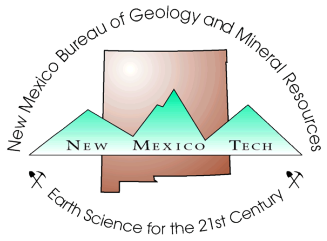
Evolution of stratigraphic nomenclature of the Upper Cretaceous of Socorro County, New Mexico

Stephen C. Hook

New Mexico Geology, v. 6, n. 2 pp. 28-33, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v6n2.28

New Mexico Bureau of Geology & Mineral Resources
New Mexico Institute of Mining & Technology
801 Leroy Place
Socorro, NM 87801-4796

https://geoinfo.nmt.edu



This page is intentionally left blank to maintain order of facing pages.

Evolution of stratigraphic nomenclature of the Upper Cretaceous of Socorro County, New Mexico

by *Stephen C. Hook*, Getty Oil Company, Houston, TX

Introduction

This paper is the companion piece to an article on the paleontology and stratigraphy of the marine Upper Cretaceous of Socorro County that was published in the 1983 New Mexico Geological Society Guidebook (Hook, 1983). Only general information on the stratigraphy and paleontology of Socorro County is presented in this paper; details can be found in Hook (1983) and in Hook and others (1983).

Molenaar (1983a) recognized that Upper Cretaceous rocks in Socorro County were deposited during the two earliest of the five major cycles of transgression and regression of the Late Cretaceous shoreline in New Mexico. These two cycles were referred to as the Greenhorn and Carlile cycles by Hook (1983). Marine Upper Cretaceous rocks in Socorro County are approximately 1,000 ft thick and consist of the upper part of the Dakota Sandstone, an unnamed lower part of the Mancos Shale, the lower and upper members of the Tres Hermanos Formation, the D-Cross Tongue of the Mancos Shale, and the Gallup Sandstone (Figs. 1a, b). Nonmarine rocks consist of the lower part of the Dakota Sandstone, the middle member of the Tres Hermanos Formation, and the Crevasse Canyon Formation. The Crevasse Canyon Formation is erosionally truncated, but exceeds 1,000 ft in thickness in much of the county. In the northern part of the county, the Twowells Tongue of the Dakota Sandstone subdivides the lower part of the Mancos Shale into an unnamed lower tongue and the Rio Salado Tongue of the Mancos Shale (Figs. 1a, b).

The emphasis of this paper is the Upper Cretaceous exposed in the Carthage area and from Puertecito to D Cross Mountain. Terminology applied to the Upper Cretaceous exposed in the Jornada del Muerto coal field and in the Joyita Hills is similar to that of the Carthage area. The major references for these two areas are Darton (1928), Wilpolt and Wanek (1951), and Tabet (1979).

Previous Investigations

Cretaceous rocks in Socorro County have been mentioned in the published literature since at least 1868 when the entomologist John L. Le Conte (1868, p. 136) mentioned the "unmetamorphosed coal from the coal mine eight miles east of San Antonio and the Rio Grande" in his study of Cretaceous coals in New Mexico. Interest has continued during the intervening 116 years in part because of the economic importance of coal, but just as importantly because of the good exposures and abundant fossils.

Socorro County contains the type localities for the following Upper Cretaceous guide fossils: *Coilopoceras colleti* Hyatt (1903), *C. inflatum* Cobban and Hook (1980), *Lopha bellaplicata novamexicana* Kauffman (1965), and *Tragodesmoceras socorroense* Cobban and Hook (1979). The type sections or type areas for the following Upper Cretaceous stratigraphic units are also in Socorro County: the Rio Salado Tongue of the Mancos Shale, the Tres Hermanos Formation, the Carthage Member and the Fite Ranch Sandstone Member of the Tres Hermanos Formation, and the D-Cross Tongue of the Mancos Shale. In 1983 alone, six papers were published that dealt with some aspect of the paleontology and stratigraphy of the Cretaceous of Socorro County (Hook, 1983; Hook and others, 1983; Johansen, 1983; Molenaar, 1983a, b; and Osburn, 1983).

Carthage area

One of the first coal mines in New Mexico was opened in the Carthage coal field by U.S. Government troops in 1861 to supply the smithing needs of Fort Selden, Fort Bayard, and Fort Stanton (Gardner, 1910; Sherman and Sherman, 1975). The first published reference to the coal field is that of Le Conte (1868), who merely mentioned it in passing, as did Stevenson (1881). Marcou (1889, p. 221, table IV), in a note about the "white sandstone with *Ammonites novi mexicani* [*Prionocyclus novimexicanus*] that forms the whole mesa between Albuquerque and the Rio Puerco," states that "Lately, 1888, Mr. J. Collett, of Indianapolis, has discovered south of Albuquerque at Carthage, near Socorro, in the continuation of the white sandstone an *Ammonites lenticularis* Meek, of the Fox Hills group of the upper Missouri basin." The white sandstone in the Rio Puerco area is presumably the Gallup Sandstone (Hook and Cobban, 1979). The ammonite identified as *Ammonites lenticularis* was later described as the new genus and new species *Coilopoceras colleti* by Hyatt (1903).

Marcou's (1889) discussion of the age and correlation of the Cretaceous rocks at Carthage is the first in the literature. Gardner (1910, p. 453) recognized that the geologic age of the coal was a disputed question. His fossil collections, from both above and below the coal, were determined by T. W. Stanton. Those below the coal consisted of forms characteristic of the Benton fauna and were assigned a Colorado (middle Cenomanian to late Santonian) age. The brackish-water forms from above the coal consisted of types that ranged in age from near the base of the Colorado up to the Laramie (Maastrichtian). Stanton (*in* Gardner, 1910) believed that the coal was older than the Laramie and that it lay within the Montana Group (late Santonian to early Maastrichtian). Previously, both Herrick and Johnson (1900) and Hyatt (1903) had assigned a Colorado age to marine fossils from Carthage.

Gardner (1910) correlated the coal-bearing unit at Carthage with the Mesaverde Formation of the San Juan Basin because of its physical similarity and its age, which he believed corresponded "closely if not exactly" with the Mesaverde.

Gardner's stratigraphic terminology consisted of only three units for the Cretaceous at Carthage: the Dakota(?) Sandstone, the Colorado Group, and the Montana Group. This basic threefold subdivision of the Cretaceous has been used with modification by the majority of those who have worked at Carthage (Fig. 2). The Colorado Group had been proposed by Clarence King, chief of the Fortieth Parallel Survey, in 1875 for the "great clay group" of the Cretaceous, which included equivalents of the Fort Benton, Niobrara, and Fort Pierre Groups of Meek and Hayden (Stanton, 1893). Eldridge (1889, p. 313) proposed the Montana Group as a method of grouping Upper Cretaceous formations in the Western Interior. Under Eldridge's scheme the Upper Cretaceous consisted of, in ascending order, the Dakota Group, the Colorado Group (Fort Benton and Niobrara), the Montana Group (Fort Pierre and Fox Hills), and the Laramie Group.

