |
| 20 | Massive yellow chalk | 37 |
| 19 | Seam | 0.4 |
| 18 | Massive yellow chalk | 6 |
| 17 | Seam | 0.4 |
| 16 | Massive yellow chalk | 18 |
| 15 | Seam | 0.4 |
| 14 | Massive yellow chalk | 23 |
| 13 | Gypsiferous seam—with iron oxide films at top and bottom | 0.5 |
| 12 | Massive yellow chalk | 28 |
| 11 | Seam—invisible in fresh chalk, crops out as a selenite ledge | 0.0 |
| 10 | Massive yellow chalk—a 0.5-cm seam lies 41 cm above the bottom | 140 |
| 9 | Bentonite unit—4.9 cm of brown clay expanded by selenite | 10 |
| 8 | Yellow chalk | 66 |
| 7 | Bentonite | 1.8 |
| 6 | Yellow chalk | 52 |
| 5 | Bentonite | 3 |
| 4 | Yellow chalk | 275 |
| 3 | Gray chalk | 180 |
| 2 | Selenite seam | 2 |
| 1 | Gray chalk | 25 |

Total thickness of measured section 1,315.1

**Locality 38**—Small bluff in W/2 of NW sec. 6, T. 15 S., R. 29 W., Gove County, Kansas. Base at 2,660 ft (811 m).

| Unit | Description | Thickness (cm) |
|---|---|---|
| 13 | Yellow chalk to top of the outcrop | ~300 |
| 12 | Seam | 0.1 |
| 11 | Massive yellow chalk | 23 |

| | | |
|---|---|---|
| 10 | Seam | 0.1 |
| 9 | Massive yellow chalk | 38 |
| 8 | Seam | 0.4 |
| 7 | Yellow chalk—has lots of *Pseudoperna* | 46 |
| 6 | Soft reddish band—forms a reentrant | 7.6 |
| 5 | Yellow chalk—has lots of *Pseudoperna* | 81 |
| 4 | Ferruginous seam | 1 |
| 3 | Yellow chalk—has lots of *Pseudoperna* | 83 |
| 2 | Ferruginous seam | 0.5 |
| 1 | Yellow chalk | 108 |

Total thickness of measured section 688.7 cm

**Locality 42**—Small butte in SW NW sec. 35, T. 13 S., R. 30 W., Gove County, Kansas. Base at 2,770 ft (845 m). Units 15–21 are Marker Unit 16 and units 42–49 are Marker Unit 17.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 50 | Yellow chalk to top of the outcrop | ~ |
| 49 | Seam | 0.4 |
| 48 | Yellow chalk | 28 |
| 47 | Seam | 0.4 |
| 46 | Yellow chalk | 25 |
| 45 | Seam | 0.4 |
| 44 | Yellow chalk | 10 |
| 43 | Seam | 0.4 |
| 42 | Yellow chalk | 31 |
| 41 | Seam | 0.4 |
| 40 | Yellow chalk | 85 |
| 39 | Ferruginous seam—produces a 8.9-cm reentrant | 2.5 |
| 38 | Yellow chalk | 78 |
| 37 | Seam | 0.5 |
| 36 | Yellow chalk | 47 |
| 35 | Seam | 0.4 |
| 34 | Yellow chalk | 25 |
| 33 | Seam | 0.4 |
| 32 | Yellow chalk | 57 |
| 31 | Unit—two, 0.3-cm, ferruginous seams separated by 11.4 cm of chalk—4 cm above the lower seam is a faint, ferruginous seam | 12 |
| 30 | Yellow chalk—the upper part is tinged with red | 90 |
| 29 | Ferruginous seam | 0.1 |
| 28 | Yellow chalk | 97 |
| 27 | Ferruginous/selenitic seam—produces a reentrant | 0.3 |
| 26 | Yellow chalk | 55 |
| 25 | Ferruginous seam—produces a reentrant | 0.7 |
| 24 | Yellow chalk | 7.6 |
| 23 | Seam | 0.4 |
| 22 | Yellow chalk | 20 |
| 21 | Seam | 0.4 |
| 20 | Yellow chalk | 35 |
| 19 | Seam | 0.4 |
| 18 | Yellow chalk | 17 |
| 17 | Seam | 0.4 |
| 16 | Yellow chalk | 9 |
| 15 | Ferruginous clay seam | 2 |
| 14 | Yellow chalk | 141 |
| 13 | Ferruginous clay seam—produces a reentrant | 1 |
| 12 | Yellow chalk | 32 |
| 11 | Ferruginous seam | 0.5 |
| 10 | Yellow chalk | 9.5 |
| 9 | Ferruginous seam | 0.1 |
| 8 | Yellow chalk | 60 |
| 7 | Ferruginous seam | 0.1 |
| 6 | Yellow chalk | 77 |
| 5 | Ferruginous seam | 0.1 |
| 4 | Yellow chalk | 61 |
| 3 | Clay seam | 1.5 |
| 2 | Yellow chalk | 86 |
| 1 | Ferruginous seam | 0.2 |

