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Stratigraphy of the Colorado Group, Upper Cretaceous, in Northern New Mexico

by
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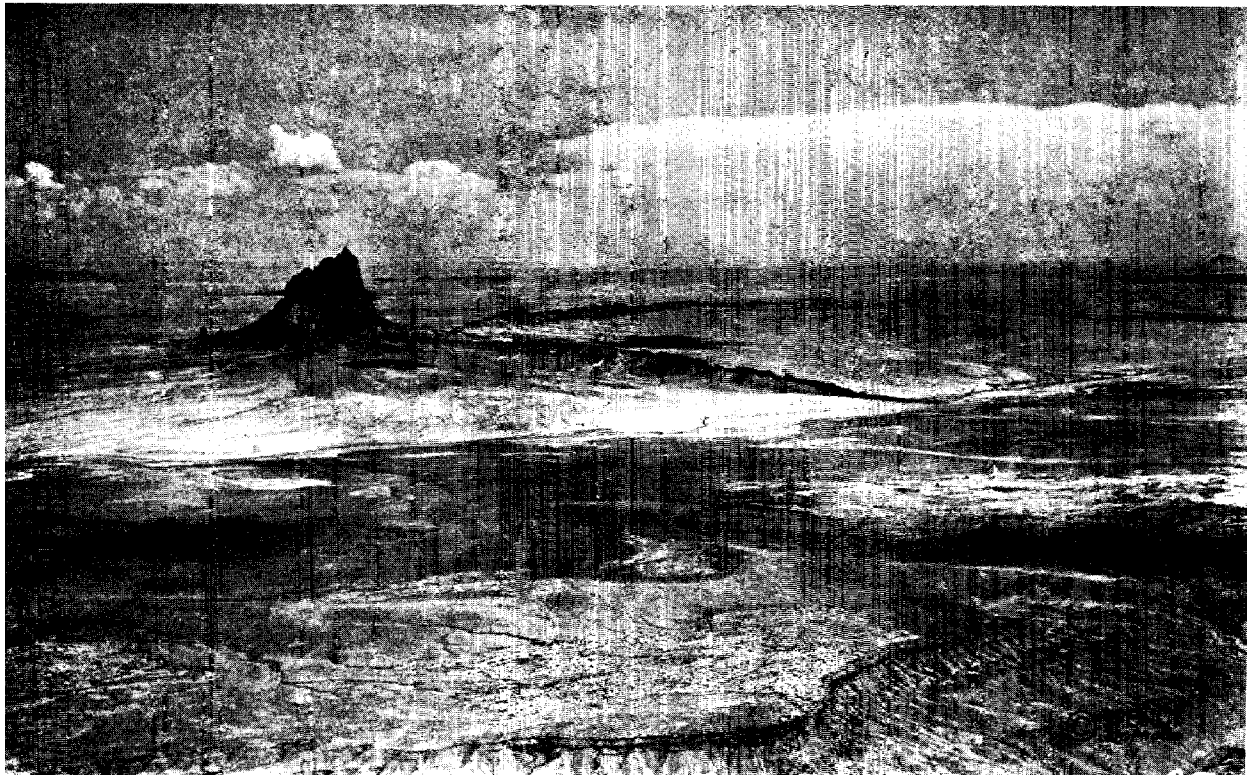

FIGURE 1.-Ship Rock, northwestern San Juan County, New Mexico. Cuesta in foreground is formed by the Juana Lopez calcareous sandstone in the upper part of the Carlile shale. Concretionary limestones crop out on the back slope between the crest and the outcrop of the Tocito sandstone, which does not form an escarpment in this view. (Spence Air Photos.)

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The New Mexico State Bureau of Mines and Mineral Resources, designated as "a department of the New Mexico School of Mines and under the direction of its Board of Regents," was established by the New Mexico Legislature of 1927. Its chief functions are to compile and distribute in-formation regarding mineral industries in the State, through field studies and collections, laboratory and library research, and the publication of the results of such investigations. A full list of the publications of the State Bureau of Mines and Mineral Resources is given on the last pages of this bulletin, following the index.

Stratigraphy of the Colorado Group, Upper Cretaceous, in Northern New Mexico

by

CHARLES H. RANKIN[1]

INTRODUCTION

In previous reports on the Cretaceous rocks of New Mexico, writers have followed the nomenclature established by Cross,[2] and have described all the rocks between the Dakota sandstone and the Mesaverde coal measures as Mancos shale. Lee[3] and Darton,[4] in describing the rocks of central and northeastern New Mexico, recognize that some subdivisions of the Colorado group can be identified; but in their measured sections these authors do not differentiate formations.

Since 1925 the writer has measured a number of sections of Cretaceous rocks in northern New Mexico while studying the economic geology and oil resources of the region. A study of these sections, which are presented herewith, supplemented by information obtained from the examination of well cuttings, reveals that all divisions of the Colorado group (Mancos shale) as described in southern Colorado, except the Fort Hays lime-stone and the Apishapa shale, can be recognized in northern New Mexico. The purpose of this paper is to identify and describe these divisions. The writer has integrated his studies with those of Lee,[5] and also with the excellent descriptions of the rocks of the Colorado group given by Dane, Pierce and Reeside.[6]

The recognition and study of the divisions of the Mancos shale throws some interesting light on a phase of the geologic history of northern New Mexico that has previously received only little attention. The persistence of the Greenhorn limestone over most of northern New Mexico aids materially in solving the problem of the Dakota (?) sandstone and contemporaneous strata in this and other areas.

[1] Geologist, Great Lakes Carbon Corporation.

[2] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, La Plata folio (no. 60), 1901.

[3] Lee, Willis T., Geology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 9-221, 1917.

[4] Barton, N. H., "Red Beds" and associated formations in New Mexico : U. S. Geol. Survey Bull. 794, pp. 40-50, 1928.

[5] Lee, Willis T., op. cit.

[6] Dane, C. H., Pierce, W. G., and Reeside, J. 13., Jr., The stratigraphy of the Upper Cretaceous rocks north of the Arkansas River in eastern Colorado: U. S. Geol. Survey Prof. Paper 186-K, 1937.

ACKNOWLEDGMENTS

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THE FORMATIONS

The stratigraphic divisions of the Upper Cretaceous rocks considered in this paper are as follows:

Colorado group
- Niobrara formation:
  - Smoky Hill marl member
  - Fort Hays limestone member
  - Apishapa shale member
  - Timpas limestone member
- Carlile shale:
  - Codell sandstone member
  - Shale member
  - Juana Lopez sandstone member
  - Shale member
- Greenhorn limestone
- Graneros shale

Dakota (?) sandstone

DAKOTA (?) SANDSTONE

The Dakota (?) sandstone, the basal formation of the Upper Cretaceous series in this region, is exposed in many places in northern New Mexico. It crops out around the entire perimeter of the San Juan basin, around the perimeter of that part of the Raton coal basin that lies in New Mexico, prominently in the vicinity of Las Vegas, around the Ortiz Mountains south of Santa Fe, and at isolated places to the south along the Rio Grande. The formation ranges in thickness from less than 20 to more than 200 feet.

GRANEROS SHALE

The Graneros shale was defined by Gilbert[7] as a laminated argillaceous *gray* shale from 200 to 210 feet thick, the lowest formation of the "Fort Benton group" (now called the Benton shale where not subdivided). The Graneros was named from a creek in the northern part of the Walsenburg quadrangle, Colorado.

In New Mexico the formation crops out above the Dakota (?) sandstone wherever the latter is found. Its thickness ranges from 60 feet in the extreme northwest corner of New Mexico to 350 feet in the valley of the Rio Puerco west of Albuquerque, a distance of 130 miles. Most of the increase in thickness in the Rio Puerco area is probably due to the presence of the thick Tres Hermanos sandstones.

It is possible that at Beautiful Mountain and Red Wash, in the northwestern part of the State, some of the sandstones included in the Dakota (?) sandstone are of Graneros age; but there is no evidence known to the writer that justifies dividing

[7] Gilbert, G. K., The underground water of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey 17th Ann. Kept., pt. 2, pp. 565-566, 570, 1896.

the so-called Dakota sandstone. Lee[8] mentions the presence of coal and carbonaceous shale above the Dakota (?) sandstone at Cerrillos and refers the beds containing them to the overlying Graneros rather than to the Dakota (?). On this basis, all sand-stones and interbedded shales above the basal 100-foot Dakota (?) sandstone at Red Wash could be referred to the Graneros rather than to the Dakota (?). The lack of supporting evidence, however, has led the writer to follow the common usage and place the entire sequence in the Dakota (?).

From information available it is not possible to subdivide the Graneros shale in northern New Mexico, except at localities where the sandstones of the Tres Hermanos are present. At these places a division has been made that would separate the sandy phase, including the Tres Hermanos, from the typical non-sandy clayey shales above. Paleontologic evidence does not seem to indicate a time break between the upper and lower phases, but there seems to be a change of fauna which would be the natural result of the change in the nature of the sedimentation.