Gardner (1910) published the first measured section of the Cretaceous at Carthage. This section (Table 1) is important because Gardner used faunal control to correlate this isolated outcrop with the Cretaceous in the San Juan Basin, and because Lee (1916), Darton (1928), and Pike (1947) used the section in regional correlations.

Lee (1916, p. 41, fig. 16), using Gardner's measured section, correlated the thick marine shale with the Mancos Shale and the coal-bearing sequence with the Mesaverde Formation (Fig. 2). He thought that the Dakota(?) Sandstone might represent the Tres Hermanos Sandstone Member of the Mancos Shale. Lee's investigations also indicated that the coal-bearing beds were of Colorado rather than Montana age as postulated by Gardner (1910).

Darton (1928, p. 74) repeated Gardner's measured section, but he correlated the shale and sandstone unit with the Mancos (Fig. 2). Darton also was in doubt as to the identity of the Dakota Sandstone in the Carthage and Joyita Hills areas, but he believed that the basal sandstone could represent both the Dakota Sandstone and the Purgatoire Formation. Darton suggested that the lower fossiliferous-sandstone bed 500 ft above the Dakota, the Atarque Sandstone Member of the Tres Hermanos Formation of present usage, was equivalent to the Greenhorn Limestone and was underlain by Graneros Shale.

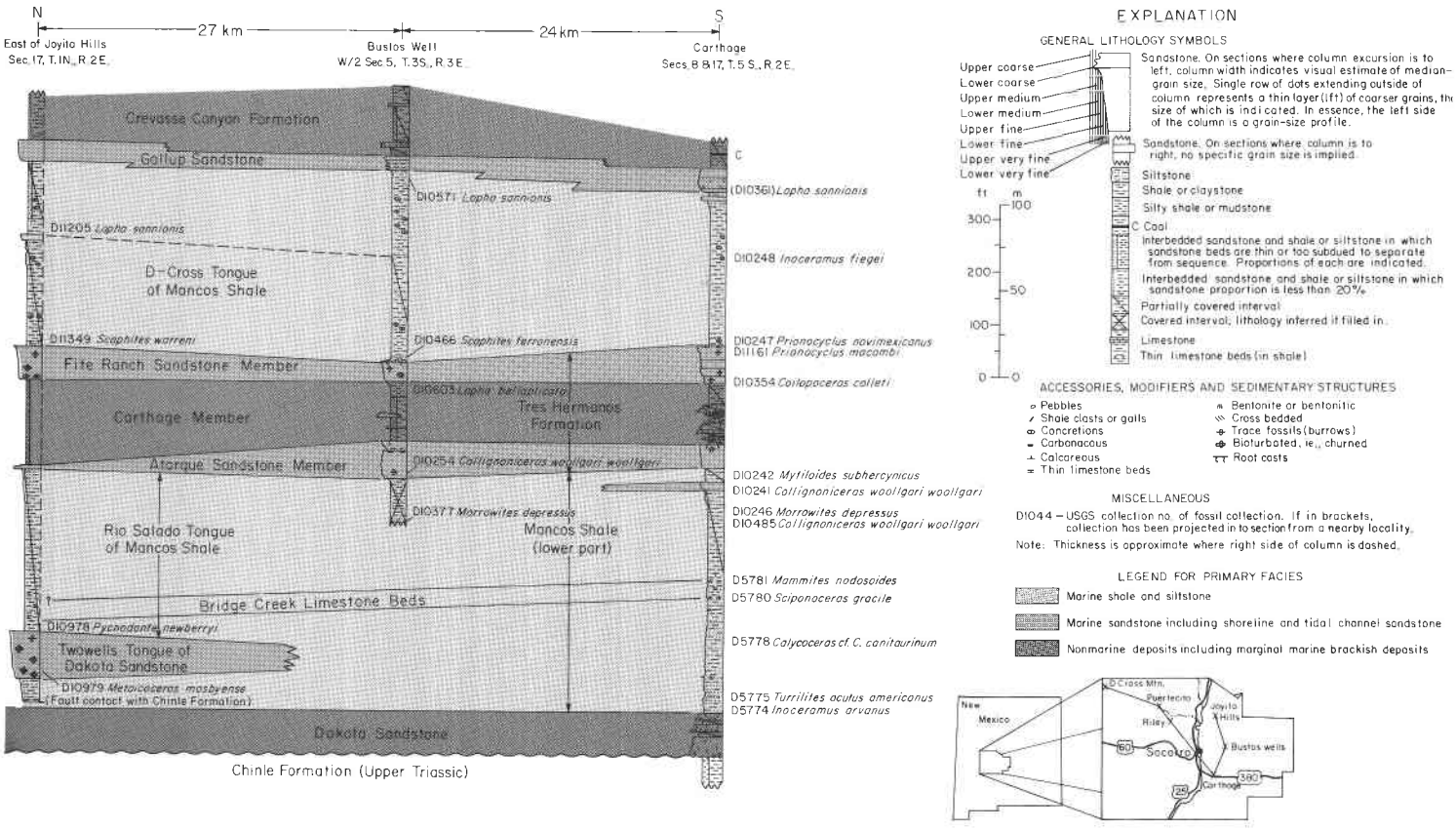


FIGURE 1a—Stratigraphic cross section of Upper Cretaceous rocks from Carthage north to the Joyita Hills, Socorro County, New Mexico (Hook, 1983; provided by C. M. Molenaar).

