Stratigraphic Terminology of the Dakota Sandstone and Mancos Shale, West-Central New Mexico

GEOLOGICAL SURVEY BULLETIN 1372-J

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By E. R. LANDIS, C. H. DANE, *and* W. A. COBBAN

CONTRIBUTIONS TO STRATIGRAPHY

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A study of the generally transgressive rock sequence at the base of the Cretaceous System — four new rock units are described

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STRATIGRAPHIC TERMINOLOGY OF THE DAKOTA SANDSTONE AND MANCOS SHALE, WEST-CENTRAL NEW MEXICO

By E. R. LANDIS, C. H. DANE, and W. A. COBBAN

ABSTRACT

The generally transgressive rock sequence that constitutes the lower part of the Cretaceous System in west-central New Mexico — the intertongued Dakota Sandstone and Mancos Shale — is here divided into named formal and informal rock units of regional significance. The formally named rock units, four of which are named in this report, are developed in fullest degree in the Laguna area. They are, in descending order, the Twowells Sandstone Tongue of the Dakota Sandstone, the Whitewater Arroyo Shale Tongue of the Mancos Shale, the Paguate Sandstone Tongue (new) of the Dakota Sandstone, the Clay Mesa Shale Tongue (new) of the Mancos Shale, the Cubero Sandstone Tongue (new) of the Dakota Sandstone, and the Oak Canyon Member (new) of the Dakota Sandstone, which can be informally divided into distinctive upper and lower parts. Eastward and southward from Laguna most of the sequence is mapped as the marine Mancos Shale. Westward and northwestward from Laguna most of the sequence is mapped in the fluviatile and paralic Dakota Sandstone.

INTRODUCTION AND ACKNOWLEDGMENTS

The intertonguing generally regressive rock sequences in the middle and upper parts of the Cretaceous System in northwestern New Mexico and adjacent areas have long been divided into named, regionally correlated rock units. This report presents part of the results of regional investigation of the intertonguing generally transgressive sequence in the lowermost part of the Cretaceous System in west-central New Mexico and adjacent areas.

As an outgrowth of earlier studies in the southern San Juan Basin, we have been studying, since July 1966, the Dakota Sandstone and lower part of the Mancos Shale in west-central New Mexico and nearby areas. Many stratigraphic sections were measured, and molluscan faunas were collected. Rock units were traced laterally in some areas of complex structural and stratigraphic geology. The present work was guided by, and still incorporates some, data of earlier studies dating back to 1954, some of the results of which have previously been reported (Dane and Bachman, 1957; Dane, 1959, 1960a, 1960b; Dane and others, 1971). Many earlier workers, such as Gilbert (1875), Howell (1875), Holmes (1877) — perhaps the earliest worker to apply the name "Dakota" to rocks in northwestern New Mexico — and Dutton (1885), recognized the great lateral continuity of the Cretaceous rock units but left many problems to be solved by later and more detailed investigations. Among the many regional studies and syntheses listed in the "Selected Bibliography," the contributions of Sears, Hunt, and Hendricks (1941), Pike (1947), Young (1960), and Owen (1963, 1966) were of particular value in the study of the sedimentary rocks deposited in west-central New Mexico during the first great transgression of the epeiric Cretaceous sea.

We have benefited from discussions, in the office and in the field, with many colleagues interested in the Cretaceous stratigraphy of the Western United States. We particularly thank C. H. Maxwell and D. G. Wyant for much aid and encouragement, and E. G. Kauffman, who provided inspiration and help in the beginning stages of the present study.

STRATIGRAPHY

The Dakota-Mancos rock sequence in west-central New Mexico is developed to its fullest degree and is well exposed in the area near the pueblo of Laguna (fig. 1). This area has been well studied in the past, and the rock units have been described and mapped by Hunt (1936), Moench (1963a, b), Moench and Puffett (1963a, b), Schlee and Moench (1963a, b), Moench (1964a, b), Moench, Schlee, and Bryan (1965), and Moench and Schlee (1967). The areas studied by these workers are of considerable extent, but broad regional relationships could only be suspected by them. In addition, the state of knowledge about the fauna in the rock sequence allowed only suggestions about gross lateral rock-unit relations.

We studied the Dakota-Mancos rock sequence in the area near Laguna, then extended the study over a much larger area (fig. 1) in order to establish broad regional relationships. The intertonguing generally transgressive sequence at the base of the Cretaceous System in west-central New Mexico can be divided into regionally correlatable rock units. Four of these units are here formally named as members and tongues of either the Dakota Sandstone or the Mancos Shale.

In descending order, the sequence in the Laguna area comprises the Twowells Sandstone Tongue of the Dakota Sandstone (Dane

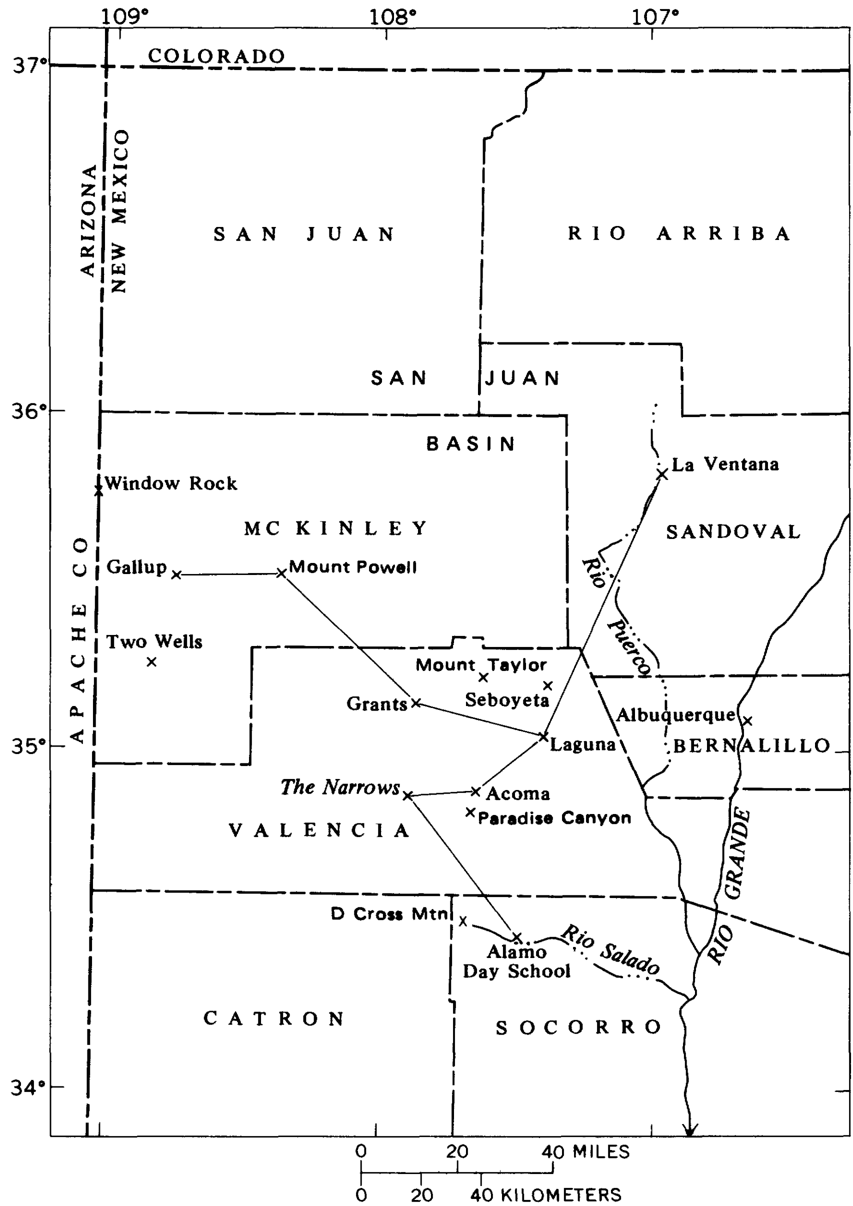


FIGURE 1. — Index map of west-central New Mexico and adjacent area.

and others, 1971), the Whitewater Arroyo Shale Tongue of the Mancos Shale (Dane and others, 1971), the Paguate Sandstone Tongue of the Dakota Sandstone, the Clay Mesa Shale Tongue of the Mancos Shale, the Cubero Sandstone Tongue of the Dakota

Sandstone, and the Oak Canyon Member of the Dakota Sandstone. The rock units are here discussed and described in descending order because (1) the upper two units are established, previously named rock units, in contrast to the lower units, which are newly named in this report; (2) the upper four units are conceptually simple and easily described and understood, in contrast to the lower two units, which require more detailed description and discussion because of lithologic diversity and complex lateral relations; and (3) the report does not attempt to present a detailed geologic history of the rock units.