At most places where the topmost beds of the Graneros are exposed, a bed of bentonite half an inch to six inches thick is present, generally about 18 inches below the Greenhorn lime-stone. It is suggested that a study might be made of the heavy-mineral content of the bentonite, with the possibility in mind of developing a method by which it could be used in establishing correlations and mapping structure.[9]

The fauna of the Graneros in northern New Mexico is similar to that in adjoining regions. Most fossils occur in the lower (sandy) portion; in places, some of the beds of the Tres Hermanos are exceedingly fossiliferous. Lee's[10] "gastropod zone" is present in most outcrops in the central part of the State. Following are some of the more common types: *Gryphaea newberryi* Stanton, *Exogyra* sp., *Pinna petrina* White ?, *Turritella* sp., *Scaphites vermiformis* Meek and Hayden, *Prionotropis* sp., and *Inoceramus labiatus* Schlotheim.

GREENHORN LIMESTONE

The Greenhorn limestone was differentiated as a formation by Gilbert[11] at Greenhorn station, 14 miles south of Pueblo, Colorado. There the formation consists of 25 to 40 feet of interbedded limestone and shale. The limestone is bluish gray to black and the shale is gray, laminated and calcareous. In northern New Mexico it does not seem advisable to attempt to correlate the individual members, as has been done in Kansas where the formation is thicker and the limestones are more prominent.

[8] Lee, Willis T., op. cit., pp. 213-214.

[9] Rankin, C. H., Use of thin bentonite beds in mapping structure: Bull. Amer. Assoc. Petrol. Geol., vol. 14, no. 8, pp. 1065-1070, 1930.

[10] Lee. Willis, T., op. cit., p. 213.

[11] Gilbert, G. K., op. cit., pp. 565-570.

Over most of northern New Mexico the formation has about the same thickness as Gilbert[12] assigns it, and about the same general character as it has at Greenhorn except that toward the south and west it becomes increasingly shaly and the lime-stones are thinner. At Carthage, New Mexico, the most southerly point studied, the individual limestones are less than eight inches thick. In the section at Cerrillos and to the south there is a rather persistent brown very calcareous sandstone near the top of the formation. This sandstone occurs in laminae less than one inch thick, usually with abundant *Ostrea congesta* Conrad.

The study of the change in facies of the Greenhorn from north to south and from east to west furnishes a definite clue to the history of sedimentation in the early Cretaceous basin that existed throughout the Rocky Mountain region. Paleogeographic maps of the Greenhorn basin show it to have had practically the same extent as the Dakota basin except that the latter extended farther west in the latitude of the Colorado-Wyoming line. The writer has seen outcrops of Greenhorn lime-stone as far south as Benson, Cochise County, Arizona; but war-time restrictions on travel prohibit the visiting of distant areas and the inclusion in this report of sections from them.

Wherever the Greenhorn has been studied in northern New Mexico, the characteristic fossil, *Inoceramus labiatus* Schlotheim, has been found. *Baculites asper* Norton is also common. Thin bentonite beds are usually found within the Greenhorn; none of these, however, is as thick or persistent as the bed that occurs at or just below the base of the formation.

Detailed sections of the Greenhorn follow.

Section measured in sec. 15, T. 15 N., R. 16 E., near Las Vegas, San Miguel County, New Mexico

	Ft.	in.
Greenhorn limestone:		
Shale, chalky, and thin limestones, poorly exposed	10	
Limestone, bluish gray to black	1	
Shale, gray to black, very calcareous	4	
Limestone, black		6
Shale, black, calcareous	3	
Limestone, bluish gray to black	2	
Shale, gray to black, very calcareous	5	6
Limestone, black, with *Inoceramus labiatus* Schlotheim	1	
Shale, very calcareous, and thin limestone	1	4
Limestone, black, dense	2	
Total Greenhorn	30	4
Graneros shale:		
Shale, black, chalky	1	3
Bentonite		5
Shale, black, fissile	Not measured	

[12] Idem.

Section measured in sec. 33, T. 15 N., R. 10 E., at Lamy, Santa Fe County, New Mexico

	Ft.	in.
Carlile shale:		
Shale, black, fissile	Not measured	
Greenhorn limestone:		
Limestone, black		4
Shale, black, calcareous	2	1
Limestone, black		5
Shale, gray to black, very calcareous	1	6
Limestone, black		6
Shale, black, fissile, very calcareous	3	11
Limestone, black		3
Shale, black, fissile, very calcareous	1	8
Limestone, black		3
Shale, chalky	8	
Limestone, black		4
Shale, chalky	6	
Limestone, with *Baculites asper* Norton, *Inoceramus labiatus* Schlotheim, *I. labiatus* sp. (high-beaked), *Baculites gracilis* Shumard		4
Shale, gray to black, chalky		6
Limestone, black, with *Inoceramus labiatus* Schlotheim		10
Shale, gray, chalky	1	3
Total Greenhorn	28	2
Graneros shale:		
Shale, gray to black, fissile	1	3
Bentonite		3
Shale, black	Not measured	

Section measured in sec. 25, T. 36 N., R. 14 W., on Mancos Creek, Montezuma County, Colorado

	Ft.	in.
Carlile shale	Not measured	
Greenhorn limestone:		
Shale, chalky, and thin limestone, covered	25	
Limestone, black		6
Shale, black, very calcareous	1	
Limestone, black, shaly		3
Shale, black, calcareous		9
Limestone, black	1	
Shale, black, calcareous		5
Limestone, black		3
Shale, black, calcareous		6
Limestone, black, with *Inoceramus labiatus* Schlotheim	1	1
Shale, black, chalky	1	2
Total Greenhorn	31	11
Graneros shale:		
Bentonite		6
Shale, black, fissile	Not measured	

Section measured in sec. 30, T. 35 N., R. 1 W., two miles southeast of Pagosa Springs, Archuleta County, Colorado

	Ft.	in.
Carlile shale	Not measured	
Greenhorn limestone :		
Shale, dark gray, very calcareous, with few thin limestones	28	
Limestone, black, hard		4

Greenhorn limestone—continued:	Ft.	in.
Shale, black, calcareous	2	
Limestone, black, hard	1	2
Shale, black and dark gray, calcareous	1	3
Limestone, black		6
Shale, dark gray, calcareous		4
Limestone, black, hard	1	6
Shale, black, chalky at top	4	
Bentonite		½
Total Greenhorn	39	1½
Graneros shale	Not measured	

Section measured on road to El. Vado dam, four miles west of Tierra Amarilla, Rio Arriba County, New Mexico

Greenhorn limestone:	Ft.	in.
Shale, gray, calcareous; top not exposed	20	
Limestone, dark blue to black		6
Shale, gray, calcareous	1	2
Bentonite		3
Limestone, black		6
Shale, gray, calcareous		8
Limestone, black, hard		5
Shale, black, calcareous; some thin limestones	7	
Limestone, dark blue to black, massive	1	
Shale, dark gray to black, fissile	1	8
Limestone, black, hard		8
Shale, gray, chalky	1	
Limestone, blue gray, massive	1	
Total Greenhorn	35	10
Graneros shale:		
Shale, black, fissile, chalky at top	4	
Bentonite		½
Shale, black, fissile	Not measured	

Section measured in sec. 10, T. 5 S., R. 2 E., at Carthage, Socorro County, New Mexico

Carlile shale:		
Shale, black, silty and sandy	Not measured	
Greenhorn limestone:	Ft.	in.
Shale, black, very calcareous, with few thin limestones	15	
Limestone, black, with *Inoceramus labiatus* Schlotheim		4
Shale, black to gray, chalky; some limestone	6	
Limestone, black		7
Shale, black, chalky	1	3
Total Greenhorn	23	2
Graneros shale:		
Shale, black, fissile		3
Bentonite		3
Shale, black, fissile	Not measured	

CARLILE SHALE

The Carlile shale in northern New Mexico conforms closely to that division of the Benton to which Gilbert[13] applied the

[13] Gilbert, G. K., The underground water of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pp. 565-570, 1896.

name at Carlile Spring, 21 miles west of Pueblo, Colorado. There it was described as a gray argillaceous shale 175 to 200 feet thick. In the Pueblo quadrangle the upper one-fourth contains some sand and the topmost portion is described as a yellow friable sandstone. Large septarian concretions occur in the upper part of the shale. In northern New Mexico the formation varies in thickness, and at Mancos Creek, Colorado, is believed to be nearly 700 feet thick. Because the Fort Hays (Timpas) limestone, the base of which marks the top of the Carlile in southern Colorado and northeastern New Mexico, does not extend into central and western New Mexico, the top of the Carlile formation is not sharply definable there. At Mancos Creek, Colorado, about 200 feet of shale with fossils of Benton age is overlain by shale containing fossils of Niobrara age; it is difficult to identify the horizon at which the change in fauna occurs. It was probably this circumstance that led Cross[14] to include beds of both Benton and Niobrara ages in the Mancos shale.

In the sections that accompany this report (Figs. 3-6), the base of the Fort Hays limestone where present is the top of the Carlile; where the Fort Hays is absent the contact between the Niobrara and the Carlile is not indicated.

Near the top of the Carlile shale in northern New Mexico is a very calcareous sandstone to which the name Juana Lopez sandstone member of the Carlile shale is here applied. The name is taken from the Mesita Juana Lopez Grant west of Cerrillos, Santa Fe County, New Mexico, where the type section was measured. (See measured section 6, pages 19-20.) The Juana Lopez sandstone, which is widespread throughout northern New Mexico and western Colorado, contains an abundant Frontier fauna. As indicated on Fig. 4, it is probably older than the Codell sandstone of the Arkansas Valley region. Evidence given below suggests that for mapping purposes in northern New Mexico the top of the Juana Lopez sandstone could well be used as the top of the Carlile.