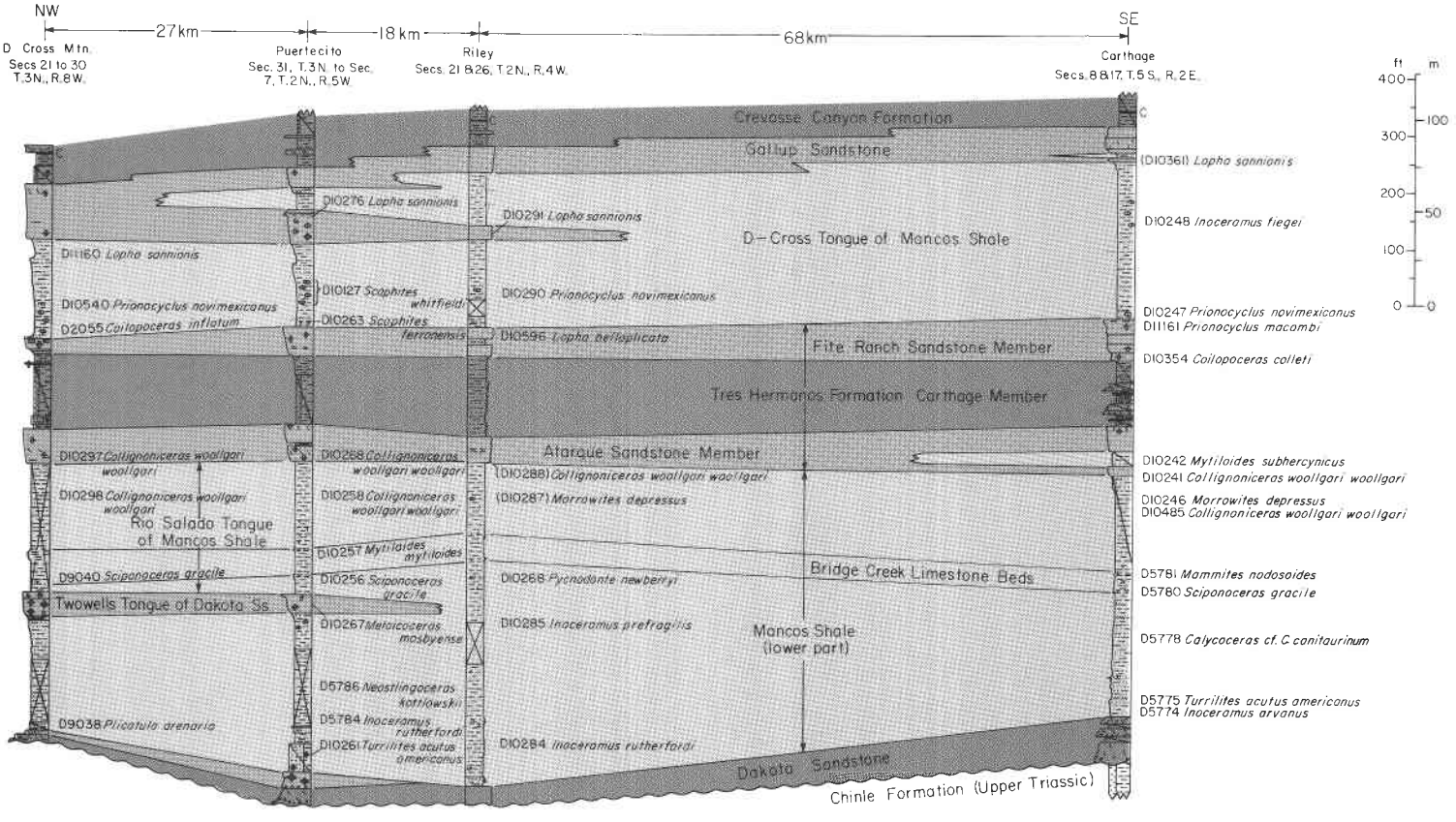


FIGURE 1b—Stratigraphic cross section of Upper Cretaceous rocks from Carthage northwest to D Cross Mountain, Socorro County, New Mexico (Hook and others, 1983; Riley section from Massingill, 1979). See Fig. 1a for explanation of symbols.

Rankin (1944) formally extended the Great Plains stratigraphic terminology of the Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Formation, all part of the Colorado Group, into the Carthage area (Fig. 2). Rankin's Greenhorn Limestone is exactly equivalent to the Bridge Creek Limestone Beds as presently used. Rankin also correlated the upper half of the present Tres Hermanos Formation with the Juana Lopez Member of the Carlile Shale, a correlation that works well paleontologically, but not lithologically (Hook and others, 1983).

Pike (1947), in his classic study of intertonguing Upper Cretaceous rocks, extended the stratigraphic nomenclature of the Zuni Basin and the southern San Juan Basin to the Carthage area (Fig. 2). He was the first to use the name Gallup Sandstone at Carthage, referring to a unit that is split into lower and upper parts by the Pescado Tongue of the Mancos Shale. Although Pike's correlations with rock units in the Zuni Basin were essentially correct, he erred in including the Tres Hermanos Formation as the lower part of the Gallup Sandstone. Molenaar (1974) used essentially the same stratigraphic framework as Pike, but he recognized the need to use the D-Cross Shale terminology and introduced the Crevasse Canyon Formation terminology for the coal-bearing sequence.

Between 1947 and 1974, a more simplified and/or informal terminology was employed by Wilpolt and Wanek (1951), Cobban and Reeside (1952), Budding (1963), and Dane and Bachman (1965). Wilpolt and Wanek (1951) recognized three major units, the Dakota(?), the Mancos, and the Mesaverde, but they subdivided the Mancos Shale into three informal members, a lower and upper shale member subdivided by a middle sandstone member. Budding (1963) used essentially the same terminology as Wilpolt and Wanek. Cobban and Reeside (1952) used the same three major subdivisions, but they recognized a limestone member in the lower part of the Mancos Shale that is equivalent to Rankin's (1944) Greenhorn Limestone. The limestone unit was later correlated with only part of the upper member of the Greenhorn Formation by Hook and Cobban (1981) and was designated the Bridge Creek Limestone Member of the Mancos Shale at Carthage. Subsequently, Hook and others (1983) reduced the Bridge Creek Limestone to a bedrank unit of the Mancos Shale. The state geologic map (Dane and Bachman, 1965) employs this same threefold division of the Cretaceous.

Cobban and Hook (1979), Hook (1983), Hook and others (1983), and Molenaar (1983a, b) correlated the middle sandstone member at Carthage with the Tres Hermanos Sandstone of Herrick (1900). Cobban and Hook (1979) used the Tres Hermanos Sandstone as a member of the Mancos Shale following Lee's (1916) usage. Hook and others (1983) later raised the Tres Hermanos to formational rank.

Figure 2 shows the evolution of the stratigraphic nomenclature at Carthage in graphic form. Although the units are not drawn to stratigraphic scale, nomenclature equivalent to that used in this paper can be traced horizontally across the diagram.

D Cross Mountain–Puertecito area

Formal studies of Cretaceous rocks in northwest Socorro County date back to 1875 (Table 2) with the publication of Gilbert's measured section in the valley east of the former Tres Hermanos Buttes, a name then used to refer to the north and south parts of D Cross Mountain and Bell Mountain. The present-day Tres Hermanos Buttes were then called Tres Huerfanos, and Alamosa Creek (now the Rio Salado) was called Tres Huerfanos Creek. The occasion on which the names changed is unknown (Dane, 1959). Herrick (1900) used the name Tres Hermanos Buttes in the same sense as today, but he referred to D Cross Mountain as Turtle Mountain. The name, D Cross, refers to natural-rock groupings on the south-facing slope of the mountain that resemble the letters D and X.