Total thickness of measured section 1,209.1 cm

**Locality 44**—Small outcrop in NW SW sec. 32, T. 12 S., R. 28 W., Gove County, Kansas. Base at 2,640 ft (805 m). Units 1–11 are part of Marker Unit H.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 18 | Massive yellow chalk to the top of the outcrop | 240 |
| 17 | Clay seam | 1.5 |
| 16 | Massive yellow chalk | 85 |
| 15 | Soft orange chalk | 219 |
| 14 | Massive yellow chalk—forms ledge | 69 |
| 13 | Ferruginous seam | 0.1 |
| 12 | Yellow massive chalk | 97 |
| 11 | Seam—locally selenitic | 0.3 |
| 10 | Yellow chalk | 89 |
| 9 | Clay seam—crops out as ferruginous ledge | 4.4 |
| 8 | Yellow chalk | 17 |
| 7 | Bentonite | 3.7 |
| 6 | Yellow chalk | 22 |
| 5 | Ferruginous seam | 0.5 |
| 4 | Yellow chalk | 18 |
| 3 | Ferruginous seam | 0.5 |
| 2 | Yellow chalk | 20 |
| 1 | Bentonite unit—0.6 cm of gray clay, expanded by iron oxide | 4.1 |

Total thickness of measured section 891.1 cm

**Locality 45**—West side of small butte at the end of long bluff, in S/2 of SE sec. 15, T. 13 S., R. 28 W., Gove County, Kansas. Base at 2,600 ft (793 m). Units 8–12 are Marker Unit 16, units 18–22 are Marker Unit 17, and units 24–28 are Marker Unit H.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 39 | Massive yellow chalk to the top of the outcrop | 668 |
| 38 | Bentonite unit—1.4 cm of gray clay, expanded by gypsum and iron oxide, crops out as two selenitic seams in a reentrant | 5.1 |
| 37 | Yellow chalk | 41 |
| 36 | Gypsiferous seam | 2 |
| 35 | Yellow chalk | 26 |
| 34 | Bentonite | 3.5 |
| 33 | Yellow chalk | 27 |
| 32 | Bentonite unit—1.4 cm of brownish-tan clay, expanded by gypsum and iron oxide | 2.5 |
| 31 | Yellow chalk | 30 |
| 30 | Bentonite | 6 |
| 29 | Yellow chalk—the top 6 cm are silty and soft | 28 |
| 28 | Ferruginous/gypsiferous seam | 2.5 |
| 27 | Yellow chalk—the bottom half is granular, paler, and forms a rounded resistant ledge | 53 |
| 26 | Bentonite unit—2.6 cm of pale-gray clay, expanded by iron oxide and gypsum | 3.5 |
| 25 | Gray and yellow chalk | 66 |
| 24 | Bentonite | 3.8 |
| 23 | Gray chalk | 100 |
| 22 | Ferruginous/gypsiferous seam | 2 |
| 21 | Gray chalk | 20 |
| 20 | Ferruginous/gypsiferous seam | 2 |
| 19 | Gray chalk | 38 |
| 18 | Bentonite | 2.5 |
| 17 | Gray chalk | 296 |
| 16 | Ferruginous/gypsiferous seam | 2 |
| 15 | Chalk | 24 |
| 14 | Gypsiferous seam—crops out as a selenite ledge | 1.5 |
| 13 | Yellow chalk | 41 |
| 12 | Ferruginous/gypsiferous seam | 3.5 |
| 11 | Tan chalk | 23 |
| 10 | Bentonite | 2.5 |
| 9 | Chalk | 7 |
| 8 | Bentonite unit—1 cm of gray-green clay, expanded by iron oxide and gypsum | 5.1 |
| 7 | Gray chalk | 83 |
| 6 | Gypsiferous seam | 2 |
| 5 | Gray chalk | 57 |

| | | |
|---|---|---|
| 4 | Bentonite | 4.4 |
| 3 | Gray chalk | 23 |
| 2 | Gypsiferous seam | 2 |
| 1 | Gray chalk | 122 |