Where the Fort Hays limestone is present, as at Pagosa Springs, Colorado, there is only 100 feet of shale between the Juana Lopez calcareous sandstone and the Fort Hays limestone. In most localities the faunal change that occurs in this shale zone is easily recognized in the field; the. Frontier fauna is so abundant and diagnostic that the change to the types of Niobrara age is seldom difficult to recognize. Lithologically there is little evidence in northern New Mexico for separating the Carlile and the Niobrara, except that the shales of the Niobrara are usually very calcareous and less sandy than the Carlile shales. These criteria become less definite as the formations are followed southward into central New Mexico.

In the Chama Valley the top of the Carlile is not difficult to determine from well samples, as the lower Niobrara contains

[14]Cross, Whitman, U. S. Geol. Survey Geol. Atlas, La Plata folio (no. 60), p. 5, 1901.

some limestone and the change to the decidedly less calcareous shale of the Carlile is easily identified. At Chama there is only 70 feet of shale between the Juana Lopez calcareous sandstone and the base of the Niobrara.

Needham[15] suggests that at Carthage, New Mexico, the top of the sandy zone containing Frontier fossils should be used as the top of the Carlile, and that all the shale between the sand-stones of the upper Carlile and the Mesaverde formation should be referred to the Niobrara formation.

Sears and others[16] suggest, on the basis of faunal evidence, that near Gallup 135 feet of shale between the uppermost sand-stones of the Carlile and the base of the Mesaverde may be of Niobrara age. Thus in that area also there is good basis for accepting the top of the fossiliferous Juana Lopez sandstone, where recognized, as the top of the Carlile where the base of the Niobrara is not marked by the Fort Hays limestone.

In the northwestern corner of the State, in the vicinity of Ship Rock, the Tocito sandstone lentil appears to belong in the Carlile rather than in the Niobrara. The conglomerate in the top of the Tocito sandstone suggests that its top should be used as the plane of separation, as this would conform with the hiatus that Johnson[17] suggests may be present at the base of the Niobrara in southeastern Colorado.

The fauna of the Carlile shale is abundant and varied; it includes *Prionocyclus wyomingensis* Meek, *Inoceramus dimidus* White, *I. labiatus* Schlotheim, *I. fragilis* Hall and Meek, *Scaphites warreni* Meek and Hayden, and *Prionotropis hyatti* Mantell. Lee[18] gives very complete faunal lists from the sections he measured in central and northern New Mexico.

NIOBRARA FORMATION

The Niobrara, the uppermost formation of the Colorado group, was named by Meek and Hayden[19] from exposures near the mouth of Niobrara River, Knox County, Nebraska. There its upper part is lead-gray calcareous marl and its lower part is light yellow to white limestone. Its total thickness at the type locality is 200 feet.

In northern New Mexico, the Niobrara formation as above described is present only east of the Sangre de Cristo Mountains, east and north of Las Vegas. In central, northern and north-western New Mexico the Niobrara is represented by calcareous shales that are difficult to separate in the field from the under-lying Carlile shale and from the overlying shales of the Montana

[15] Needham, C. E., personal communication.

[16] Sears, Julian D., Hunt, C. B., and Hendricks, T. A., Transgressive and regressive Cretaceous deposits in southern San Juan basin, New Mexico: U. S. Geol. Survey Prof. Paper 193-F, p. 109, 1941.

[17] Johnson, J. Harlan, Unconformity in Colorado Group in eastern Colorado: Bull. Amer. Assoc. Petrol. Geol., vol. 14, no. 6, pp. 789-794, 1930.

[18] Lee, Willis T., Geology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 175-177, 214, 1917.

[19] Meek, F. B., and Hayden, F. V., Phila. Acad. Sci. Proc., vol. 13. pp. 419, 422, 1862.

group. In the Chama Valley, parts of the Niobrara are distinctly sandy and in places resemble the calcareous sandstones of the upper Carlile except that they do not contain the abundant Frontier fauna. In southern Colorado the Fort Hays limestone is recognizable as far west as Pagosa Springs, but farther west the limestones thin out and grade into shales. At Mancos Creek in southwestern Colorado, the shales equivalent to the Apishapa and possibly to the Fort Hays limestone are recognizable and contain a representative Niobrara fauna; but it is difficult to determine either the top or bottom of the formation. In north-western New Mexico and at Mancos Creek, Colorado, the Niobrara shale contains several layers of concretionary limestone, some of which are rather persistent but only sparingly fossiliferous. The study of well samples will furnish additional information on the thickness of the Niobrara in northern and northwestern New Mexico and later it may be possible accurately to determine its thickness. In well cuttings it is not difficult to separate the shales of the lower Pierre, which are generally only slightly calcareous, from those of the Niobrara, which are as a rule very calcareous and chalky.

MEASURED SECTIONS OF THE COLORADO GROUP

In those of the following sections that are quoted from other sources, the authors generally describe the weathered appearance of the materials. The shales are described as drab, olive drab, or gray, and the limestones generally as white. In the writer's sections, the color given is that of the fresh, unweathered rock. Limestones of the Greenhorn and the Niobrara are usually chalky white when weathered but when observed in well samples or on unweathered outcrops they are usually dark blue to black, sometimes pearly gray. The shales when fresh are usually dark gray to black. The Greenhorn is generally not reported on drillers' well logs, because in well cuttings its color is only slightly different from that of the shales with which it is associated.

The numbers of the measured sections correspond to the numbered localities on the map, Fig. 2, and are given on the stratigraphic sections, Figs. 3-6.

1. Arkansas Valley section.
Section in Arkansas River Valley, eastern Colorado.
Constructed from measured sections and other data given by Dane, Pierce and Reesido[20]

	Ft.	in.
Pierre shale		
Niobrara formation:		
Smoky Hill marl (Apishapa shale) member (estimated from well logs):		
Shale, gray to black, chalky; weathers gray to buff and in places distinctly yellow; contains a few thin limestone and bentonite beds	700	
Fort Hays limestone member (secs. 16 and 21, T. 21 S., R. 49 W., Bent County, Colorado):		
Limestone and shale, concealed	17	½
Shale, light tan, chalky		7
Limestone, white	3	2
Limestone and shale, interbedded, partly concealed	4	6
Limestone, white, with *Inoceramus deformis* Meek, and fucoids	2	3
Limestone, white, chalky, and gray shale		4
Limestone, white, chalky, irregularly bedded	1	8
Chalk, white to gray, shaly		5
Limestone, white		10
Shale, gray to tan, with *Inoceramus deformis* Meek?		5
Limestone, white, chalky	1	4
Chalk, white		2
Limestone, white; weathers to small tabular pieces	2	6
Chalk, shaly		1
Limestone, white		10
Shale, tan to gray, with *Inoceramus* sp.		6
Limestone, white; lower two feet massive	3	6
Chalk, tan to gray, shaly		1½
Limestone, white	1	2
Chalk, tan		1
Limestone, white		8
Shale, tan, chalky		5
Shale, blue		3
Limestone, white	1	10
Chalk, tan, and limestone		1 1/2
Limestone, white	1	5
Shale, greenish gray		6
Limestone, white		8
Shale and thin limestone		9
Limestone, white; weathers to tabular pieces	1	1
Shale, gray, chalky		2
Limestone, white; abundant *Inoceramus deformis* Meek	1	3
Limestone and chalky shale, thin, alternating	3	
Limestone, white, weathers to tabular pieces	1	
Limestone and chalky shale, alternating, thin-bedded	1	10 1/2
Limestone, white	1	
Limestone, white, and tan chalk		8
Limestone, white	1	6
Chalk, tan, shaly		2
Limestone, white	1	3
Shale, tan, chalky		3
Limestone, white, with pyrite nodules	3	
Total Niobrara	764	4

[20] Dane, C. H., *Pierce,* W. G., and Reeside, J. B.. Jr.. The stratigraphy of the Upper Cretaceous rocks north of the Arkansas River in eastern Colorado: U. S. Geol. Survey Prof. Paper 186-K, 1937.

	Ft.	in.
Benton formation:		
Carlile shale:		
Codell sandstone member:		
Sandstone and shale, gray, cemented with lime; contains lenses of hard limestone		0-6
Sandstone, gray to brown, hard; contains fragments of fossils and fucoids. From 0 to	1	6
Sandstone, gray, earthy, calcareous, poorly bedded; contains fossil fragments and fucoids		5-20
Shale member (type locality of Carlile shale):[21]		
Shale, argillaceous, silty to sandy in upper one-fourth; contains many large septarian concretions from 20 to 50 feet below top		175-200
Total Carlile		180-222
Greenhorn limestone (1½ miles north of McClave, Bent County, Colorado):		
Shale, marly		5+
Limestone		4
Shale, tan, calcareous		5
Limestone, gray		2
Shale, calcareous	1	1
Limestone, gray, with *Inoceramus labiatus* Schlotheim		3
Marl, tan, chalky, with shell fragments		3
Limestone, gray		3
Marl, tan	1	3
Limestone, light blue gray; contains *Inoceramus labiatus* Schlotheim		5
Marl and shale		2
Limestone, marly		6
Shale and marl	1	5
Limestone, light gray		6
Shale, calcareous	3	6
Limestone, light gray		4
Marl	2	6
Limestone, blue gray, with *Inoceramus labiatus* Schlotheim		10
Marl, tan		10
Limestone		3
Marl, tan		8
Limestone, blue gray, hard		3
Marl, with small amount of limestone		2
Marl and shale, buff		8
Limestone, gray		5
Marl	1	5
Limestone, granular, soft		3
Marl, tan, shaly, with *Inoceramus labiatus* Schlotheim		7
Limestone, white to light gray		9
Marl, with small amount of limestone	2	10
Limestone, gray, with *Inoceramus labiatus* Schlotheim		5
Marl, tan	1	
Limestone, white		6
Marl, tan	1	3
Limestone, blue gray		$1^1/_2$
Marl		10

[21] Gilbert, G. K., op. cit., pp. 565-570.