Gilbert's section, which was partly measured with an aneroid barometer and partly estimated during the 1873 field season, is of more than just historical interest because it demonstrates that ". . . observations carefully made and accurately recorded can be readily interpreted and translated into the framework of later, more detailed geologic knowledge" (Dane, 1959, p. 91). Although Gilbert applied no formal stratigraphic names to his units, they can be correlated easily with the formally named units used today because he integrated both physical and paleontological data into his description (Table 2). Gilbert was the first geologist to recognize the stratigraphic importance of the Bridge Creek Limestone Beds and their contained fauna. These beds were designated as unit 9 by Gilbert and described as gray shale with a band of limestone containing *Ostrea*. The band of limestone is the base of the Bridge Creek Limestone Beds and the *Ostrea* is *Pycnodonte newberryi* (Stanton), which occurs in great numbers at D Cross Mountain (Hook and Cobban, 1977, fig. 3). Gilbert (1875) was also the first geologist to measure a section across the D Cross Mountain fault (Givens, 1957) which duplicated the upper part of the section (Table 2, units 4 and 5). This error was later committed by both Winchester (1920) and Pike (1947), leading to discrepancies in the thickness of the marine Cretaceous rocks that were not corrected until 1957 (Dane and others, 1957).

Clarence L. Herrick, one of the unsung pioneers of New Mexico geology, journeyed up Alamosa Creek in December, 1899, and studied the Upper Cretaceous of that area. His contributions to geology, particularly the naming of the Tres Hermanos Sandstone in the Puertecito area (Fig. 3), have been a matter of considerable confusion and controversy since 1900. This controversy is discussed

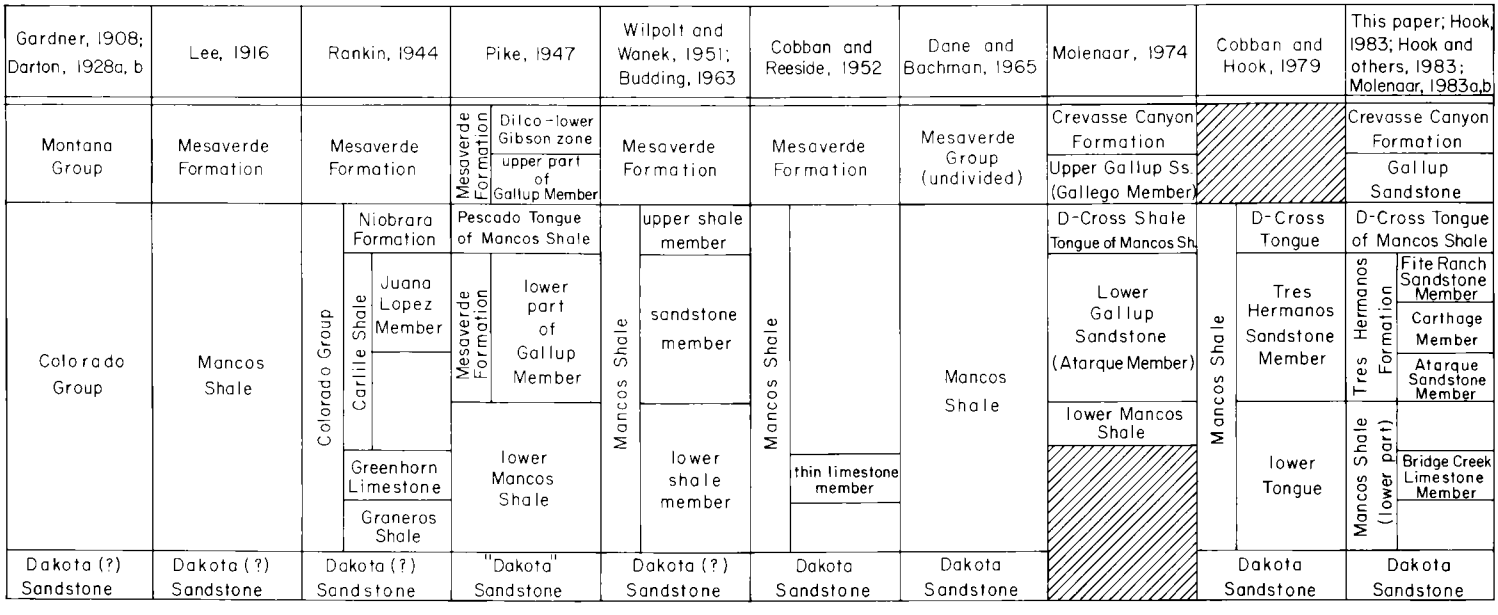


FIGURE 2—Evolution of Upper Cretaceous stratigraphic nomenclature at Carthage, Socorro County, New Mexico, from 1910 to the present.

TABLE 1—GARDNER'S (1910, PP. 454–455) MEASURED SECTION OF THE UPPER CRETACEOUS AT CARTHAGE. Updated information is in brackets.

Unit	Lithology	Thickness ft
Montana:		
	Sandstone, tan-colored and drab shale with traces of coal	600
	Shale and thin beds of sandstone, top contains *Ostrea* sp. [*Flemingostrea* sp.], *Anomia micronema* Meek?, *Modiola* [*Brachiodontes*] related to *M.* [*B.*] *regularis* (White), *Corbicula*? sp., *Corbula* sp., *Melania* sp., and *Admetopsis* sp.	40
	Coal, Carthage	5
	Shale, drab [Crevasse Canyon Formation from this unit to top of section]	20
	Sandstone, massive, brown [Gallup Sandstone]	20
	[Total thickness]	[685]
Colorado:		
	Shale, drab, with yellowish lime concretions	120
	Shale, yellowish, with brown sandstone [D-Cross Tongue of Mancos Shale, this unit and the one above]	45
	Sandstone, massive, soft, brown, fossiliferous containing *Ostrea* sp., *Ostrea lugubris* var. *belliplicata* Shumand [*Lopha bellaplicata novamexicana* Kauffman], *Pinna* sp., *Pholadomya* sp., *Fasciolaria*? sp., *Prionotropis woolgari* (Mantell)? [*Prionocyclus macombi* Meek], and *Coilopoceras colleti* Hyatt [Fite Ranch Sandstone Member of the Tres Hermanos Formation]	15
	Shale, drab [Carthage Member of the Tres Hermanos Formation]	40
	Shale, drab, with thin brown sandstone	135
	Sandstone, massive, gray	10
	Sandstone and shale, in center fossiliferous sandstone containing *Inoceramus labiatus* (*I. subhercynicus*), *Cardium* sp., *Cyprimeria* sp., *Psilomya* sp., *Fasciolaria*? sp., and *Volutoderma*? sp. [Atarque Sandstone Member of the Tres Hermanos Formation, this unit and the two above]	30
	Shale, drab [lower part of the Mancos Shale]	500
	[Total thickness]	[895]
Dakota(?):		
	Sandstone, hard, gray, in bold hogback, some thin shale	200

TABLE 2—GILBERT'S (1875, PP. 549, 550) MEASURED SECTION OF THE CRETACEOUS EAST OF D CROSS MOUNTAIN. Updated information is in brackets.