Total thickness of measured section 1,831.4 cm

**Locality 47**—Outcrop near bottom of draw in NE SW sec. 11, T. 13 S., R. 29 W., Gove County, Kansas. Base at 2,660 ft (811 m). Units 1–8 are Marker Unit 17 and units 18–30 are Marker Unit H.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 40 | Massive yellow chalk to top of the outcrop | ~ |
| 39 | Seam | 0.1 |
| 38 | Yellow chalk | 56 |
| 37 | Seam | 0.1 |
| 36 | Yellow chalk | 11 |
| 35 | Seam | 0.1 |
| 34 | Yellow chalk | 31 |
| 33 | Soft tan chalk—forms a reentrant | 5.1 |
| 32 | Ferruginous seam | 0.5 |
| 31 | Yellow chalk | 91 |
| 30 | Ferruginous/gypsiferous seam | 2.5 |
| 29 | Yellow chalk | 50 |
| 28 | Seam | 2.5 |
| 27 | Yellow chalk | 21 |
| 26 | Seam | 2.5 |
| 25 | Yellow chalk | 20 |
| 24 | Ferruginous/gypsiferous seam | 7 |
| 23 | Yellow chalk | 41 |
| 22 | Ferruginous seam—locally expanded to 3.8 cm | 0.5 |
| 21 | Yellow chalk—a 1 cm gypsiferous seam lies 12.7 cm down from the top | 44.5 |
| 20 | Ferruginous/gypsiferous seam | 8.9 |
| 19 | Gray and yellow chalk | 75 |
| 18 | Ferruginous/gypsiferous seam | 3 |
| 17 | Yellow chalk | 13 |
| 16 | Ferruginous/gypsiferous seam | 3 |
| 15 | Gray to yellow chalk | 137 |
| 14 | Gypsiferous seam | 0.6 |
| 13 | Gray chalk | 9 |
| 12 | Gypsiferous seam | 0.6 |
| 11 | Gray chalk | 97 |
| 10 | Ferruginous/gypsiferous seam | 2.5 |
| 9 | Yellow chalk | 16.5 |
| 8 | Ferruginous/selenitic seam | 1.2 |
| 7 | Yellow chalk | 29 |
| 6 | Ferruginous/selenitic seam | 1.2 |
| 5 | Chalk | 18 |
| 4 | Gypsiferous seam | 0.6 |
| 3 | Chalk | 7 |
| 2 | Ferruginous seam | 0.5 |
| 1 | Gray chalk | 30.5 |

Total thickness of measured section 1,115 cm

**Locality 51**—N/2 of SE sec. 13, T. 13 S., R. 30 W., Gove County, Kansas. Base at 2,740 ft (835 m). Units 2–14 are Marker Unit H.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 17 | Yellow chalk to top of the outcrop | ~200 |
| 16 | Reddish-tan clay seam | 1.9 |
| 15 | Yellow chalk | 107 |
| 14 | Ferruginous/gypsiferous seam | 5 |
| 13 | Yellow chalk | 30 |
| 12 | Ferruginous/gypsiferous seam | 1 |
| 11 | Yellow chalk | 24 |
| 10 | Ferruginous/gypsiferous seam | 2.5 |
| 9 | Yellow chalk | 22 |
| 8 | Ferruginous/gypsiferous seam | 2.2 |
| 7 | Yellow chalk | 25 |
| 6 | Bentonite unit—4.4 cm of orange clay expanded by gypsum, produces a major reentrant | 7 |
| 5 | Chalk | 24 |
| 4 | Ferruginous/gypsiferous seam | 1.9 |
| 3 | Chalk | 56 |
| 2 | Gypsiferous seam | 1 |
| 1 | Gray chalk | ~ |