'Greenhorn limeston—continued:	Ft.	in.
Limestone		1½
Marl, tan	1	
Limestone, light gray		6
Marl		2
Limestone, blue gray, hard		1½
Marl, tan and light gray	1	8
Limestone, blue gray		4
Marl, tan and dirty brown	1±	
Limestone, light gray, vertically jointed		4
Marl, tan		10
Limestone, white		3
Marl, tan		11
Bentonite		7
Shale, chalky		7
Limestone, white		3
Shale, chalky tan		6
Limestone, white		10
Shale, chalky tan		6
Limestone, white		10
Chalk, marly	2	
Total Greenhorn measured	56	8½

Graneros shale:

Shale, argillaceous, fissile, with calcareous concretionary zones 30 to 40 feet above base and 50 feet below top. Lower concretionary zone is sandy to the south. Shale contains many beds of bentonite less than one inch thick and a few thicker beds. Fossils include *Ostrea congesta* Conrad, *Inoceramus* aff. *I. bellvuensis* Reeside, *Inoceramus n.* sp., related to *fragilis* Hall and Meek, *Turritella whitei* Stanton, *Pteria* sp., *Pecten* sp., *Leda* sp., and others ---------- 200

Shale, slightly sandy; transition zone ---------- 5

Total Graneros shale ---------- 205

Dakota sandstone

2. La Veta section.
Measured near Cucharas Camps, southwest of La Veta, Huerfano County, Colorado

Niobrara formation:	Feet
Apishapa shale member:	
Shale, fissile, thin-bedded, very calcareous and chalky, with few thin limestones	400+
Fort Hays limestone member:	
Limestone and interbedded calcareous shale	40
Carlile shale:	
Shale, gray to black, with a thin calcareous sand-stone at top grading down into sandy shale; large septarian concretions in upper part	192
Greenhorn limestone:	
Limestone and chalky shale; limestone contains *Inoceramus labiatus* Schlotheim, *Inoceramus* sp., and few small *Baculites asper* Morton	50
Graneros shale:	
Shale, black, thin-bedded, fissile, sandy at base; sandy zone with brown concretionary beds about 35 feet above base	203

Dakota (?) sandstone

3. Pagosa Springs section.
Composite section measured in the vicinity of Pagosa Springs, Colorado. Niobrara section measured near the head of the Piedra River

	Feet
Niobrara formation:	
Shale, very calcareous and chalky, fissile, with many *Globigerina;* weathers grayish to white; contains several beds of very fine thin-bedded calcareous gray sand and thin seams of bentonite; *Ostrea congesta* Conrad is common; few *Inoceramus* sp. ----------	500
Limestones, thin, and interbedded calcareous shale ----------	35
Carlile shale:	
Shale, black, argillaceous, sandy in upper part; 90 feet below top is a thin zone (Juana Lopez member) containing layers of calcareous sandstone one-half inch to one inch thick. Sandstone weathers dark tan to brown and contains an abundant Frontier fauna. Sand grains are very fine, mostly rounded and in some layers subordinate to calcareous material. Layers containing large septarian concretions are found above and below the sandy zone. Concretions are large and rounded and many are fossiliferous, occurring in places in continuous layers ----------	250
Greenhorn limestone:	
Alternating layers of chalky shale and thin limestone. Limestones toward base are thicker and more numerous; contain *Inoceramus labiatus* Schlotheim ----------	30
Graneros shale:	
Shale, black, fissile; contains brown concretionary and ironstone beds near base ----------	113
Dakota (?) sandstone	

4. Mancos Creek section.
Composite section measured in the vicinity of the type locality of the Mancos shale near Mancos, Montezuma County, Colorado

	Feet
Niobrara formation:	
Shale, gray to black, calcareous and in places chalky; weathers light and on old weathered slopes is slightly yellow; contains thin layers of sandstone with *Ostrea congesta* Conrad; thickness indeterminate ----------	500?
Carlile shale:	
Shale, black, with few thin concretionary limestone beds - ------	200
Sandstone, very calcareous, or sandy limestone (Juana Lopez member); thin-bedded; weathers brown and breaks out on slopes in large flags; contains abundant typical Frontier fauna; *Prionocycius wyomingensis* Meek is common ----------	5
Shale, sandy, with thin layers of very fine sandstone near top; large limestone concretions, many of which are fossiliferous, in upper 50 feet ----------	150
Greenhorn limestone:	
Limestone and interbedded chalky and calcareous shale; contains *Inoceramus labiatus* Schlotheim, *Lunatia* sp.; limestone beds are more prominent in lower part ----------	32

	Feet
Graneros shale:	
Shale, black, fissile; concretionary limestone near base ---------	83
Dakota (?) sandstone:	
Sandstone, earthy; contains fucoids and *Halyinenites;* grades downward into sandy shale; forms prominent low bench; sand grains are angular and medium to coarse; thickness includes some of transition zone at base ----------	50
Shale, black, fissile; contains some sandy shale and thin sandstones with prominent coal beds near base ----------	100
Sandstone, massively bedded, quartzitic in places, conglomeratic: in lower ten feet; grains fine and angular. Appears to rest on an erosion surface; thickness variable ------	60
Morrison formation:	
Shale, variegated, red and green	

5. Las Vegas section.
Section of Greenhorn and Graneros shale measured northeast of the Dakota hogback at Romeroville, south of Las Vegas, San Miguel County, New Mexico. Upper part of section. taken from Darton[22]

	Feet
Niobrara formation:	
Shale, chalky, dark gray to black when fresh but weathers white to tan ----------	500
Limestone with interbedded shale; limestones are one to two feet thick and have been quarried near Springer ----------	50
Carlile shale:	
Shale, black, fissile, well bedded; contains sandy limestone with characteristic Frontier fossils near top; upper part has many concretionary beds that form low benches ----------	218
Greenhorn limestone:	
Limestone with interbedded chalky shales containing *Inoceramus labiatus* Schlotheim and a high-beaked unnamed *Inoceramus* ----------	30
Graneros shale:	
Shale, black, fissile; thin bentonite bed at top just below Greenhorn; brown concretionary beds near base ----------	137
Dakota (?) sandstone:	
Exposures near Romeroville have zone of black carbonaceous shale and thin coal seams near the top of the formation.	

6. Cerrillos section.Measured in sec. 32, T. 15 N., R. 7 E., on the Mesita Juana Lopez Grant, six miles northwest of Cerrillos, Santa Fe County, New Mexico

	Ft.	in.
Carlile shale:		
Shale, black, slightly calcareous, fissile; top not exposed	Not measured	
Sandstone, Juana Lopez member, very calcareous,		

[22] Darton, N. H., 'Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, 1928.

	Ft.	in.
thin-bedded; weathers brown; very fossiliferous, containing *Prionocyclus wyomingensis* Meek, *Inoceramus* labiatus Schlotheim; grades into shale at base. Type section of the Juana Lopez member	10	
Shale, black. fissile, silty to sandy at top; contains few thin bentonite beds at top	178	
Shale, black, fissile; contains large septarian concretions that weather brown, some of which contain fossils; thin yellow concretionary limestone at top	134	
Sandstone, hard, brown. very calcareous and fossiliferous; contains Ostrea sp., *inocceramus labiatus* Schlotheim; forms low ridge	2	
Total Carlile shale	324	
Greenhorn limestone:		
Shale, dark gray, very calcareous; contains few thin limestones	10	
Limestone, black; weathers light gray; contains *Inoceramus labiatus* Schlotheim; forms low ridge		6
Shale, black, calcareous		2
Limestone, black; weathers light gray; contains *Inoceramus labiatus* Schlotheim; forms low ridge		3
Shale, black, calcareous		4
Limestone, black; weathers light gray; contains *Inoceramus labiatus* Schlotheim; forms low ridge		5
Shale, dark gray, very calcareous; contains a few thin limestones	9	
Limestone, dark on fresh fracture; weathers light gray		4
Shale, dark gray, calcareous	8	
Limestone, dark on fresh fracture; weathers light gray		4
Shale, light gray, chalky	1	
Limestone; forms most prominent ridge		4
Shale, dark gray, calcareous; contains a few bentonite streaks one-half inch thick	5	
Limestone, dark blue; contains *Inoceramus labiatus* Schlotheim	6	
Shale, chalky	1	6
Bentonite		1
Shale, black	1	
Bentonite		3
Shale, black, calcareous	3	
Shale, very calcareous, or shaly limestone	1	
Total Greenhorn	48	6
Graneros shale:		
Shale, black, fissile	5	
Bentonite		4
Shale with some sandy beds, mostly covered	111	
Sandstone, Tres Hermanos, shaly in lower part	5	
Sandstone, fine, even-grained, angular	15	
Sandstone, silty to shaly, grading down into shale	15	
Shale with large brown limestone concretions	5	
Shale, black, fissile	66	
Limestone with very dark brown concretions; Lee's "gastropod zone"	4	
Shale, black, carbonaceous and sandy at base	20	
Total Graneros	246	4