Unit	Lithology	Thickness ft
3	Shale, sandstone, and lignite; a series of rapidly alternating sandstone and shale beds, the sandstone [is] green–yellow color and soft, and the shale yellow and gray, with fillets of lignite [Crevasse Canyon Formation]	750
4	Massive yellow sandstone [upfaulted Gallup Sandstone]	75
5	Shaly yellow sandstone and gray shale [upfaulted D-Cross Tongue of the Mancos Shale and Gallup Sandstone]	400
6	Massive yellow sandstone [Gallup Sandstone]	75
7	Shaly yellow sandstone and gray shale [Carthage and Fite Ranch Sandstone Members of the Tres Hermanos Formation and D-Cross Tongue of the Mancos Shale]	300
8	Massive yellow sandstone (*Inoceramus*) [Atarque Sandstone Member of the Tres Hermanos Formation]	75
9	Gray shale with band of limestone (*Ostrea*) [Bridge Creek Limestone Beds of and overlying part of Rio Salado Tongue of the Mancos Shale]	125
10	Soft orange sandstone [Twowells Tongue of the Dakota Sandstone]	20
11	Gray, green, and blue, argillaceous shale [lower part of the Mancos Shale]	100
12	Conglomerate of metamorphic pebbles [Dakota Sandstone]	10
	[Total thickness]	[1,930]

in detail in Hook and others (1983). In spite of the controversy, Dane's (1959) observation concerning Gilbert is just as pertinent to Herrick and was utilized in the revision of the Tres Hermanos (Hook and others, 1983).

Lee (1916), using Winchester's (at that time unpublished) data, and Wells (1919) introduced the Dakota–Mancos–Mesaverde terminology to the area (Fig. 3). The confusion in the placement of the Mancos–Mesaverde boundary was the result of Winchester's error in measuring across the D Cross Mountain fault which duplicated the upper part of the section. Winchester (1920) defined the Miguel Formation, the Chamiso Formation, and the Gallego and Bell Mountain Sandstone Members of the Miguel Formation (Fig. 3). These names have since been abandoned. His Chamiso Formation was merely the upfaulted duplication of the upper part of the Miguel Formation, and his Bell Mountain Sandstone was the upfaulted duplication of the Gallego Sandstone. The Gallego Sandstone terminology was abandoned by Molenaar (1983b), and the unit is now simply referred to as the Gallup Sandstone.

Pike (1947) correlated the rocks at D Cross Mountain with those in the Zuni Basin, just as he did at Carthage, and extended the Zuni Basin terminology into Socorro County (Fig. 3). He also had measured across the D Cross Mountain fault, which resulted in a Cretaceous section that was too thick. In addition, he called the Twowells Tongue of the Dakota Sandstone the Tres Hermanos Sandstone, a miscorrelation that was not corrected until 1973 by Landis and others (1973). Cobban and Reeside (1952) used Pike's nomenclature.

Tonking (1957) and Givens (1957), who mapped adjacent 15-min quadrangles in northwest Socorro County, used the standard threefold stratigraphic division, Dakota–Mancos–Mesaverde, and introduced the La Cruz Peak Formation of the Mesaverde Group. Subsequently, that name was abandoned.

Dane and others (1957) and Dane (1959) cleared up the confusion regarding the duplication of units across the D Cross Mountain fault, but they caused as much, if not more, confusion regarding the correct identity of the Tres Hermanos Sandstone, particularly at Puertecito (Fig. 3). At D Cross Mountain they correlated the Twowells Tongue with the Tres Hermanos, whereas at Puertecito they correlated the basal Dakota with the Tres Hermanos. Dane and others (1957) also named the D-Cross Tongue of the Mancos Shale for a shale tongue at D Cross Mountain that they thought was a distinct and higher tongue of the Mancos Shale than the Pescado Tongue of Pike (1947). Subsequent work has shown that the two shale tongues were deposited during the same transgressive episode, but that the D-Cross Tongue is thicker and its upper portion is younger than the Pescado Tongue. Hook and others (1983) have retained both names, using the Pescado terminology in the Zuni Basin and the D-Cross terminology in the Acoma Basin.

Dane and Bachman (1965) also used the standard threefold division of the Cretaceous and drew the line between the Mancos and Mesaverde at the base of the present Tres Hermanos Formation.

Landis and others (1973) finally resolved the question of which sandstone should be called the Twowells and which should be called the Tres Hermanos. However, they left the question of the upper contact of the Tres Hermanos Sandstone unresolved.

Molenaar (1974) employed a modified version of Pike's (1947) nomenclature at D Cross ☞

Mountain. Molenaar believed that there was too much confusion surrounding the Tres Hermanos Sandstone, so he included it in the Gallup Sandstone and called it the Atarque Member. Molenaar's (1974) Atarque Member corresponds exactly with the Tres Hermanos Sandstone Member of the Mancos Shale as used by Hook and Cobban (1979) and with the Tres Hermanos Formation as used in this paper and by Hook (1983), Hook and others (1983), Molenaar (1983a, b), and Osburn (1983).

The stratigraphic terminology presently in use in the D-Cross–Puertecito area (Fig. 3) resulted in part from a cooperative agreement between the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey to determine the coal resources of the Acoma and Zuni Basins. That terminology, including the recently defined Rio Salado Tongue of the Mancos Shale and the recently revised Tres Hermanos Formation (Hook and others, 1983) will be used on all the maps that result from that agreement. In the northwest corner of Socorro County, Hook and others (1980, fig. 2) recognized an additional, lower marine tongue of the Dakota Sandstone, the Paguate Tongue. The Paguate, however, pinches out into the lower part of the Mancos Shale approximately 2 mi north of the measured section at D Cross Mountain (Fig. 1). North of this pinchout, the lower part of the Upper Cretaceous in Socorro County consists of, in ascending order, the Dakota Sandstone, the lower part of the Mancos Shale, the Paguate Tongue of the Dakota Sandstone, the Whitewater Arroyo Tongue of the Mancos Shale (not Clay Mesa Tongue as erroneously stated in Hook, 1983, p. 166), and the Twowells Tongue of the Dakota Sandstone.

ACKNOWLEDGMENTS—I thank Frank E. Kottlowski, Director of the New Mexico Bureau of Mines and Mineral Resources, for his continuing support of my research on the Upper Cretaceous of New Mexico. Draft copies of the manuscript were reviewed by W. A. Cobban and C. M. Molenaar of the U.S. Geological Survey. This paper is published with permission of Getty Oil Company. Figures 1a and 1b are used with permission of the New Mexico Geological Society.

References

Budding, A. J., 1963, Field trip 7, Carthage area: New Mexico Geological Society, Guidebook to 14th field conference, pp. 74–77.

Cobban, W. A., and Hook, S. C., 1979, *Collignoniceras woollgari woollgari* (Mantell) ammonite fauna from Upper Cretaceous of the Western Interior, United States: New Mexico Bureau of Mines and Mineral Resources, Memoir 37, 51 pp.