The type sections for the newly named rock units — the Paguate, Clay Mesa, Cubero, and Oak Canyon — are presented in the Laguna measured section which follows. Other measured sections are discussed under "Description of Local Sequences."

Laguna measured section

[NE¼SE¼ sec. 20 and SW¼NW¼ sec. 21, T. 10 N., R. 5 W., Laguna 7½-minute quadrangle, Valencia County, N. Mex. Measured by E. R. Landis, W. A. Cobban, and C. H. Maxwell, Oct. 4, 1969, and by E. R. Landis and W. A. Cobban, Oct. 17, 1970]

Top of measured section.

	Ft	*in*
Mancos Shale, main body (incomplete):		
1. Limestone, slightly clayey, light-gray; weathers yellowish gray with very soft pale greenish cast; fossiliferous; contains "*Gryphaea*" sp. and *Inoceramus* sp.; angular chips and pieces		6
2. Shale, medium-gray; weathers grayish yellow; flaky; forms soft slope	4	0
3. Limestone, slightly clayey, gray, lenticular; weathers white; nodular; contains "*Gryphaea*" *newberryi* and *Sciponoceras gracile*. USGS Mesozoic loc. D7088		5
4. Shale; same as unit 2	7	6
5. Shale, silty, medium-gray, flaky; grades abruptly downward to soft grayish-orange-weathered slope-forming silty sandstone. Entire unit has abundant "*Gryphaea*" *newberryi* (broad form). USGS Mesozoic loc. D7087	14	0
Total Mancos Shale, main body (incomplete)	26	5
Twowells Sandstone Tongue of the Dakota Sandstone:		
6. Sandstone, silty, light-gray; weathers grayish orange; mostly in very irregular horizontal beds 2 in. to 4 ft thick; fine to mostly very fine grained; forms rough jagged bold cliffs	51	0
7. Sandstone; weathers yellowish gray; laminated to shaly, very fine grained; soft groove former; sharp upper and lower contacts. USGS Mesozoic loc. D7086 (*Exogyra levis* and others) is float probably from overlying sandstone (unit 6)		8
8. Sandstone, silty to very silty, yellowish-gray, very fine to fine-grained; some dark-colored rounded fine grains;		

	Ft	in
Twowells Sandstone Tongue of the Dakota Sandstone — Con.		
parallel crossbeds 3–6 in. thick within horizontal beds 15 in. to 3 ft thick; forms massive cliff	22	0
Total Twowells Sandstone Tongue of the Dakota Sandstone	73	8
Whitewater Arroyo Shale Tongue of the Mancos Shale:		
9. Covered	32	6
10. Siltstone, clayey to sandy, medium-dark-gray, chunky	4	0
11. Covered	6	0
12. Partly covered; seems to be all medium-gray shale	12	0
13. Bentonite		2
14. Shale, medium-gray, flaky; 4 ft above base is 2-ft-thick and 5-ft-long cone-in-cone limestone concretion that weathers to grayish-yellow angular pieces	16	4
15. Bentonite		2
16. Siltstone; clayey at top to sandy at base; weathers dark yellowish brown; shaly to chunky; forms soft slope	15	0
17. Covered	4	0
Total Whitewater Arroyo Shale Tongue of the Mancos Shale	90	2
Paguate Sandstone Tongue of the Dakota Sandstone:		
18. Sandstone, light-gray; weathers grayish orange; fine grained; mostly subrounded; not as well cemented as underlying unit and weathers back from edge of cliff formed by underlying unit	2	0
19. Sandstone, light-gray; weathers grayish yellow to grayish orange; fine grained; massive in lower 5 ft but bedded crudely in upper 8 ft. Upper part of unit is coarser grained than lower and has abundant borings and trails	13	0
20. Sandstone, silty; weathers grayish orange; forms massive crumbly soft ledge	2	3
21. Sandstone, light-gray; weathers grayish yellow to grayish orange; fine to medium grained; mostly subrounded; horizontal beds 4 in. to 1 ft thick; abundant tracks, trails, borings, and *Ophiomorpha*; softer than underlying unit	3	6
22. Sandstone, light-gray; weathers grayish yellow to grayish orange; fine grained; mostly subangular; forms massive cliff with dark-brown-weathered limy ledge at top	12	6
23. Siltstone, medium-gray to dark-yellowish-brown; carbonaceous in lower part, less carbonaceous and more sandy in upper part; forms soft slope. USGS Mesozoic loc. D7085 (*Exogyra* sp.) from 1 ft below top	16	8
24. Sandstone, light-gray; weathers yellowish gray; very fine grained; laminated; limy; has a few smeary carbonaceous spots; lower part is interbedded with siltstone same as underlying unit; upper 3 ft is very limy, weathered dark brown, very fossiliferous. Forms soft		

	Ft	in
Paguate Sandstone Tongue of the Dakota Sandstone — Con.		
irregular ledge. USGS Mesozoic loc. D7084 (*Acanthoceras amphibolum* and others) from 3 ft below top	12	0
Total Paguate Sandstone Tongue of the Dakota Sandstone	61	11
Clay Mesa Shale Tongue of the Mancos Shale:		
25. Siltstone, sandy, clayey, carbonaceous; weathers grayish yellow; forms weak ledge; grades upward to overlying unit	8	2
26. Shale, very silty, medium-dark-gray to brownish-gray, chunky; grades upward into overlying unit; sparse gray limestone concretions 1 ft in diameter near middle	17	0
27. Partly covered; seems to be all same as underlying unit	15	0
28. Shale, medium-dark-gray to brownish-gray, flaky; slightly silty near middle	10	0
29. Covered; probably shale as above and below	3	0
30. Shale, medium-dark-gray to brownish-gray, flaky; medium-gray smooth limestone concretions as much as 10 in. thick and 4 ft long near middle of unit	10	0
31. Covered	6	6
Total Clay Mesa Shale Tongue of the Mancos Shale	69	8
Cubero Sandstone Tongue of the Dakota Sandstone:		
32. Sandstone, clayey and silty, carbonaceous, medium-dark-gray; finer grained upward as unit grades to silty shale at top	2	5
33. Sandstone, light-gray; weathers grayish orange; fine grained; disturbed beds 3 in. to 1 ft thick, with abundant borings, trails, and *Ophiomorpha*; weathers to rough, holey, iron-stained ledge	7	0
34. Sandstone, silty, light-gray; weathers grayish orange; very fine grained; plant fragments in lower part, less silty upward with less plant debris; massive; forms faceted ledge. USGS Mesozoic loc. D7083 (*Exogyra* sp.) from 7 ft above base; USGS Mesozoic loc. D7082 (*Exogyra* sp.) from 2 ft above base	24	0
35. Sandstone, silty, medium-gray; partly weathered to grayish yellow; very fine to fine grained; has carbonaceous plant debris and dark spots and streaks; forms soft slope; grades into overlying unit	15	0
36. Sandstone, silty, light-gray; weathers yellowish gray; very fine grained; laminated and interlaminated with carbonaceous siltstone same as underlying unit; forms soft slope	2	1
Total Cubero Sandstone Tongue of the Dakota Sandstone	50	6
Oak Canyon Member of the Dakota Sandstone:		
Upper part:		
37. Siltstone, very sandy; weathers yellowish gray; carbonaceous; forms soft slope		10