Dakota (?) sandstone:	Feet
Sandstone, hard, poorly sorted, grains sub-angular to rounded; conglomeratic in lower part with chert pebbles up to one inch in diameter	3
Sandstone, white, massive, fine-grained, angular	20
Shale, carbonaceous and sandy, coaly in places	5
Sandstone, cross-bedded, poorly sorted, conglomeratic in places	15
Total Dakota (?)	43
Unconformity	
Morrison formation:	
Sandstone, white, very fine	50±

7. Chama section.
Determined from examination of samples from wells on or near the south end of the Chromo anticline on the Colorado-New Mexico line about 12 miles northwest of Chama, Rio Arriba County, New Mexico

Niobrara formation:	Feet
Shale, dark gray to black, chalky; contains numerous *Globigerina* and other micro-fossils; pyrite and fragments of *Inoceramus* and other shells are common. Part of the shale is described by some workers as the birdseye shale on account of the speckled appearance caused by chalk inclusions	500
Limestone, black, shaly; occurs in broken layers	15
Carlile shale:	
Shale, black, slightly calcareous	43
Shale, black, non-calcareous	42
Shale and thin streaks of very fine sand	5
Shale, black; some Foraminifera	25
Sandstone, Juana Lopez member, very calcareous, very fine, with rounded and varicolored grains	24
Shale with some thin sandstone; sandstone very calcareous, very fine with rounded and varicolored grains	30
Shale, slightly sandy	15
Shale, black, silty, non-calcareous	59
Total Carlile	243
Greenhorn limestone:	
Shale, very calcareous; *Globigerina*	15
Limestone and shale, black	28
Graneros shale:	
Shale, black, fissile; contains some sand grains near base	98
Dakota (?) sandstone	

8. Carthage section.
Measured near Tokay, T. 14 N., R. 2 E., Socorro County, New Mexico, by C. E. Needham; supplemented by details added by the author

Mesaverde formation	
Niobrara formation:	Feet
Shale, gray, calcareous and sandy	200±

Carlisle shale:	Feet
Sandstone, massive, coarse, angular	10
Shale, black, sandy	5
Sandstone, massive, coarse, angular	20
Shale	3
Sandstone	4
Shale, black, sandy	5
Sandstone, buff, massive, coarse, angular, fossiliferous	18
Shale, black, sandy, with numerous concretions	55
Sandstone, lighter colored than above	5
Shale, black, slightly sandy	15
Sandstone	5
Shale, black	5
Sandstone	6
Shale	4
Sandstone	5
Shale, black, sandy; beds of concretionary limestone and coal	15
Shale, black, sandy, fossiliferous	20
Sandstone, coarse, angular	20
Shale, silty to sandy; contains numerous limestone concretions	110
Total Carlile	330

Greenhorn limestone:	
Shale, black, calcareous; thin calcareous sandstones at top; four-inch to eight-inch limestones near base	30

Graneros shale:	
Shale, black, fissile, very sandy near base	157

Dakota (?) sandstone

9. Red Wash section.Composite section from surface measurements and well information. Measured on Red Wash, 15 miles west of Ship Rock, San Juan County, New Mexico

Niobrara formation

Carlile shale:	Feet
Shale, black, slightly sandy	0-50
Sandstone, coarse, angular, poorly sorted; in places conglomeratic at top; thickness variable; Tocito sandstone	50
Shale, silty to sandy; contains one or more thin layers of limestone and numerous thin concretionary zones	50
Shale, black; silty in upper part; contains limestone concretions	167
Sandstone, very calcareous, or sandy limestone; occurs in thin layers interbedded with black shale and contains an abundant Frontier fauna; Juana Lopez member	10
Sandstone and silty shale; transition zone	30
Shale, black, fissile; contains limestone concretions, some of which are fossiliferous	365
Total Carlile	672-722

Greenhorn limestone:	
Limestone and interbedded black calcareous shale, containing *Inoceramus labiatus* Schlotheim	15

Graneros shale: Feet
Shale, black, fissile, slightly sandy at base; contains a six-inch bentonite bed at top ---------- 59
Dakota (?) sandstone

10. Beautiful Mountain section.
Measured in T. 9 N., R. 4 W., northeast of Beautiful Mountain, San Juan County, New Mexico

As shown on Fig. 6, this section is very similar to the Red Wash section; consequently it is not included here.

11. Gallup section.
Measured by Sears[23] in sec. 1, T. 15 N., R. 18 W., near the north end of the Hogback, McKinley County, New Mexico

Mesaverde formation

Mancos shale: ---------- Feet
Shale, olive gray to drab, mostly sandy ---------- 176
Sandstone, very shaly, and sandy shale ---------- 7
Shale, olive gray to drab ---------- 67
Sandstone, gray, soft, poorly bedded ---------- 4
Shale, olive gray to drab ---------- 16
Sandstone, gray, soft, poorly bedded ---------- 3
Shale, olive gray to drab ---------- 157
Sandstone, very shaly; concretionary band at top ---------- 4
Shale, drab ---------- 40
Shale, bluish gray to drab ---------- 101
Sandstone, calcareous, and marl, containing many shells of *Gryphaea newberryi* 10
Shale, sandy, gray and buff ---------- 6
Sandstone, buff, massive ---------- 25
Shale, sandy in upper part, bluish gray and fissile in lower part ---------- 109
Total Mancos shale ---------- ---------- 725
Dakota (?) sandstone

Sears, Hunt and Hendricks[24] report that all of the Mancos in the Gallup section below the uppermost shale unit is of Carlile age, and that the upper 135 feet of this unit, in which no fossils were found, may be of Niobrara age. The writer studied the section and could not find either the Greenhorn limestone or the Juana Lopez member of the Carlile. It may be assumed that these members were not deposited in this shoreward facies of the Colorado group.

12. Rio Puerco section.
Measured in T. 13 N., R. 3 W., Sandoval County, New Mexico

Mesaverde formation: Feet
Gallup sandstone member:
Sandstone, massive, buff ---------- 105

[23] Sears, Julian D., The geology and fuel resources of the southern part of the San Juan basin, New Mexico: U. S. Geol. Survey Bull. 860. p. 12. 1934.
[24] Sears, Julian D., Hunt, C. B., and Hendricks. T. -A., Transgressive and regressive Cretaceous deposits in southern San Juan basin. New Mexico: U. S. Geol. Survey Prof. Paper 193-F. p. 109, 1941.

Niobrara and Mesaverde: Feet
Shale, dark gray to black, sandy at top; upper 150 feet contains fossils of Montana age ---------- 365

Carlile shale:
Sandstone, thin-bedded, very calcareous; Juana Lopez member; Weathers brown; contains an abundant Frontier fauna similar to that of the Juana Lopez in the Cerrillos section---------- 20
Shale, black, with numerous calcareous concretions in upper half ---------- 310

Greenhorn limestone:
Limestone and shale, interbedded; limestones are thin, dark, bluish gray to black; shales are calcareous to chalky ---------- 30

Graneros shale:
Shale, black, fissile, with thin bentonite bed at top ---------- 26
Sandstone, massive to poorly bedded, coarse, angular; Tres Hermanos; upper part contains many fossils including *Gryphaea newberryi* Stanton ---------- 68
Shale, black, sandy, with thin sandstones ---------- 43
Sandstone, coarse, angular, massive to poorly bedded ---------- 93
Shale, black, fissile, and thin sandstones; brown concretionary layer near base ---------- 118
Total Graneros ---------- 348

Datoka (?) sandstone:
Sandstone, conglomeratic; thickness variable ---------- 20

Morrison formation

13. Lamy section.
Measured in sec. 33, T. 15 N., R. 10 E.,
one mile west of Lamy, Santa Fe County, New Mexico

Carlile shale: Feet
Shale, black, fissile, sandy in part; not fully exposed ---------- 50

Greenhorn limestone:
Limestone and shale, alternating; limestone is black; shale is very calcareous and chalky and contains *Inoceramus labiatus* Schlotheim, a high-beaked unnamed *Inoceramus*, and *Baculites asper* Morton 30

Graneros shale:
Shale, black, fissile; contains a three-inch bentonite bed at top ------- 38
Sandstone, coarse, angular, poorly bedded; Tres Hermanos ----------27
Shale, black, sandy ----------65
Sandstone, coarse, concretionary in places; very fossiliferous, with *Scaphites vermiformis* Meek and Hayden ---------- 10
Shale, black, sandy ----------65
Shale, black, sandy, carbonaceous ---------- 8
Sandstone, coarse, angular ---------- 3
Total Graneros ---------- 216

Unconformity: Dakota (?) absent

Morrison formation:
Sandstone, white, very fine-grained; contains chert pebbles ----------50+

HISTORICAL GEOLOGY

A study of the formations described and correlated prompts the following remarks regarding the Cretaceous history of northern New Mexico and parts of southern Colorado. It is evident that whatever orogeny developed in this region before or during deposition of the Mesaverde coal measures did not begin until after Carlile time. The evidence that the Greenhorn and the Carlile formations were deposited in relatively quiet basins is conclusive. Johnson[25] has suggested there was an hiatus between the Carlile and Niobrara periods of sedimentation, and that following this hiatus—however brief it may have been—there was a change in the extent and nature of the sediments deposited. Thus the Greenhorn and Carlile formations were deposited uniformly over a greater area than the Niobrara formation.