———, 1980, The Upper Cretaceous (Turonian) ammonite family Coilopoceratidae Hyatt in the Western Interior of the United States: U.S. Geological Survey, Professional Paper 1192, 28 pp.

Cobban, W. A., and Reeside, J. B., Jr., 1952, Correlation of the Cretaceous formations of the Western Interior of the United States: Geological Society of America, Bulletin, v. 63, no. 10, pp. 1,011–1,044.

Dane, C. H., 1959, Historical background of the type locality of the Tres Hermanos Sandstone Member of the Mancos Shale: New Mexico Geological Society, Guidebook to 10th field conference, pp. 85–91.

Dane, C. H., and Bachman, G. O., 1965, Geologic map of New Mexico: U.S. Geological Survey, scale 1:500,000.

Dane, C. H., Wanek, A. A., and Reeside, J. B., Jr., 1957, Reinterpretation of section of Cretaceous rocks in Alamosa Creek valley area, Catron and Socorro Counties, New Mexico: American Association of Petroleum Geologists, Bulletin, v. 41, no. 2, pp. 181–196.

Darton, N. H., 1928, "Red beds" and associated formations in New Mexico: U.S. Geological Survey, Bulletin 794, 356 pp.

Eldridge, G. H., 1889, Some suggestions upon the methods of grouping the formations of the middle Cretaceous and the employment of an additional term in its nomenclature: American Journal of Science, v. 38, pp. 313–321.

Gardner, J. H., 1910, The Carthage coal field, New Mexico: U.S. Geological Survey, Bulletin 38, pt. 2, pp. 452–460.

Gilbert, G. K., 1875, Report on the geology of portions of New Mexico and Arizona examined in 1873: Report upon geographical and geological explorations and surveys west of the one hundredth meridian (Wheeler), v. 3, pt. 5, pp. 503–567.

Givens, D. B., 1957, Geology of Dog Springs quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 58, 40 pp.

Herrick, C. L., 1900, Report of a geological reconnaissance in western Socorro and Valencia Counties: American Geologist, v. 25, no. 6, pp. 330–346; University of New Mexico, Bulletin 2, pp. 1–17.

Herrick, C. L., and Johnson, D. W., 1900, The geology of the Albuquerque sheet: Denison University Scientific Laboratories, Bulletin, v. 11, pp. 175–239; University of New Mexico, Bulletin 2, pp. 1–67.

Hook, S. C., 1983, Stratigraphy, paleontology, depositional framework, and nomenclature of marine Upper Cretaceous rocks, Socorro County, New Mexico: New Mexico Geological Society, Guidebook to 34th field conference, pp. 165–172.

Hook, S. C., and Cobban, W. A., 1977, *Pycnodonte newberryi* (Stanton)—common guide fossil in Upper Cretaceous of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1976–1977, pp. 48–54.

———, 1979, *Prionocyclus novimexicanus* (Marcou)—common Upper Cretaceous guide fossil in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1977–1978, pp. 34–42.

———, 1981, Late Greenhorn (mid-Cretaceous) discontinuity surfaces, southwest New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 180, pp. 5–21.

Hook, S. C., Cobban, W. A., and Landis, E. R., 1980, Extension of the intertongued Dakota Sandstone–Man-

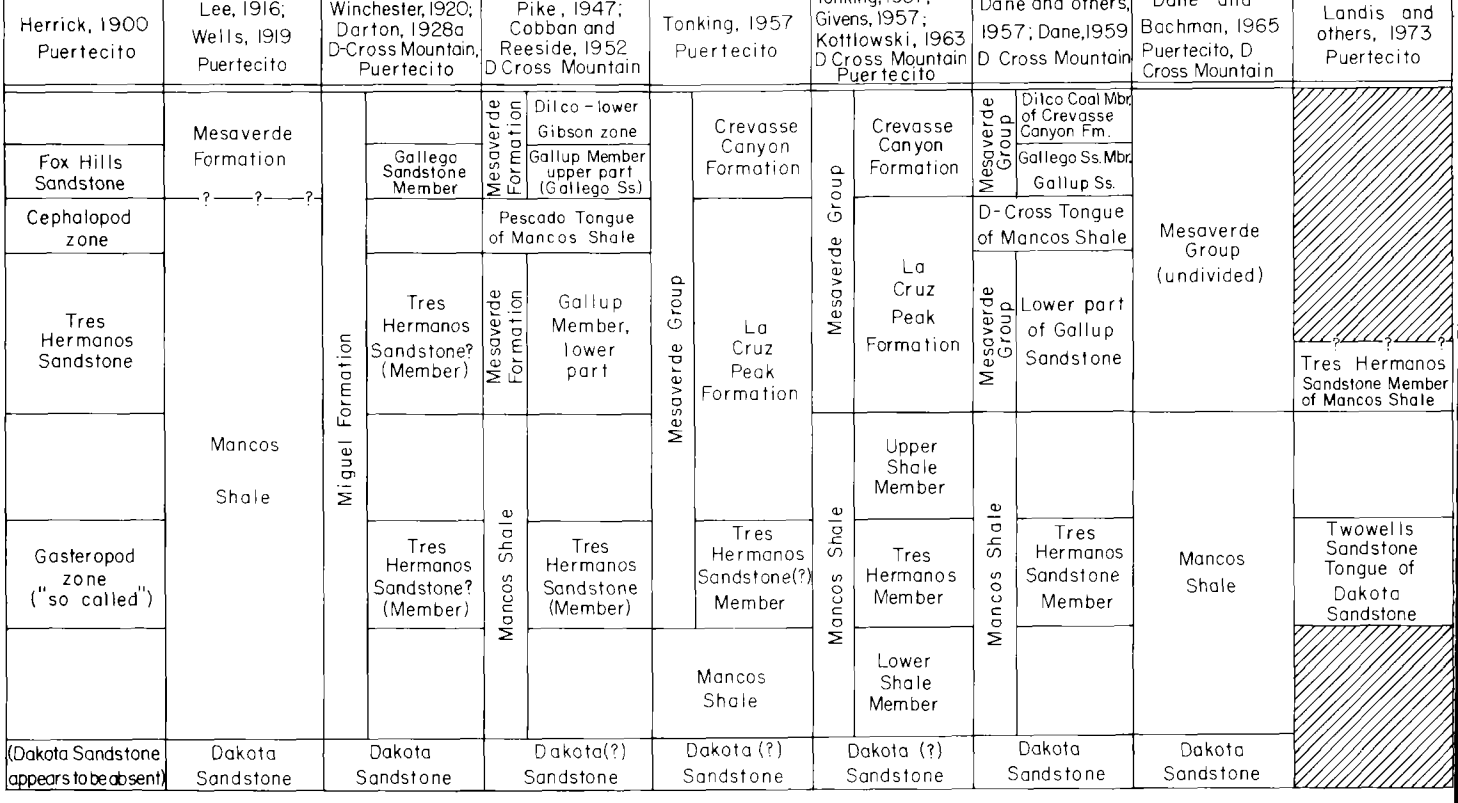


FIGURE 3—Evolution of Upper Cretaceous stratigraphic nomenclature at D Cross Mountain and Puertecito, Socorro County, New Mexico,