	Ft	in
Oak Canyon Member of the Dakota Sandstone — Con.		
Upper part — Con.		
38. Shale, medium-dark-gray, flaky		2
39. Limestone, silty; medium gray at base to light gray at top; forms massive hard ledge. USGS Mesozoic loc. D7081 (*Plicatula arenaria* and others) from upper part		8
40. Partly covered; seems to be all dark-gray very silty shale and siltstone; forms soft slope	13	10
41. Siltstone, limy; weathers grayish yellow; massive; weathers to soft rounded pieces		4
42. Limestone, silty, medium-light-gray; weathers pale brown to dark yellowish brown; forms massive hard fossiliferous ledge in places; laterally changes to platy limy siltstone. USGS Mesozoic loc. D7080 (*Exogyra* sp. and many others)	1	4
43. Siltstone, very clayey, and silty shale; sandy (very fine grained) in part; dark gray; shaly to chunky; forms soft slope	3	3
44. Bentonite		4
45. Partly covered; upper few feet is dark-gray chunky silty shale similar to unit 43; lower part is similar to underlying unit. Some carbonaceous material in lower 1 ft	10	0
46. Shale, dark-gray, flaky to chunky; uppermost 7 in. is silty	8	3
47a. Partly covered; mostly shale as in unit 46; bentonite streak near top	1	2
Total upper part	40	2
Lower part:		
47b. Partly covered; mostly carbonaceous silty sandstone that is gypsiferous in lower 1 ft	3	6
48. Sandstone, silty, carbonaceous, light- to medium-gray; weathers grayish yellow; forms massive soft slope	3	2
49. Sandstone, silty; carbonaceous, but less so than overlying and underlying units; grains mostly subangular and very fine; irregular beds 2–6 in. thick; trails, borings, and other markings; forms rounded ledge	3	0
50. Sandstone, silty, carbonaceous, light- to medium-gray; weathers grayish yellow; forms massive soft slope	4	0
51. Covered	4	0
52. Partly covered; seems to be all flaky slightly carbonaceous dark-gray shale	7	0
53. Sandstone; weathers grayish orange to dark yellowish orange; very fine grained; carbonaceous material (plant debris) abundant near base, less abundant upward; forms massive ledge which has rough irregular purplish-streaked top	1	6
54. Sandstone, silty, carbonaceous (plant debris and streaks and patches); weathers light gray; very fine grained; forms soft slope; grades into overlying unit	2	2

	Ft	in
Oak Canyon Member of the Dakota Sandstone — Con.		
Lower part — Con.		
55. Sandstone; weathers grayish orange; mostly fine grained and rounded; bottom 3 in. contains lensing patches of coarse grains and granules; lower 3 ft is mostly massive; upper part of unit consists of irregular beds 1–15 in. thick which contain borings and markings and which are siltier and softer than lower part. Forms ledge with underlying unit	5	2
56. Sandstone; weathers pale yellowish brown; clayey in part; fine to coarse grained and granular. Coarser material is subangular quartz and subangular to subrounded rock fragments that are mostly white to pale-red quartzite. Lower contact is regular, but along length of outcrop it seems to be a very smooth channeling or truncating contact		4
Total lower part	33	10
Total Oak Canyon Member of the Dakota Sandstone	74	0
Jackpile sandstone (informal term of economic usage) of Morrison Formation	Unmeasured	

TWOWELLS SANDSTONE TONGUE OF THE DAKOTA SANDSTONE AND THE WHITEWATER ARROYO SHALE TONGUE OF THE MANCOS SHALE

The Twowells Sandstone and Whitewater Arroyo Shale Tongues, originally named by Owen (1966; see also Owen, 1963), are recognized as described by Dane, Landis, and Cobban (1971).

In the Laguna area the Twowells is mostly silty, fine to very fine grained sandstone that forms bold jagged cliffs. However, in some places, as between Laguna and Seboyeta (fig. 1), the upper part of the unit is softer and siltier and makes a subdued outcrop. The Twowells is persistent throughout most of west-central New Mexico. It extends as far north as Window Rock, Ariz., and La Ventana, N. Mex. (fig. 1) (Dane and others, 1971). As shown in figure 3, the Twowells thins west of Laguna because beds that form part of the Twowells at Laguna are included with the upper part of the Whitewater Arroyo Shale Tongue of the Mancos Shale in the Grants and Mount Powell areas. The Twowells persists southward from the Laguna area at least as far as the Alamo Day School measured section (figs. 2 and 4) near the Rio Salado (fig. 1) and was recognized by Landis, Cobban, and C. H. Maxwell at D Cross Mountain (fig. 1).

The Whitewater Arroyo is composed of soft, slope-forming shale and siltstone containing bentonite layers and yellow-weathering cone-in-cone limestone concretions.

The Whitewater Arroyo Shale Tongue of the Mancos Shale is present over much of west-central New Mexico — wherever the overlying Twowells Sandstone Tongue and either the underlying Paguate Sandstone Tongue of the Dakota Sandstone or the underlying main body of the Dakota are present. As shown in figures 1, 2, and 4, the Paguate Sandstone Tongue pinches out south of Laguna, and in the measured sections at Acoma and at Alamo Day School, the equivalents of the Whitewater Arroyo are included in the lower part of the Mancos Shale. North of La Ventana area (fig. 1), the Twowells becomes too thin to recognize (Dane and others, 1971), and the equivalents of the Whitewater Arroyo compose the lower part of the Mancos Shale.

The Twowells Sandstone Tongue of the Dakota Sandstone is fossiliferous at many places where it has been examined. The upper part of the Twowells and (or) the immediately overlying sediments commonly contain large numbers of a distinctive broad form of *"Gryphaea" newberryi* Stanton (Dane and others, 1971). In addition, *Exogyra levis* Stephenson and some distinctive but as-yet-undescribed *Exogyra, Plicatula goldenana* Stephenson, *Acanthocardia tritis* (White), *Pinna* sp., and the ammonites *Metoicoceras* sp. and *Calycoceras* sp. were collected from the Twowells in the measured sections shown in figures 3 and 4. The Whitewater Arroyo Shale Tongue of the Mancos Shale, which is not as fossiliferous as the Twowells, is commonly characterized by much the same fauna but in addition contains other distinctive *Exogyra* that are as yet undescribed. In many areas a large ammonite described by Haas (1949) as *Mantelliceras canitaurinum* was collected from the Whitewater Arroyo, but the same or similar ammonites may be present in the Twowells Sandstone Tongue. The fauna of the Twowells is of the age of the higher part of the Hartland Shale Member, the middle member of the Greenhorn Limestone of southwestern Kansas and southeastern Colorado (Dane and others, 1971), and the fauna of the Whitewater Arroyo is slightly older but still of the age of the Hartland.

As pointed out previously (Dane and others, 1971), the fauna, physical character, and regional stratigraphic relations indicate that the Twowells Sandstone Tongue is an extensive offshore shallow-water marine shelf sandstone derived from a source area to the southwest. A source to the southwest for the Twowells was suggested (Dane and others, 1971) because the upper part of the Twowells seems to be slightly younger toward the southwest, the unit is thicker in that direction, and the metamorphic-type heavy minerals found in it suggest a southerly source (Owen, 1963, p. 221).