Total thickness of measured section 510.5 cm

**Locality 54**—Small exposure just south of the road in NE 1/4 of SW 1/4, Sec. 22, T. 8 S., R. 24 W., Graham County, Kansas. Base at 2,250 ft (686 m). Units 4–10 are Marker Unit 17 and units 14–28 are Marker Unit H.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 39 | Massive yellow chalk to top of the outcrop | 51 |
| 38 | Ferruginous seam | 0.3 |
| 37 | Massive yellow chalk | 27 |
| 36 | Ferruginous seam | 0.1 |
| 35 | Massive yellow chalk | 29 |
| 34 | Ferruginous seam | 0.1 |
| 33 | Massive yellow chalk | 11 |
| 32 | Ferruginous seam | 0.1 |
| 31 | Yellow chalk | 32 |
| 30 | Bentonite | 2.9 |
| 29 | Yellow chalk—a 0.1-cm ferruginous seam lies 41 cm above the bottom | 92 |
| 28 | Ferruginous/gypsiferous seam | 3.4 |
| 27 | Yellow chalk—bottom 10 cm is softer and produces a reentrant | 31 |
| 26 | Ferruginous/gypsiferous seam | 1 |
| 25 | Yellow chalk | 22 |
| 24 | Tan ferruginous seam | 0.6 |
| 23 | Yellow chalk | 22 |
| 22 | Grayish-tan clay seam | 1.5 |
| 21 | Yellow chalk | 22 |
| 20 | Bentonite | 3.9 |
| 19 | Yellow chalk | 18 |
| 18 | Reddish-tan clay seam | 2 |
| 17 | Yellow chalk | 36 |
| 16 | Reddish-tan clay seam | 2.5 |
| 15 | Yellow chalk | 56 |
| 14 | Bentonite | 2.9 |
| 13 | Yellow chalk | 10 |
| 12 | Bentonite | 1.5 |
| 11 | Gray chalk | 77 |
| 10 | Ferruginous/gypsiferous seam | 2 |
| 9 | Gray chalk | 18 |
| 8 | Ferruginous/gypsiferous seam | 2 |
| 7 | Gray chalk | 24 |
| 6 | Unit—two ferruginous/ gypsiferous seams, the upper 1 cm and the lower 1.6 cm thick, separated by chalk | 4.6 |
| 5 | Gray chalk | 24 |
| 4 | Ferruginous/gypsiferous seam | 0.6 |
| 3 | Gray chalk | 128 |
| 2 | Ferruginous/gypsiferous seam | 0.5 |
| 1 | Gray chalk | 122 |

Total thickness of measured section 884.5 cm

**Locality 55**—Small outcrop on east side of small draw in N/2 of SW sec. 13, T. 8 S., R. 24 W., Graham County, Kansas. Base at 2,240 ft (683 m). Units 17–19 are Marker Unit 18.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 30 | Yellow chalk | 114 |
| 29 | Seam | 0.4 |
| 28 | Yellow chalk | 62 |
| 27 | Ferruginous seam | 0.4 |
| 26 | Massive yellow chalk | 28 |
| 25 | Ferruginous seam | 1.5 |
| 24 | Massive yellow chalk | 132 |
| 23 | Pale-gray clay seam | 2 |
| 22 | Yellow chalk | 5.6 |
| 21 | Ferruginous seam | 0.2 |
| 20 | Yellow chalk | 63 |
| 19 | Bentonite | 10 |
| 18 | Yellow chalk | 52 |
| 17 | Bentonite | 5.7 |
| 16 | Yellow chalk—a 0.2-cm ferruginous seam lies in the middle | 109 |
| 15 | White chalk seam | 0.2 |
| 14 | Yellow chalk | 36 |
| 13 | Dark-tan clay seam | 2 |
| 12 | Soft yellow chalk | 150 |
| 11 | Massive yellow chalk—forms a resistant ledge | 23 |
| 10 | Ferruginous seam | 0.2 |
| 9 | Massive yellow chalk | 28 |
| 8 | Seam | 0.1 |

| | | |
|---|---|---|
| 7 | Massive yellow chalk | 26 |
| 6 | Seam | 0.1 |
| 5 | Massive yellow chalk | 10 |
| 4 | Seam | 0.1 |
| 3 | Massive yellow chalk | 33 |
| 2 | Ferruginous seam | 2 |
| 1 | Yellow chalk | 91 |