cos Shale terminology into the southern Zuni Basin: New Mexico Geology, v. 2, no. 3, pp. 42–44, 46.
Hook, S. C., Molenaar, C. M., and Cobban, W. A., 1983, Stratigraphy and revision of nomenclature of upper Cenomanian to Turonian (Upper Cretaceous) rocks of west-central New Mexico; *in* Hook, S. C. (compiler), Contributions to mid-Cretaceous paleontology and stratigraphy of New Mexico—part II: New Mexico Bureau of Mines and Mineral Resources, Circular 185, pp. 7–28, sheet 1.
Hyatt, Alpheus, 1903, Pseudoceratites of the Cretaceous: U.S. Geological Survey, Monograph 44, 351 pp.
Johansen, Steven, 1983, The thick-splay depositional style of the Crevasse Canyon Formation, Cretaceous of west-central New Mexico: New Mexico Geological Society, Guidebook to 34th field conference, pp. 173–178.
Kauffman, E. G., 1965, Middle and late Turonian oysters of the *Lopha lugubris* group: Smithsonian Miscellaneous Collections, v. 148, no. 6, 92 pp.
Kottlowski, F. E., 1963, Paleozoic and Mesozoic strata of southwestern and south-central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 79, 100 pp.
Landis, E. R., Dane, C. H., and Cobban, W. A., 1973, Stratigraphic terminology of the Dakota Sandstone and Mancos Shale, west-central New Mexico: U.S. Geological Survey, Bulletin 1372–J, 44 pp.
Le Conte, J. L., 1868, Cretaceous coals in New Mexico: American Journal of Science, 2nd ser., v. 45, p. 136.
Lee, W. T., 1916, Relation of the Cretaceous formations to the Rocky Mountains in Colorado and New Mexico: U.S. Geological Survey, Professional Paper 95, pp. 27–58.
Marcou, Jules, 1889, The Mesozoic series of New Mexico: American Geologist, v. 4, pp. 155–165, 216–229.
Massingill, G. L., 1979, Geology of the Riley–Puertecito area, southeastern margin of the Colorado Plateau, Socorro County, New Mexico: D.Sc. thesis, University of Texas (El Paso), 272 pp.; New Mexico Bureau of Mines and Mineral Resources, Open-file Report 107, 316 pp.
Molenaar, C. M., 1974, Correlation of the Gallup Sandstone and associated formations, Upper Cretaceous, eastern San Juan and Acoma Basins, New Mexico: New Mexico Geological Society, Guidebook to 25th field conference, pp. 251–258.
———, 1983a, Major depositional cycles and regional correlations of Upper Cretaceous rocks, southern Colorado Plateau and adjacent areas; *in* Reynolds, M. W., and Dolly, E. D. (eds.), Mesozoic paleogeography of the west-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography Symposium 2, pp. 201–224.
———, 1983b, Principal reference section and correlation of Gallup Sandstone, northwestern New Mexico; *in* Hook, S. C. (compiler), Contributions to mid-Cretaceous paleontology and stratigraphy of New Mexico—part II: New Mexico Bureau of Mines and Mineral Resources, Circular 185, pp. 29–40.
Osburn, J. C., 1983, Geology and coal resources of Alamo Band Navajo Reservation, Socorro County, New Mexico: New Mexico Geology, v. 5, no. 1, pp. 5–8.
Pike, W. S., Jr., 1947, Intertonguing marine and nonmarine Upper Cretaceous deposits of New Mexico, Arizona, and southwestern Colorado: Geological Society of America, Memoir 24, 103 pp.
Rankin, C. H., 1944, Stratigraphy of the Colorado Group, Upper Cretaceous, in northern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 20, 30 pp.
Sherman, J. E., and Sherman, B. H., 1975, Ghost towns and mining camps of New Mexico: Norman, University of Oklahoma Press, pp. 32–33.
Stanton, T. W., 1893, The Colorado Formation and its invertebrate fauna: U.S. Geological Survey, Bulletin 106, 288 pp.
Stevenson, J. J., 1881, Note on the Laramie Group of southern New Mexico: American Journal of Science, 3rd ser., v. 22, pp. 370–372.
Tabet, D. E., 1979, Geology of the Jornada del Muerto coal field, Socorro County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 168, 20 pp.
Tonking, W. H., 1957, Geology of Puertecito quadrangle, Socorro County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 41, 67 pp.
Wells, E. H., 1919, Oil and gas possibilities of the Puertecito district, Socorro and Valencia Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 3, 47 pp.
Wilpolt, R. H., and Wanek, A. A., 1951, Geology of the region from Socorro and San Antonio east of Chupadera Mesa, Socorro County, New Mexico: U.S. Geological Survey, Oil and Gas Investigations Map OM–121, scale: 1:63,360.
Winchester, D. E., 1920, Geology of Alamosa Creek valley, Socorro County, New Mexico: U.S. Geological Survey, Bulletin 716–A, 15 pp. □

<table>
<tr><th>Molenaar, 1974
Puertecito,
D Cross Mountain</th><th colspan="2">Hook and Cobban, 1979
Puertecito</th><th colspan="2">This paper; Hook, 1983; Hook and others, 1983; Molenaar, 1983a, b; Osburn, 1983; Puertecito, D Cross Mountain</th></tr>
<tr><td>Crevasse Canyon Formation</td><td colspan="2"></td><td colspan="2">Crevasse Canyon Formation</td></tr>
<tr><td>Gallego Sandstone (Member of Gallup Ss)</td><td colspan="2">Gallego Member of Gallup Sandstone</td><td colspan="2">Gallup Sandstone</td></tr>
<tr><td>D-Cross Tongue of Mancos Shale</td><td colspan="2">D-Cross Tongue</td><td colspan="2">D-Cross Tongue of Mancos Shale</td></tr>
<tr><td rowspan="3">Gallup Sandstone: Lower Gallup (Atarque Member)</td><td rowspan="3">Mancos Shale</td><td rowspan="3">Tres Hermanos Sandstone Member</td><td rowspan="3">Tres Hermanos Formation</td><td>Fite Ranch Sandstone Member</td></tr>
<tr><td>Carthage Member</td></tr>
<tr><td>Atarque Sandstone Member</td></tr>
<tr><td rowspan="2">Lower Mancos Shale</td><td rowspan="2">middle tongue</td><td rowspan="2">Mancos Shale</td><td>Rio Salado Tongue</td></tr>
<tr><td>Bridge Creek Limestone Beds</td></tr>
<tr><td rowspan="3"></td><td>Dakota Sandstone</td><td>Twowells Tongue</td><td>Dakota Sandstone</td><td>Twowells Tongue</td></tr>
<tr><td>Mancos Shale</td><td>lower tongue</td><td>Mancos Shale</td><td>lower part</td></tr>
<tr><td colspan="2">Dakota Sandstone</td><td colspan="2">Dakota Sandstone</td></tr>
</table>

from 1900 to the present.