Following Niobrara deposition, certain areas to the south and west must have developed more positive characteristics, resulting in Mesaverde sediments that differed from those of the Niobrara. This change in sediments, as suggested by Sears, Hunt and Hendricks,[26] was not due to uplift of the areas of deposition. There is definite evidence that the transgressive and regressive deposition of the Mesaverde was due, at least in part, to changes in the sedimentary processes, whether or not the areas of deposition suffered orogenic movement.

It appears to the writer that the deposition of the lower part of the Graneros was affected by processes similar to those of the Mesaverde sedimentation, and that the sources of the materials which were deposited were in the same general areas. Thus the deposition of the Mesaverde was a rejuvenation of a process that was initiated in early Graneros time or possibly during late Dakota time.

In the period between Dakota or medial Graneros time and the hiatus at the end of Carlile time, conditions affecting deposition must have been relatively stable, otherwise we could not find the Greenhorn limestone deposited so uniformly over such a wide area. Considering the areal extent of the Greenhorn, it is most unusual to find such a uniformity of faunal types throughout the formation. This stability probably endured through most of Carlile time, as we find the same uniformity of faunal characteristics and types in the Carlile as in the Greenhorn.

Facies which developed in post-Colorado time suggest that certain areas in which we now find the greatest thicknesses of formations of Montana age must have developed negative characteristics while areas to the south and west were being shoaled. This theory would account for the great thickness of rocks of

[25] Johnson, J. Harlan, Unconformity in Colorado Group in eastern Colorado: Bull. Amer. Assoc. Petrol. Geol.. vol. 14, no. 6, pp. 789-794, 1930. 26 Sears, Julian D., Hunt, C. B., and Hendricks. T. A., op. cit.

Montana age deposited in the Mancos Creek and Vermejo Park regions of Colorado. Thus while Mesaverde sediments were being deposited offshore in the Gallup area after the end of Niobrara time, basinward sediments were being deposited at Mancos Creek.

The evidence now at hand suggests that southwest of a line drawn through Crown Point, McKinley County, and Carthage, Socorro County, New Mexico, there was a positive area during early Graneros time and that this area again became positive during Montana time. This conclusion does not conflict with the established premise of transgressive and regressive deposition, but rather implements that theory and outlines the area in which the process worked.

It is suggested that whatever movements caused the Mesaverde formation to cut across time boundaries did not originate until after Carlile time and probably not until the Colorado epoch had closed.

CONCLUSIONS

From the evidence presented in the foregoing pages the writer has arrived at the following conclusions.

1. The Greenhorn limestone and the upper Carlile, the Juana Lopez sandstone, can be recognized over wide areas in northern New Mexico. Recognition of these formations enables the field worker to map the top of the Graneros shale and to make a very close approximation of the top of the Carlile.

2. It is impossible in the field to map the Niobrara with any certainty or to recognize its top, and for that reason it is not advisable at this time to discontinue the use of the name Mancos to describe all the formations between the Dakota (?) sandstone and the Mesaverde formation. This usage does not preclude the recognition of formations within the Mancos.

INDEX

Figures in *italic* indicate main references.

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PUBLICATIONS OF THE MINERAL RESOURCES SURVEY

No.	*Title and Author*	*Date*	*Price*
1	The Mineral Resources of New Mexico; Fayette A. Jones	1915	Out of print
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3	Oil and Gas Possibilities of the Puertecito District, Socorro and Valencia Counties, New Mexico; E. H. Wells	1919	Out of print

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BULLETINS

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9	The Oil and Gas Resources of New Mexico; Dean E. Winchester (First edition; superseded by Bulletin 18)	1933	Out of print
10	The Geology and Ore Deposits of Sierra County, New Mexico; G. Townsend Harley	1934	.60
11	The Geology of the Organ Mountains; with an Account of the Geology and Mineral Resources of Dona Ana County, New Mexico; Kingsley Charles Dunham	1935	1.00
12	The Non-Metallic Mineral Resources of New Mexico and their Economic Features (Exclusive of Fuels) ; S. B. Talmage and T. P. Wootton	1936	.50
13	Geology and Economic Features of the Pegmatites of Taos and Rio Arriba Counties, New Mexico; Evan Just	1937	.50
14	Some New Mexico Fusulinidae; C. E. Needham	1937	.50
15	The Geology and Ore Deposits of Northeastern New Mexico (Exclusive of Colfax County); G. Townsend Harley	1940	.60
16	Mining, Oil, and Mineral Laws of New Mexico; C. H. Fowler and S. B. Talmage (Supersedes Bulletin 6)	1941	.75
17	Pennsylvanian System in New Mexico; M. L. Thompson	1942	.50
18	The Oil and Gas Resources of New Mexico; compiled by Robert L. Bates (Second edition; supersedes Bulletin 9)	1942	2.50
19	Manganiferous Iron-ore Deposits near Silver City, New Mexico; Lawson P. Entwistle	1944	.50
20	Stratigraphy of the Colorado Group, Upper Cretaceous, in Northern New Mexico; Charles H. Rankin	1944	.25

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3	First, Second, and Third Annual Reports of the Director, and Preliminary Report for the Fourth Year; E. H. Wells	1931	Out of print
4	The Hobbs Field and Other Oil and Gas Areas, Lea County, New Mexico; Dean E. Winchester	1931	Out of print
5	Gold Mining and Gold Deposits in New Mexico; E. H. Wells and T. P. Wootton, 1932; revised by T. P. Wootton	1940	No charge
6	Carbon Dioxide in New Mexico; E. H. Wells and A. Andreas (Superseded by Circular 9)	1938	Out of print
7	Outlook for Further Ore Discoveries in the Little Hatchet Mountains, New Mexico; S. G. Lasky	1940	Out of print
8	Selected Bibliography on Coal in New Mexico; Robert L. Bates	1943	No charge
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REPORTS OF THE U. S. GEOLOGICAL SURVEY, PREPARED IN COOPERATION WITH THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

U.S.G.S. Prof. Paper 870	Geology and Ore Deposits of the Bayard Area, Central Mining District, New Mexico; Samuel G. Lasky	1936	$0.80
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MAPS

Oil and Gas Map of New Mexico; Dean E. Winchester, 1931; revised by Robert L. Bates to July, 1942. (This map is included in Bulletin 18.)	1942	.75 (paper) 1.25 (cloth)
Topographic Map of New Mexico; N. H. Darton. Scale about 8 miles to 1 inch; contour interval 100 meters. U. S. Geological Survey	1925	.75
Geographic Map of New Mexico. Scale 12 miles to 1 inch. General Land Office, Washington, D. C.	1936	.35
A Reconnaissance and Elevation Map of Southeastern New Mexico; Walter B. Lang. Scale 4 miles to 1 inch. U. S. Geological Survey	1943	1.50
Topographic maps of approximately 75 quadrangles in New Mexico and adjacent parts of Arizona and Texas. Scales range from 1,000 feet to 1 inch, to 4 miles to 1 inch. U. S. Geological Survey		.10 each