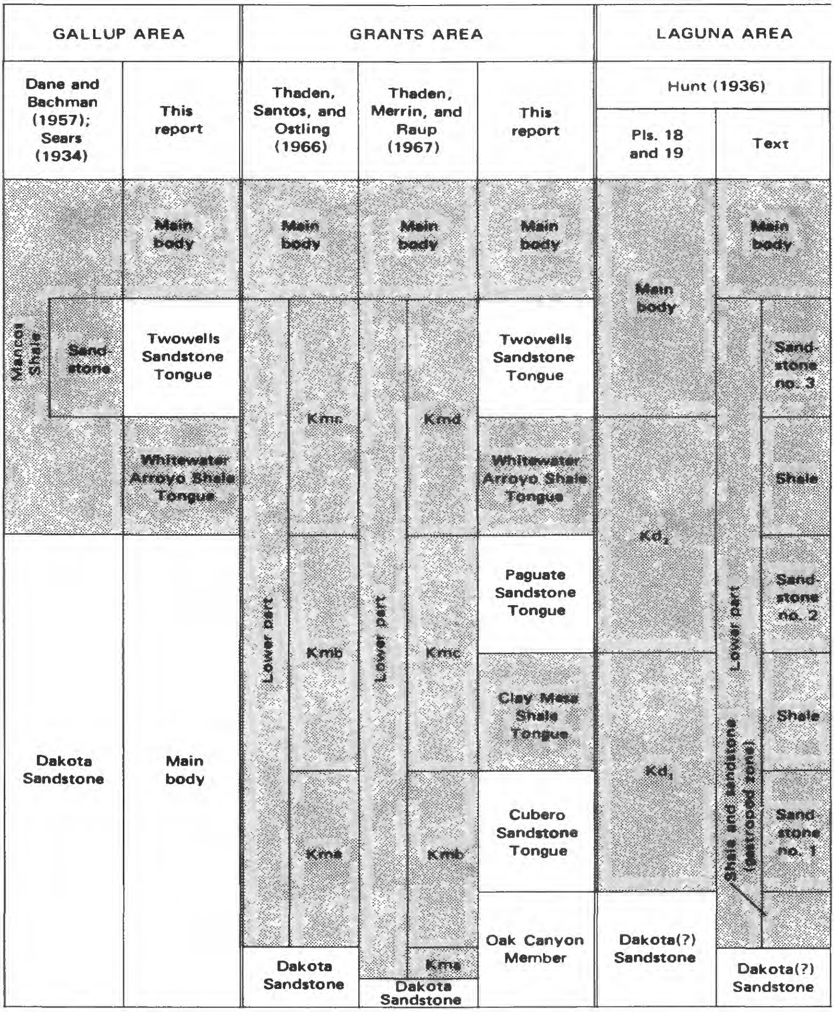
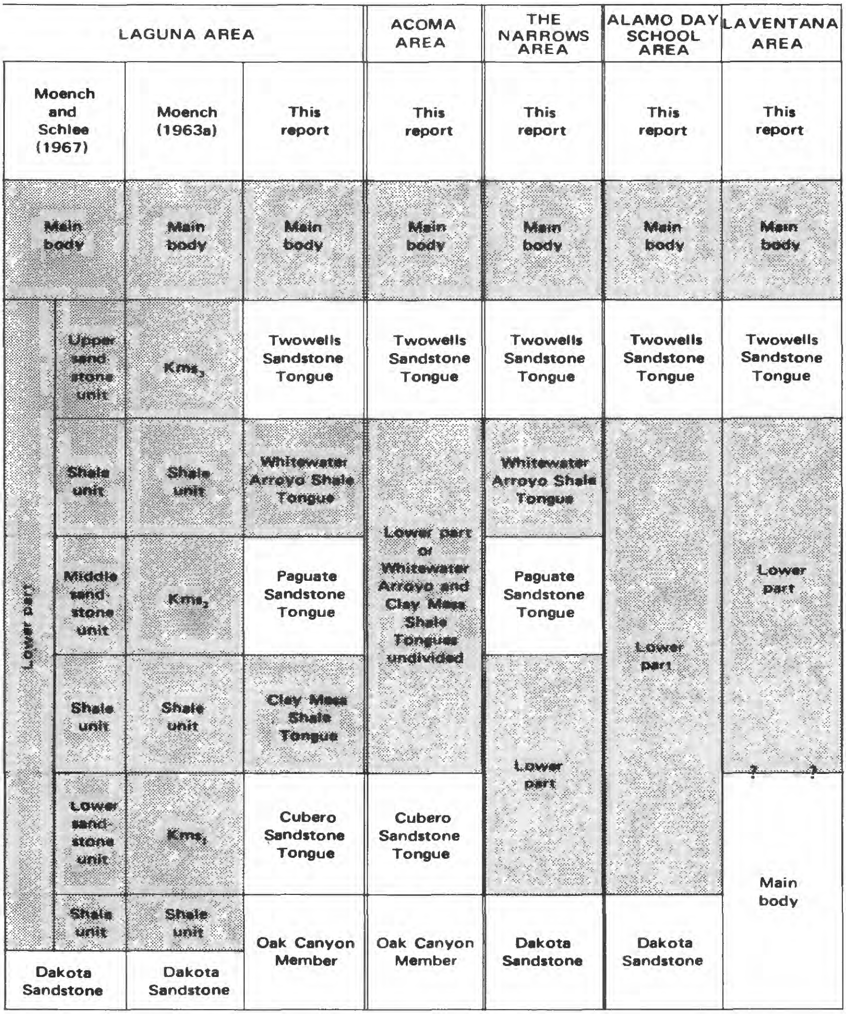


FIGURE 2. — Stratigraphic terminology of the Dakota

The fauna of the Whitewater Arroyo Shale Tongue indicates a shallow-water marine shelf environment similar to the depositional environment of the Twowells. However, part of the Whitewater Arroyo is composed of clay shale that contains bentonites and limy concretions but does not contain megafossils. These parts probably represent deposition in quieter and, perhaps, deeper water.

Older stratigraphic terminology for the Twowells and Whitewater Arroyo sequence is shown in figure 2. The Twowells has been confused in the past with a younger sandstone of Carlile age



Sandstone (unpatterned) and Mancos Shale (gray).

that was named the Tres Hermanos Sandstone by Herrick (1900). (See Dane and others, 1971.) The Whitewater Arroyo, which was named as a shale member of the Dakota Sandstone by Owen (1966), had previously been considered to be a shale unit of the Mancos Shale (fig. 2), and this previous usage is here retained.

PAGUATE SANDSTONE TONGUE OF THE DAKOTA SANDSTONE

The Paguate Sandstone Tongue of the Dakota Sandstone, whose type section is units 18–24 of the Laguna measured section, is named for the town of Paguate, 7 miles north of Laguna (fig. 1).