Geographic names

U.S. Board on Geographic Names

Daugherty Ridge—ridge, 4 km (2.5 mi) long, highest elevation 2,501 m (8,204 ft); in the Sacramento Mountains 22.5 km (14 mi) northwest of Ruidoso; reportedly named for Jasper Newton Daugherty, government trapper, miner and rancher of the area; Lincoln County, New Mexico; sec. 31, T. 9 S., R. 11 E., and secs. 34, 35, and 36; T. 9 S., R. 10 E., NMPM; 33°28′30″ N., 105°50′46″ W. (east end), 33°28′50″ N., 105°53′18″ W. (west end); *not:* Doherty Ridge.

Daugherty Spring—spring, on the northwest slope of Daugherty Ridge, 16.9 km (10.5 mi) south of Carrizozo and 23.3 km (14.5 mi) northwest of Ruidoso; Lincoln County, New Mexico; sec. 35, T. 9 S., R. 10 E., NMPM; 33°28′53″ N., 105°52′34″ W.; *not:* Horse Spring.

Elder Canyon—canyon, 6.1 km (3.8 mi) long, heads at 33°28′58″ N., 105°50′59″ W. in the Sacramento Mountains, trends northwest to Cottonwood Creek 14.5 km (9 mi) southwest of Carrizozo; Lincoln County, New Mexico; sec. 28, T. 9 S., R. 10 E., NMPM; 33°29′33″ N., 105°54′18″ W.; *not:* Cottonwood Creek.

Jarocita Park—park, 0.8 km (0.5 mi) long, at the head of Rio Chiquito; in the Sangre de Cristo Mountains 24.9 km (15.5 mi) southeast of Taos; Taos County, New Mexico; 36°17′07″ N., 105°20′05″ W.; *not:* Jarocito Park.

Lincoln Canyon—canyon, 8 km (5 mi) long, heads at 33°26′52″ N., 105°51′20″ W., trends southwest to Three Rivers Canyon 19.3 km (12 mi) northwest of Ruidoso; Lincoln County, New Mexico; sec. 34, T. 10 S., R. 10 E., NMPM; 33°24′12″ N., 105°53′53″ W.

McGaffey Ridge—ridge, 3.7 km (2.3 mi) long, in Sangre de Cristo Mountains; highest elevation 2,491 m (8,174 ft); east of McGaffey Canyon and 4 km (2.5 mi) south of Ranchos de Taos; Taos County, New Mexico; 36°19′25″ N., 105°36′00″ W. (north end), 36°17′30″ N., 105°35′40″ W. (south end).

Osha Park—park, 0.4 km (0.25 mi) long, at the head of Rito Osha; in the Sangre de Cristo Mountains 16.9 km (10.5 mi) southeast of Taos; Taos County, New Mexico; 36°17′21″ N., 105°27′10″ W.

Paradise Park—park, at the head of Paradise Canyon; in the Fernando Mountains, 0.48 km (0.3 mi) south of Sierra de Don Fernando and 15.3 km (9.5 mi) east-southeast of Taos; Taos County, New Mexico; 36°20′15″ N., 105°25′31″ W.

Pine Canyon—canyon, 4.8 km (3 mi) long, heads on the northeast slope of Diamond Peak in the Sierra Blanca at 33°33′07″ N., 105°47′14″ W., trends northeast to open out 11.3 km (7 mi) southeast of Carrizozo; Lincoln County, New Mexico; sec. 26, T. 8 S., R. 11 E., NMPM; 33°35′02″ N., 105°46′12″ W.; *not:* Windy Canyon.

Playas—populated place, in Playas Valley, on the northwest slope of the Little Hatchet Mountains 26 km (16 mi) east-southeast of Animas; Hidalgo County, New Mexico; 31°55′00″ N., 108°31′59″ W.

Pot Creek—populated place, along Rito de la Olla 9.7 km (6 mi) south-southeast of Ranchos de Taos; Taos County, New Mexico; 36°16′30″ N., 105°34′20″ W.

Ranchos Peak—peak, elevation 2,871 m (9,420 ft), at the head of Ranchos Canyon; in the Sangre de Cristo Mountains 2.1 km (1.3 mi) west of Palo Encebado Peak and 8.9 km (5.5 mi) east of Taos; Taos County, New Mexico; sec. 8, T. 25 N., R. 14 E., NMPM; 36°24′36″ N., 105°28′40″ W.

Rattlesnake Canyon—canyon, 2.4 km (1.5 mi) long, heads at 33°26′32″ N., 105°51′07″ W., trends southwest to Lincoln Canyon 21 km (13 mi) northwest of Ruidoso; Lincoln County, New Mexico; sec. 14, T. 10 S., R. 10 E., NMPM; 33°26′11″ N., 105°52′32″; *not:* Lincoln Canyon.

Red Fox Spring—spring, in Skull Canyon, 19.3 km (12 mi) northwest of Ruidoso; Lincoln County, New Mexico; sec. 33, T. 9 S., R. 11 E., NMPM; 33°29′27″ N., 105°48′01″ W.; *not:* Skull Spring.

Sanders Canyon—canyon, 7.2 km (4.5 mi) long, heads in the Sierra Blanca at 33°29′20″ N., 105°50′05″ W., trends northwest to join Chaves Canyon at the head of Chaves Draw 1.1 km (0.7 mi) northeast of Chaves Mountain and 14.5 km (9 mi) southwest of Carrizozo; Lincoln County, New Mexico; sec. 22, T. 9 S., R. 10 E., NMPM; 33° 30′55″ N., 105°53′35″ W.

Shady Spring—spring, north of The Hogback and 15.3 km (9.5 mi) south of Carrizozo; Lincoln County, New Mexico; sec. 23, T. 9 S., R. 10 E., NMPM; 33°30′24″ N., 105°52′41″ W.

Skull Canyon—canyon, 1.6 km (1 mi) long, heads at 33°29′32″ N., 105°48′25″ W., trends southeast to Tanbark Canyon, 18.5 km (12.5 mi) northwest of Ruidoso; Lincoln County, New Mexico; sec. 34, T. 9 S., R. 11 E., NMPM; 33°29′07″ N., 105°47′32″ W.; *not:* Tanbark Canyon.

Skull Spring—spring, at the mouth of Skull Canyon, 18.5 km (12.5 mi) northwest of Ruidoso; Lincoln County, New Mexico, sec. 34, T. 9 S., R. 11 E., NMPM; 33°29′07″ N., 105°47′32″ W.

—David W. Love
NMBMMR Correspondent