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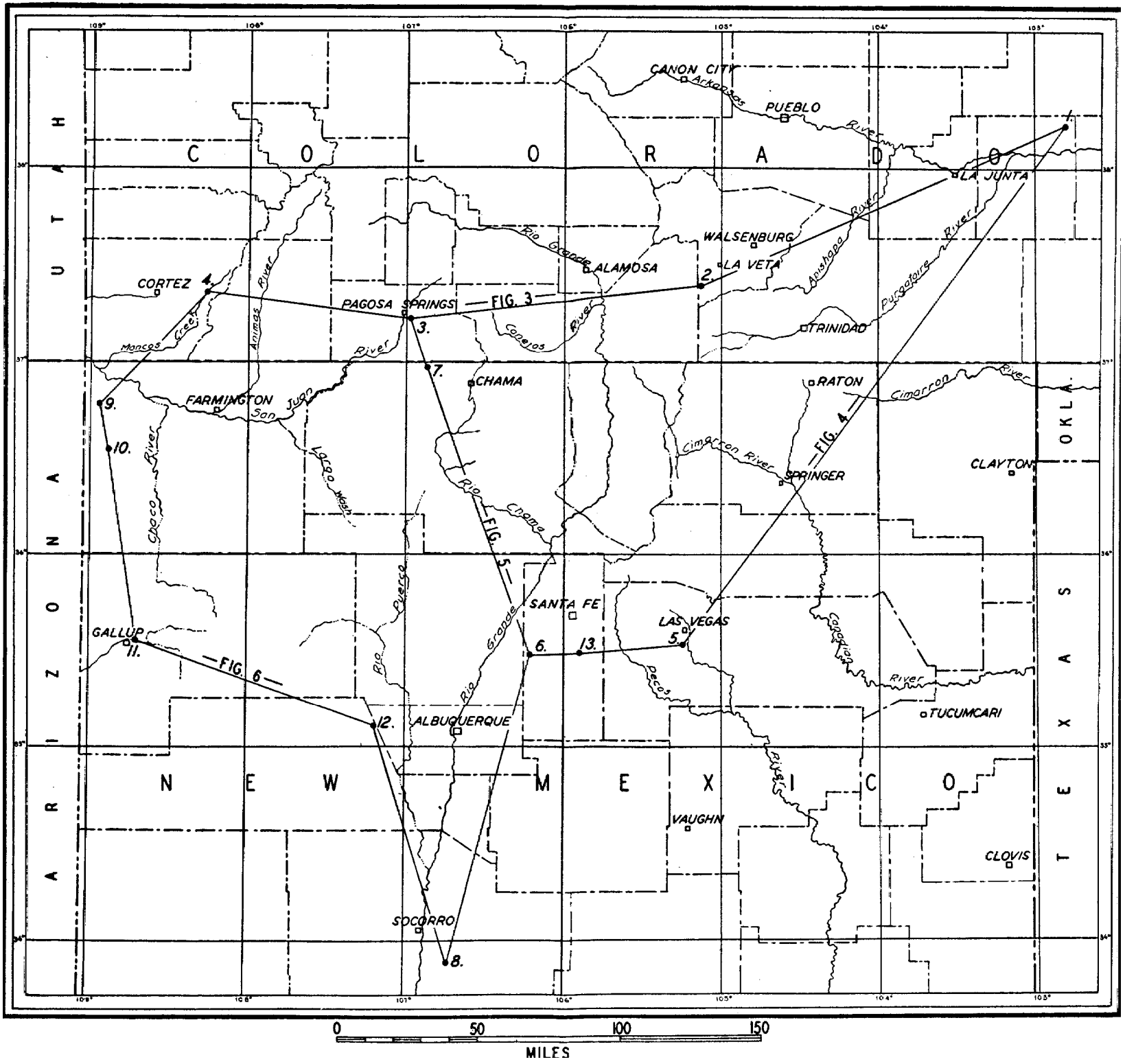

FIGURE 2.-Map showing locations of measured sections correlated in Figs. 3-6.

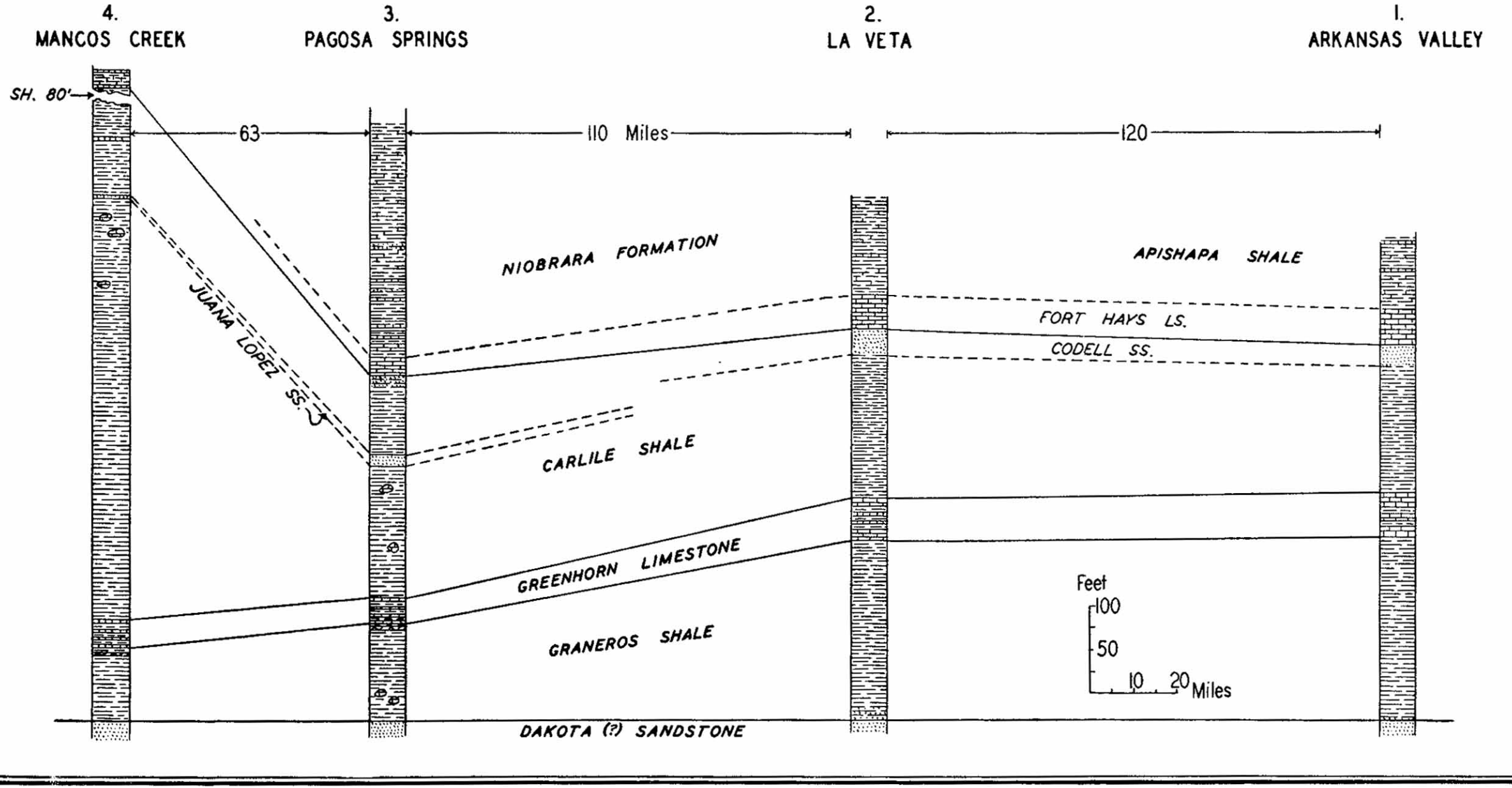

FIGURE 3.—Correlation of the Colorado group in southern Colorado. Locations of sections are shown on map, Fig. 2. Legend is given on Fig. 4.

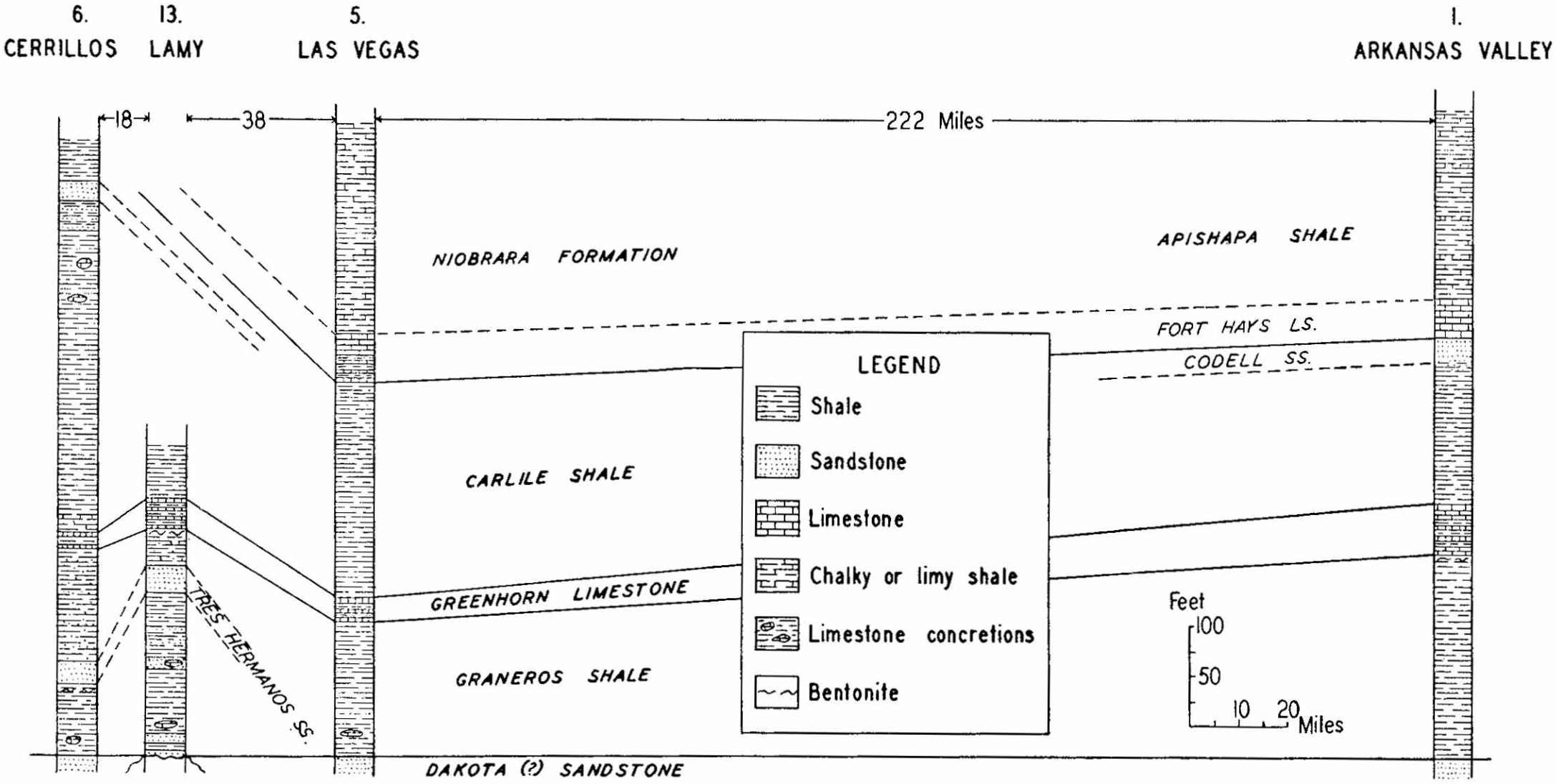

FIGURE 4.—Correlation of the Colorado group in northeastern New Mexico and southeastern Colorado. Locations of sections are shown on map, Fig. 2.