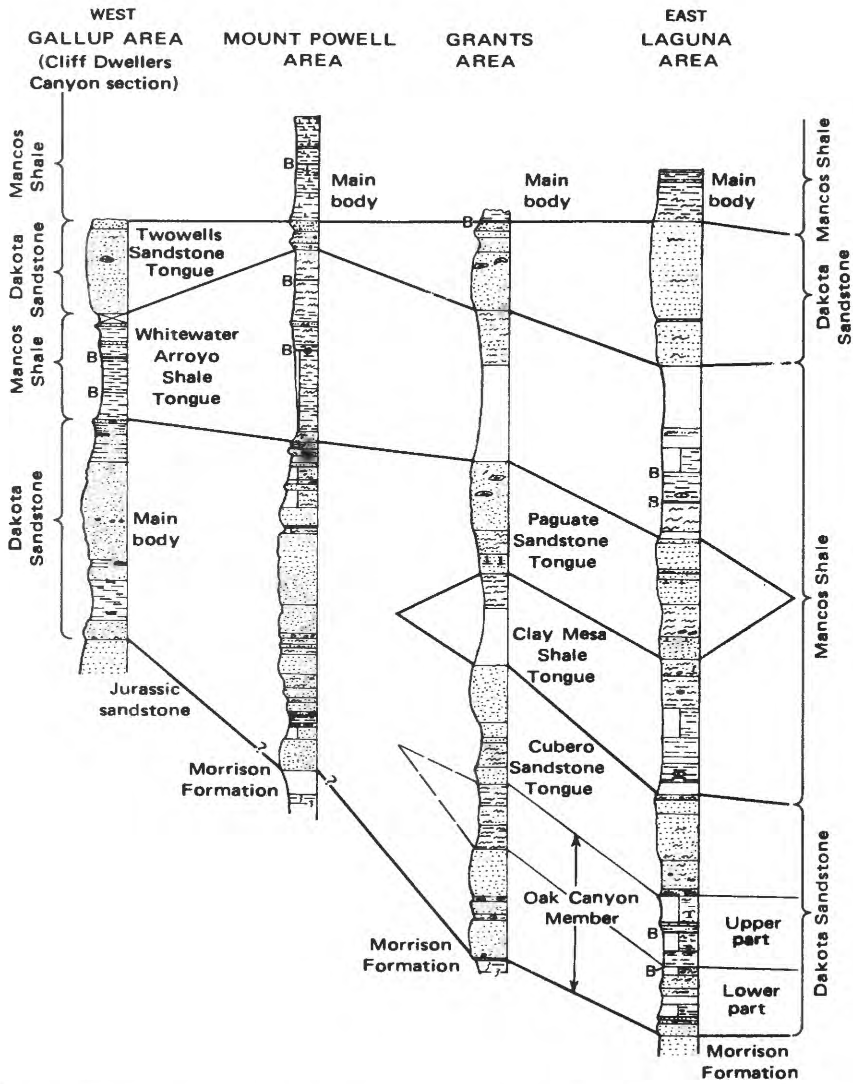
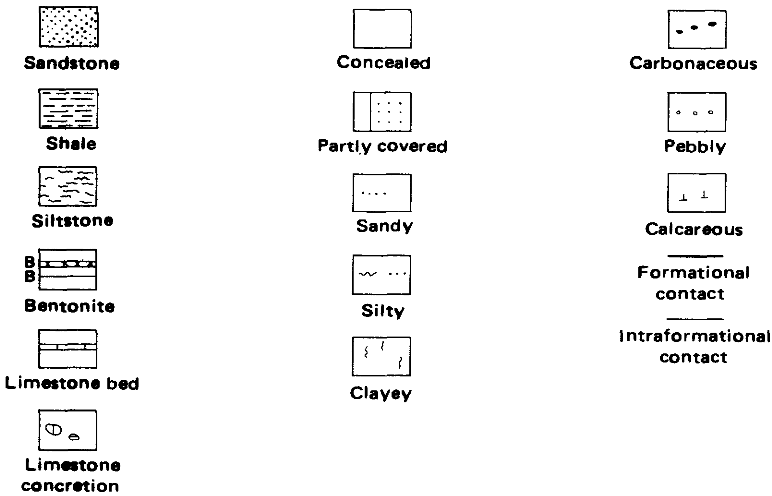


FIGURE 3. — East-west graphic columnar representation of measured sections.

Much of the town is built upon an outcrop of this sandstone. In the Laguna area the Paguate is composed mostly of very fine and fine-grained sandstone, silty in part, but has some interbedded siltstone and a very minor amount of medium-grained sandstone. Some of the sandstone beds are very limy and weather to dark-brown rounded concretionary masses. Some of the limy parts are extremely fossiliferous, as in the top part of unit 24 of the Laguna measured section.

EXPLANATION



The Paguate is recognizable northeastward from the Laguna area to about 6 miles south of La Ventana, where its identity becomes obscure (fig. 1). For most of this distance the Paguate is a bold cliff-forming sandstone unit, but it thins rapidly near its distal end, and although thin sandstone and siltstone beds are present at the appropriate stratigraphic position near La Ventana and northward, the unit is probably not traceable beyond La Ventana area. Westward from the Laguna area the Paguate is well developed to a point about a dozen or so miles west of Grants, where it merges with the main body of the Dakota Sandstone (fig. 3). The Paguate of the Laguna and Grants area is, therefore, the lateral equivalent of beds in the uppermost part of the main body of the Dakota at Mount Powell and Gallup (fig. 3). A subsurface study of the Dakota in the San Juan Basin by Tyrrell (1959) indicated that the Paguate merges with the main body of the Dakota Sandstone along a line trending from the Mount Powell area east of Gallup northeastward to a point near the center of the San Juan Basin.

Southward from the Grants area the Paguate forms a bold outcrop to a point near The Narrows measured section (fig. 4), and from there it thins rapidly to extinction in a southward direction. The Paguate can be observed to pinch out about 15 miles west-southwest of Laguna; it is not present in the Acoma measured section (fig. 4) or in the Alamo Day School measured section (fig. 4) and therefore seems not to have been deposited in the area south and southeast of Laguna.

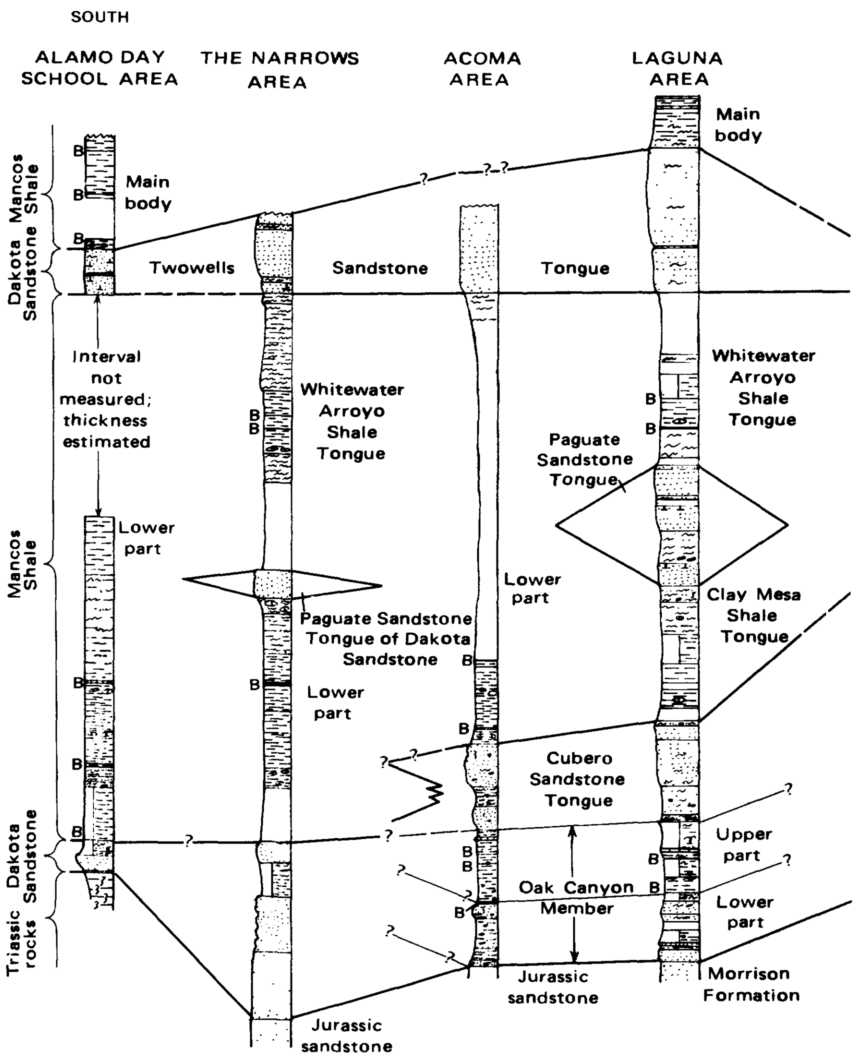
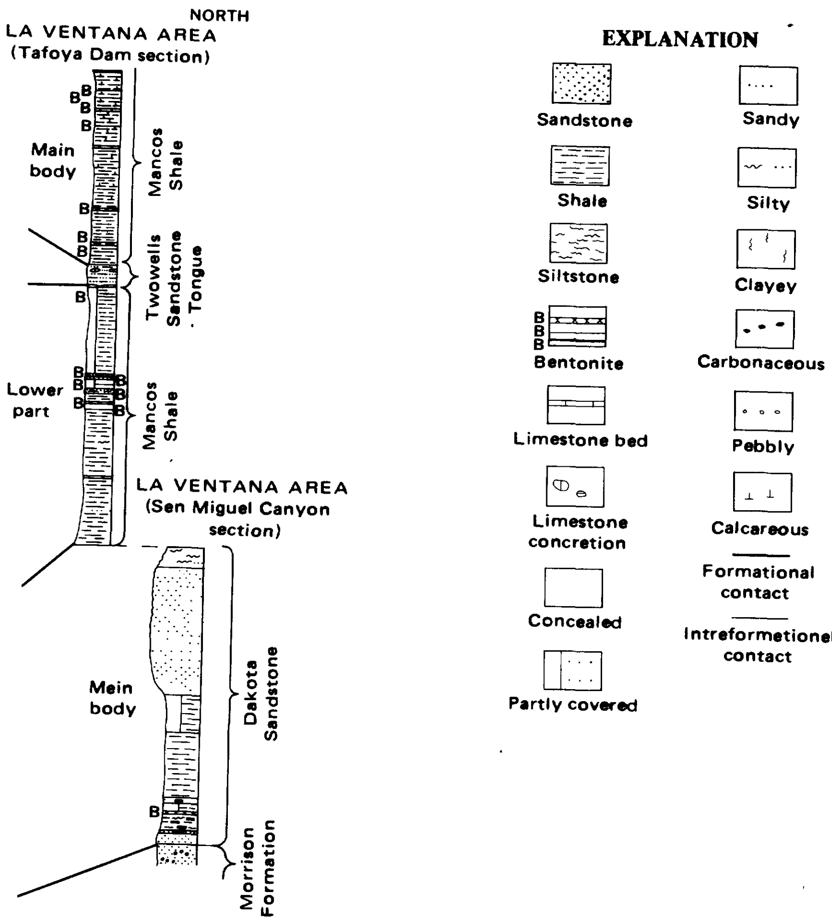