Total thickness of measured section 935.5 cm

**Locality 60**—Just north of road and west of oil well at center of line between sec. 6 and 7, T. 8 S., R. 23 W., Graham County, Kansas. Base at 2,250 ft (686 m). Units 13–17 are Marker Unit 16.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 45 | Indistinct ferruginous seam | 1 |
| 44 | Yellow chalk | 34 |
| 43 | Bentonite | 1.9 |
| 42 | Yellow chalk | 35 |
| 41 | Bentonite | 2 |
| 40 | Yellow chalk | 9.5 |
| 39 | Soft tan clay seam | 0.3 |
| 38 | Yellow chalk | 16.5 |
| 37 | Seam | 0.0 |
| 36 | Yellow chalk | 36 |
| 35 | Ferruginous seam | 0.3 |
| 34 | Yellow chalk | 13.3 |
| 33 | Ferruginous seam | 0.4 |
| 32 | Yellow chalk | 11.4 |
| 31 | Bentonite | 2.2 |
| 30 | Yellow chalk | 14 |
| 29 | Ferruginous seam | 0.1 |
| 28 | Yellow chalk | 4.4 |
| 27 | Ferruginous seam | 0.5 |
| 26 | Yellow chalk | 104 |
| 25 | Ferruginous seam | 0.1 |
| 24 | Pale-yellow chalk | 3.5 |
| 23 | Ferruginous seam | 0.3 |
| 22 | Yellow chalk | 56 |
| 21 | Bentonite | 2.5 |
| 20 | Yellow chalk | 23 |
| 19 | Red-tan clay seam | 0.7 |
| 18 | Yellow chalk | 37 |
| 17 | Ferruginous seam | 0.6 |
| 16 | Yellow chalk | 20 |
| 15 | Ferruginous seam | 0.5 |
| 14 | Yellow chalk | 6.7 |
| 13 | Bentonite | 2 |
| 12 | Yellow chalk | 81 |
| 11 | Seam | 0.1 |
| 10 | Yellow chalk | 69 |
| 9 | Bentonite | 2.9 |
| 8 | Yellow chalk | 31 |
| 7 | Ferruginous seam | 0.2 |
| 6 | Yellow chalk | 24 |
| 5 | Ferruginous seam | 0.1 |
| 4 | Gray chalk | 342 |
| 3 | Ferruginous/gypsiferous seam | 1.2 |
| 2 | Gray chalk | 84 |
| 1 | Bentonite | 5.1 |

Total thickness of measured section 1,080.3 cm

**Locality 64**—SW sec. 21, T. 8 S., R. 24 W., Graham County, Kansas. Base at 2,280 ft (695 m). Units 3–9 are Marker Unit 20. (Not illustrated.)

| Unit | Description | Thickness (cm) |
|---|---|---|
| 14 | Chalk to top of the outcrop | ~ |
| 13 | Seam | 0.5 |
| 12 | Yellow chalk | 16.5 |
| 11 | Ferruginous seam | 0.1 |
| 10 | Massive yellow chalk | 145 |
| 9 | Ferruginous seam | 0.5 |
| 8 | Massive yellow chalk | 28 |
| 7 | Ferruginous seam | 0.5 |
| 6 | Massive yellow chalk | 47 |
| 5 | Bentonite unit—waxy tan clay between films of iron oxide | 1.5 |
| 4 | Yellow chalk | 1.5 |
| 3 | Ferruginous seam | 1.5 |
| 2 | Yellow chalk | 67 |
| 1 | Ferruginous seam | 0.5 |

Total thickness of measured section 310.1 cm

**Locality 72**—West side of drainage in NW SW sec. 24, T. 14 S., R. 31 W., Gove County  Base at 2,740 ft (835 m). Units 4–5 are Marker Unit 15.

| Unit | Description | Thickness (cm) |
|---|---|---|
| 18 | Resistant yellow chalk—forms a cap on outcrop | 100 |
| 17 | Ferruginous seam—in 25-cm reentrant | 0.2 |
| 16 | Massive yellow chalk | 120 |
| 15 | Soft yellow chalk—forms a reentrant | 6.5 |
| 14 | Massive yellow chalk—a 0.2-cm ferruginous seam lies 90 cm above the bottom | 132 |
| 13 | Bentonite unit—2.5 cm of gray clay expanded by iron oxide | 6 |
| 12 | Yellow chalk—a seam lies 89 cm above the bottom | 183 |
| 11 | Bentonite | 2.5 |
| 10 | Yellow chalk | 242 |
| 9 | Ferruginous/gypsiferous seam | 1.8 |
| 8 | Yellow chalk | 12.5 |
| 7 | Ferruginous/gypsiferous seam | 2.5 |
| 6 | Gray chalk | 155 |
| 5 | Bentonite | 2.5 |
| 4 | Paler granular chalk—a seam lies 34 cm above the bottom | 54 |
| 3 | Gray chalk | 500 |
| 2 | Ferruginous/gypsiferous seam | 2.5 |
| 1 | Gray chalk | 100 |

Total thickness of measured section     1,623.0 cm