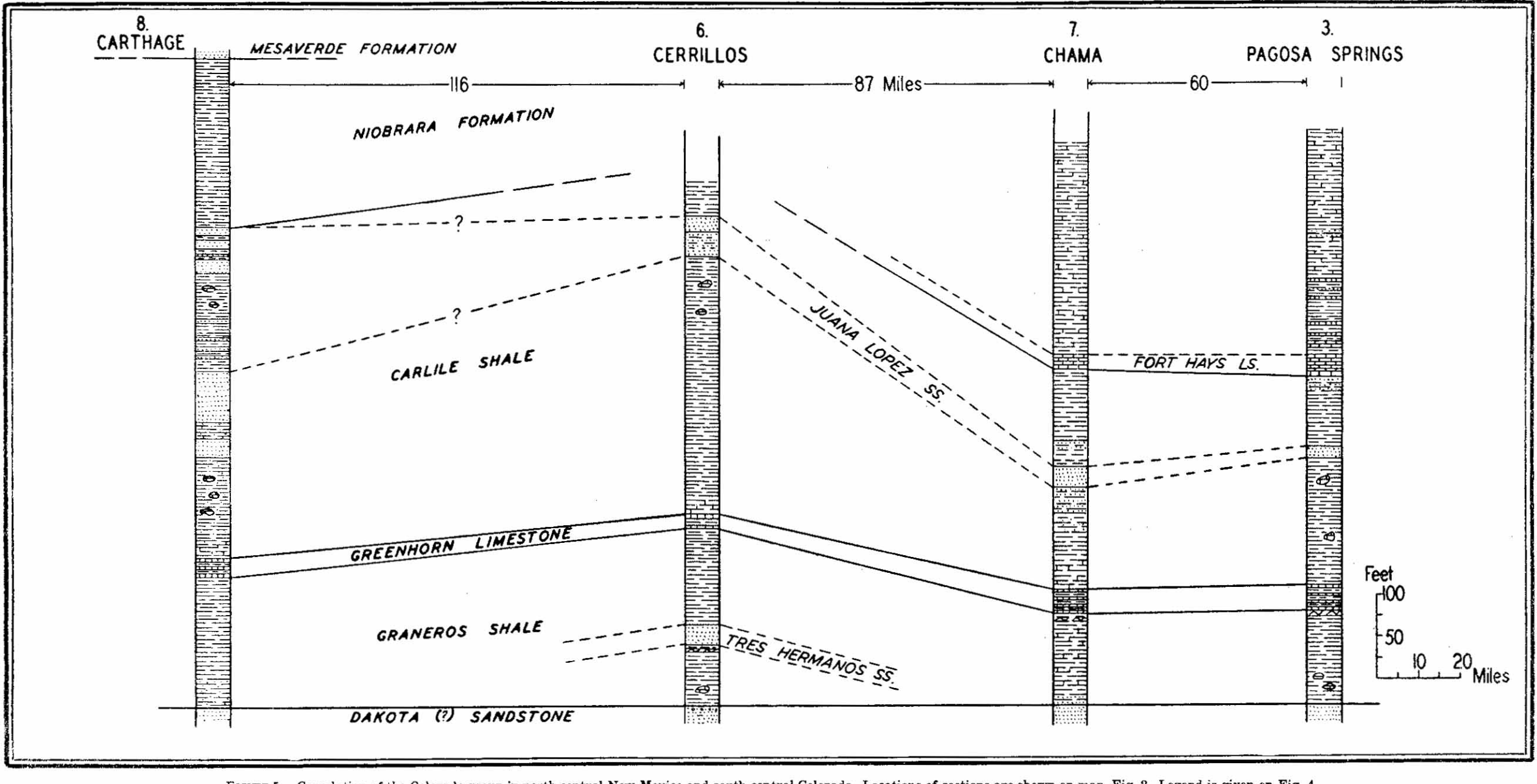

FIGURE 5.—Correlation of the Colorado group in north central New Mexico and south central Colorado. Locations of sections are shown on map, Fig. 2. Legend is given on Fig. 4.

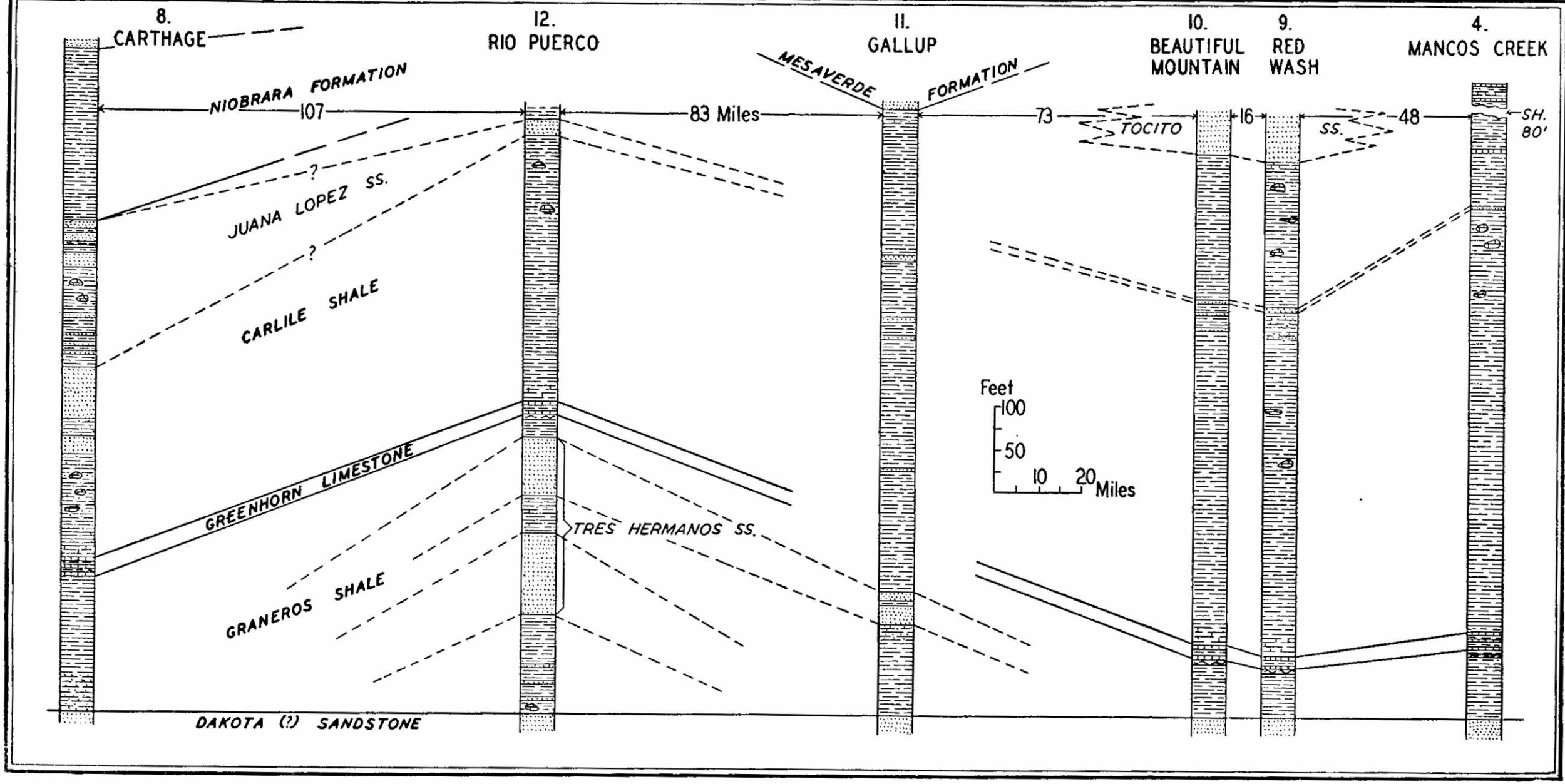

FIGURE 6.—Correlation of the Colorado group in northwestern New Mexico and southwestern Colorado. Locations of sections are shown on map, Fig. 2. Legend is given on Fig. 4.