FIGURE 4. — North-south graphic columnar representation of measured sections.

The Paguate Sandstone Tongue of the Dakota Sandstone is sparsely fossiliferous in many localities, and in the Laguna area the limy sandstone in the lower part is abundantly fossiliferous, both in total numbers of individuals and in numbers of species. The fauna includes *Exogyra* cf. *E. oxyntas* (Coquand), *Exogyra levis* Stephenson, an as-yet-undescribed *Exogyra, Idonearca depressa* Meek, *Phelopteria gastrodes* Meek, *"Gryphaea"* cf. *"G." kellumi* (Jones), *Acanthocardia tritis* (White), *Turrilites acutus*



Passy, *Acanthoceras amphibolum* Morrow, *Paracompsoceras landisi* Cobban, *Eutrephoceras*? sp., and many others. The fauna is near the age of the Lincoln Limestone Member of the Greenhorn Limestone of southeastern Colorado.

The Paguate Sandstone Tongue in the Laguna area is a complex rock sequence composed of a mixture of open-marine shelf sandstones and nearshore marine siltstones and sandstones which in total make up a generally regressional marine sequence that also records some shoreline fluctuation. The lower contact is conformable and gradational into the Clay Mesa Shale Tongue of the Mancos Shale. The upper contact in many places is poorly exposed because the lower part of the Whitewater Arroyo weathers back from the ledge-forming upper part of the Paguate, and in these places the contact of the two units seems to be very sharp, perhaps disconformable. In the few exposures where the lower part of the Whitewater Arroyo is exposed, as in the Laguna measured section, the Paguate seems to grade rapidly upward into silty beds in the lower part of the Whitewater Arroyo.

The fauna of the Paguate is similar to that of the Twowells in that it represents an open-marine shelf environment. The distribution of the Paguate indicates a northwesterly or westerly source for the clastic material that makes up the unit.

Figure 2 shows some of the older terminology that has been applied to the Paguate Sandstone Tongue of the Dakota Sandstone in the west-central New Mexico area. Other appellations have been informally applied but have not gained wide usage; for example, the Paguate in most places falls into the "middle Dakota" of Tyrrell (1959).

CLAY MESA SHALE TONGUE OF THE MANCOS SHALE

The Clay Mesa Shale Tongue of the Mancos Shale, whose type section is units 25–31 of the Laguna measured section, is named for exposures on the east and south side of Clay Mesa, about 3 miles northwest of Laguna. The Clay Mesa Shale Tongue is composed mostly of medium- to dark-gray clay shale, silty in part, but has bentonites, limy concretions, and thin limestone beds. The upper part of the Clay Mesa commonly includes a few sandy beds and is siltier than the rest of the unit. The bentonites, thin limestone beds, and limy concretions are more common in the lower half of the rock unit. The Clay Mesa forms soft slopes between the resistant ledge- and cliff-forming sandstones above and below it, which define the top and bottom of the Clay Mesa Tongue.

The Clay Mesa wedges out in the main body of the Dakota Sandstone between the Grants and Mount Powell areas (figs. 1, 2, and 3), is equivalent to beds in the lower half of the lower part of the Mancos Shale in the Acoma and Alamo Day School areas, and is equivalent to beds in at least the upper part of the lower part of the Mancos Shale in The Narrows area.

The Clay Mesa and equivalent beds are in general more fossiliferous than the Whitewater Arroyo Shale Tongue of the Mancos Shale. The upper part of the Clay Mesa and its equivalents contain *Acanthoceras amphibolum* Morrow, "*Gryphaea*" cf. "*G.*" *kellumi* (Jones), and *Inoceramus rutherfordi* Warren; the middle and lower parts contain *Acanthoceras alvaradoense* Moreman and *Plicatula* sp.; and several levels throughout the tongue contain *Ostrea beloiti* Logan, *Tarrantoceras* sp., and *Pecten* sp.

The Clay Mesa Shale Tongue of the Mancos Shale and equivalent beds in the lower part of the Mancos Shale are composed mostly of fine-grained clastics deposited in quiet marine waters. The underlying coarser grained sediments grade very rapidly upward into the clay shales and laterally extensive bentonites and limy beds of the Clay Mesa Tongue. The upper part of the Clay Mesa is commonly silty and (or) sandy, and the Clay Mesa grades slowly upward to the coarser clastics of the Paguate Sandstone Tongue. The Clay Mesa thus records a period of shallow to deeper water deposition — relatively nearer shore to relatively farther from shore — followed by progressively shallower water deposition. The fauna of the Clay Mesa follows the same pattern; that is, the fauna of the finer grained parts of the Clay Mesa and equivalents is commonly of open-marine, deeper water type, such as ammonites, whereas the fauna of the siltier parts of the Clay Mesa at top and base is commonly of shallower water type, such as oysters and clams.

As shown in figure 2, the Clay Mesa has generally been considered to be a unit of the Mancos Shale. Some authors, for example Tyrrell (1959), have included the Clay Mesa as part of informal subdivisions of the Dakota Sandstone.

CUBERO SANDSTONE TONGUE OF THE DAKOTA SANDSTONE

The Cubero Sandstone Tongue of the Dakota Sandstone, whose type section is units 32–36 of the Laguna measured section, is named for exposures on the east side of Cubero Mountain, about 8 miles west of Laguna. The Cubero is mostly composed of very fine to fine-grained sandstone that is silty and carbonaceous in part. In some areas almost 25 percent of the Cubero is composed of siltstone and clay shale that contain abundant carbonaceous material, mostly in the form of comminuted plant debris. The Cubero, particularly the upper part, is a resistant ledge-forming unit similar to the Paguate and Twowells.

The Cubero Sandstone Tongue merges with the main body of the Dakota Sandstone along a line trending roughly northeast from a point a few miles west of Grants (fig. 1), becomes unrecognizable or merges with the main body of the Dakota Sandstone about 14 miles south of La Ventana (fig. 1), and is not recognized at The Narrows or at Alamo Day School, though equivalent beds are present.

The Cubero is not as fossiliferous as the other sandstone tongues of the Dakota. The most important of the very limited fauna are *Exogyra columbella* Meek and *Exogyra acroumbonata* Kauffman, which are found in the lower part of the Cubero at some localities, and *Exogyra* aff. *E. columbella* Meek and a larger, as-yet-undescribed *Exogyra,* which are found in the middle and upper parts of the Cubero. Very few ammonites have been found in the Cubero, compared with overlying rock units, but *Calycoceras* sp. has been collected.

In most of its area of occurrence, the lower, generally finer grained part of the Cubero contains marine fossils. This lower part of the Cubero is similar to the lower parts of the Paguate and Twowells Sandstone Tongues and reflects a similar depositional environment. The upper part of the Cubero resembles the upper parts of the Paguate and Twowells in being generally unfossiliferous — except for large quantities of "trace fossils"— and in being coarser grained than the lower part. The Cubero apparently reflects deposition of increasingly coarser sediments in a shallowing sea; this was followed by an abrupt transition to deposition in deeper waters, in which the lower part of the Clay Mesa Shale Tongue of the Mancos Shale was deposited.

Figure 2 shows some of the older informal terminology that has been applied to the Cubero in west-central New Mexico. The Cubero has been included by some workers in other informal units, such as the "middle Dakota" (Tyrrell, 1959).

OAK CANYON MEMBER OF THE DAKOTA SANDSTONE

The Oak Canyon Member of the Dakota Sandstone, whose type section is units 37–56 of the Laguna measured section, is named for exposures on the sides of the small mesas west of Oak Canyon, about 4–5 miles northeast of Laguna. The Oak Canyon in the Laguna-Acoma-Grants area is a complex assemblage of fluviatile, lagoonal, estuarine, and open-marine rocks composed of shales, silty sandstones, and sandstones, all of which are commonly carbonaceous, and clay shale, bentonite, limy siltstone, and limestone. In most of its area of occurrence the Oak Canyon can be subdivided roughly into two parts: an upper part that consists mostly of fine-grained open-marine sediments, and a lower part that contains some relatively coarser grained paralic sediments.

UPPER PART

The upper part of the Oak Canyon Member, units 37–46 and the upper part of unit 47 of the Laguna measured section, is composed mostly of clay shale and silty clay shale, though it also contains substantial quantities of clayey siltstone and siltstone. Thin bentonites that seem to be widespread over much of the Laguna-Acoma area are found in the lower part of this sequence, and dark-brown-weathering limestone and silty limestone units (units 39 and 42 of the Laguna measured section) that are very fossiliferous at most localities are found in the upper part. The limestones, which in places pass laterally into limy siltstone beds or discrete rounded limestone concretions, and the bentonites are by far the most persistent and recognizable units in the upper part of the Oak Canyon Member.

The upper part of the Oak Canyon Member grades upward into the Cubero Sandstone Tongue of the Dakota Sandstone and downward into the lower part of the Oak Canyon Member. The upper and lower parts can be distinguished in most areas by placing the contact at the top of the highest sandstone bed beneath the marine fossil-bearing shale and bentonite sequence that constitutes the bulk of the upper part of the Oak Canyon. When so placed, the contact is at the position chosen by Moench and Schlee (1967, p. 22 and 24) as the contact between the Dakota Sandstone and the lowest shale unit of the Mancos Shale in the Laguna area (fig. 2). However, Moench and Schlee (1967, p. 22 and 24) pointed out that the sandstone bed at the top of the Dakota as it was mapped by them is absent in some places; furthermore, according to C. H. Maxwell (written commun., 1970, 1971), the sandstone beds in the lower part of the Oak Canyon Member of this report are lenticular, and other criteria for distinguishing the upper and lower parts must be used. In the area southwest of Laguna, Maxwell preferred to place the contact between the upper and lower parts of the Oak Canyon at the top of strata that contain comparatively large pieces of plant debris (megascopic) in contrast to overlying strata that contain lesser quantities of comminuted carbonaceous material (microscopic), or none. Maxwell also stated that the contact is also marked by "limestone and (or) siderite (weathered to goethite) oolites, or ironstone crusts or nodules." In practice, in the area southwest of Laguna, this means that the contact between the upper and lower parts of the Oak Canyon Member is placed immediately below or within a few feet below the upper of the bentonites shown in the Laguna section in figure 3 and a few feet below the lowest limestone beds or concretions — that is, some place in unit 45 of the Laguna measured section.

If recognition of the upper part of the Oak Canyon is based upon the presence of fine-grained open-marine sediments, the rock unit is barely recognizable as far west as Grants but is present at Acoma, and lateral equivalents are present as far northeast as about 14 miles south of La Ventana (fig. 1). Beds equivalent to the upper part of the Oak Canyon either were not deposited or are composed of sandstone at The Narrows and at Alamo Day School.

The fossiliferous silty limestone units in the upper part of the Oak Canyon Member are in general the most consistently fossiliferous units in the entire intertonguing Dakota-Mancos sequence. These beds are lithologically similar to and faunally identical with the Thatcher Limestone Member of the Graneros Shale of southeastern Colorado. The Thatcher contains the oldest marine megafossil assemblage found in the Upper Cretaceous rocks of the Western Interior. The faunal assemblage found in the upper part of the Oak Canyon Member is mostly oysters, clams, and gastropods, though ammonites have been collected at several localities. Common species are *Exogyra columbella* Meek, *Pinna petrina* White, *Camptonectes* cf. *C. cavanus* (Stephenson), *Psilomya* aff. *P. concentrica* (Stanton), *Arrhoges modesta* (Cragin) ?, and *Plicatula arenaria* Meek; less common species are *Inoceramus eulessanus* Stephenson, *Turrilites acutus* Passy, *Calycoceras* sp., and *Borissiakoceras* sp. These animals are largely shallow-water open-marine forms.

The largely open-marine sediments of the upper part of the Oak Canyon Member were deposited during transgression of the Cretaceous sea into the Laguna-Acoma area from the east and northeast. The gradation upward of the Oak Canyon Member to the Cubero Sandstone Tongue records deposition during a seaward retreat of the shoreline.

The upper part of the Oak Canyon Member was treated as part of the Mancos Shale by some previous authors (fig. 2), either as a separate shale unit, as part of a shale and sandstone unit, or as part of a unit that included the Cubero Sandstone Tongue. After considering alternatives from a regional viewpoint, we decided to treat the sediments here described as the upper part of the Oak Canyon Member of the Dakota Sandstone as an informal subdivision of a member because of the difficulty of selecting a contact of more than local significance between the unit discussed here and the underlying sediments. This definition does not preclude mapping this informal unit wherever possible and desirable.

LOWER PART

The lower part of the Oak Canyon Member of the Dakota Sandstone, the lower part of unit 47 and units 48–56 of the Laguna measured section, is composed of coarse to very fine grained sandstone that is in places conglomeratic, containing granule- and pebble-size clasts, and in places silty. Carbonaceous, almost coaly, shales and medium- to dark-gray shale containing small amounts of comminuted plant debris are common and in some localities are a major constituent of the unit. Bentonite beds are found in the unit but are not common. No megafossils have been found in the unit, but many of the sandy beds (such as units 49 and 55 in the Laguna measured section) have abundant borings, marks, tracks, and trails. The lowest bed of the unit is generally a sandstone that may be conglomeratic (as unit 56 of the Laguna measured section), but the sandstone is not everywhere present, and in many areas the basal beds of the lower part of the Oak Canyon Member are shale.

Inherent in the definition of the lower part of the Oak Canyon Member is the requirement that the upper part of the Oak Canyon constitute a recognizable unit. Wherever this requirement is not met, the equivalent rocks either constitute part of an undivided Oak Canyon Member or constitute part or all of a unit designated either as Dakota Sandstone or as the main body of the Dakota Sandstone. In some areas it is possible that beds equivalent in time to all or part of the Oak Canyon (particularly the lower part) were never deposited.

No megafossils have been collected from the lower part of the Oak Canyon Member, but plant microfossils from shales in the unit have been identified by R. H. Tschudy (written commun., 1967) as palynomorphs of Early Cretaceous age. The flora, which is similar to that of the Thermopolis Shale of Montana and Wyoming, is mostly of Albian age, though one sample yielded palynomorphs of possible Aptian age. The samples from two of five localities, both south of La Ventana, appeared to contain winnowed assemblages, thus introducing an element of doubt about the age of deposition of the sampled rocks. Two of the five samples, including one from the Laguna area, contained hystrichospheres and dinoflagellates, indicating marine deposition of the enclosing rocks.

The lower part of the Oak Canyon Member unconformably overlies nonmarine rock units assigned a Jurassic age in most of west-central New Mexico and successively truncates older Jurassic formations and some Triassic units southward from the Laguna area to the Alamo Day School area. The rocks composing the lower part of the Oak Canyon were deposited marginal to the shoreline as the Cretaceous sea advanced westward through west-central New Mexico. Some of the rocks, particularly local basal conglomeratic sandstone beds, may be fluviatile deposits shoreward of the strandline, but the bulk of the rocks are lagoonal, littoral, or shallow marine deposits marginal to the shoreline.

In most areas the beds of the lower part of the Oak Canyon Member have been assigned as part or all of the Dakota Sandstone by previous authors. They have been included in informal units, such as the "lower Dakota" (Tyrrell, 1959), by some authors.

LOWER PART OF MANCOS SHALE

The lower part of the Mancos Shale in west-central New Mexico comprises marine rocks in the sequence that have not been, or cannot be, assigned to one or more of the previously discussed and named rock units of member rank that are part of either the

Dakota Sandstone or the Mancos Shale. As thus defined, the lower part of the Mancos Shale shown in figures 2 and 4 is made up of rocks of different time equivalency in different parts of the area. For example, the lower part of the Mancos Shale at The Narrows includes rocks laterally and temporally equivalent to the Clay Mesa Shale Tongue of the Mancos Shale, and it includes lateral equivalents of some parts of the Paguate and Cubero Sandstone Tongues and, perhaps, Oak Canyon Member of the Dakota Sandstone. In the Acoma area the lower part of the Mancos Shale includes rocks lithogenetically equivalent to the Whitewater Arroyo and Clay Mesa Shale Tongues of the Mancos Shale, but it cannot be subdivided because of the absence of the Paguate Sandstone Tongue of the Dakota Sandstone. Similarly, the lower part of the Mancos Shale in the Alamo Day School area cannot be subdivided because neither the Paguate nor the Cubero Sandstone Tongue is recognized in the area.

As defined, the lower part of the Mancos is composed mostly of marine rocks, and the dominant lithology is clay shale. The shale is silty in places and contains subordinate quantities of siltstone, sandstone, limy beds or concretions, and bentonites.

The lower part of the Mancos Shale contains a fauna similar to that of the rock units that are its temporal and lithological equivalents. The most common fossils are open-water marine animals, which are found in the limy or concretionary parts of the unit.

The very fine grained sediments, extensive bentonites (fig. 4), limy beds and concretions, and offshore fauna of the lower part of the Mancos Shale all indicate deposition in quiet open-marine offshore waters.

DAKOTA SANDSTONE

The rocks called the main body of the Dakota Sandstone in some areas and simply the Dakota Sandstone in other areas are marginal marine and nonmarine rocks which make up the lowest part of the sequence in west-central New Mexico and which cannot be included, or have not yet been included, in one of the other named rock units in the sequence.

The foregoing definition thus includes (1) the rocks beneath the lowest recognized tongue of the Mancos Shale in areas such as Mount Powell and Gallup (figs. 2 and 3), and (2) the basal sandstone beds of the sequence in areas such as Alamo Day School and The Narrows (fig. 4), where correlation of these basal beds with any other named part of the Dakota is undesirable or impossible at this time.

The main body of the Dakota in the Mount Powell area is about 175 feet thick, but the unit thins westward — it is only about 115 feet thick in the Gallup measured section and is as little as 68 feet thick at other places in the Gallup area. Some of this westward thinning may be internal, but most of the difference in thickness is caused by the onlapping relationship of the Dakota to the underlying rocks. The rocks assigned to the Dakota Sandstone in areas such as The Narrows are probably the lateral equivalents of some part of the Oak Canyon Member in the Laguna-Acoma area, but they do not have the distinctive lithologic features of the Oak Canyon; therefore, the rocks at the base of the sequence at The Narrows, for example, are grouped, at this time, as Dakota Sandstone. For similar reasons the basal sandstone beds of the sequence at Alamo Day School are simply called the Dakota Sandstone, and no attempt is made at lateral correlation of the unit.

The parts of the sequence in west-central New Mexico that are here assigned to the Dakota Sandstone of Early and Late Cretaceous age have been so considered by most previous authors.

In general, the rocks assigned to both the Dakota Sandstone and the main body of the Dakota Sandstone do not contain megafossils. However, in some places marine megafossils are present in the upper part of the main body of the Dakota, as at Mount Powell and at Gallup. The fauna includes *Inoceramus rutherfordi* Warren, *Ostrea beloiti* Logan, *Idonearca* sp., *Tellina* sp., *Cymbophora* aff. *C. securis* Stephenson, *Exogyra levis* Stephenson, and an as-yet-undescribed *Exogyra*. These fossils are of Late Cretaceous age. The lower part of the Oak Canyon Member is of Early Cretaceous age, as shown by the plant microfossils, and the lower part of the main body of the Dakota in the Mount Powell and Gallup areas may also be of Early Cretaceous age. In the absence of information to the contrary, the main body of the Dakota and those rocks assigned in figures 2, 3, and 4 as Dakota Sandstone must be considered to be of Early and Late Cretaceous age.

Most of the main body of the Dakota is composed of fluviatile sandstone and siltstone and of lagoonal and littoral carbonaceous siltstone, sandstone, and clay shale. A few parts are composed of sandstone and clay-shale beds that may have been deposited in estuarine or bay environments open to marine waters.

LOCAL SEQUENCES

Figure 2 shows stratigraphic terminology of the Dakota Sandstone and Mancos Shale according to various authors in different parts of west-central New Mexico and also presents the terminology proposed in this report. The vertical spacing of units within each of the columns of figure 2 is believed to accurately represent lateral correlation relationships but carries no implication of relative thickness relations.

Figures 3 and 4 are graphic representations of sections measured in west-central New Mexico, showing generalized lithology, lateral correlation, and relative thickness relations of the rock units of the Dakota and Mancos in the areas listed in figure 2. An additional measured section — at Mount Powell, near midway between the Gallup and Grants areas — is shown in figure 3 to aid in visualizing lateral changes in thickness of some parts of the rock sequence.

LAGUNA AREA

The intertongued Dakota-Mancos rock sequence, as described in the Laguna measured section and as shown in figures 2, 3, and 4, is persistent over a considerable area north of the pueblo of Laguna and east of the Mount Taylor volcanic pile (fig. 1). Hunt (1936) mapped the Dakota-Mancos sequence during a study of fuel resources in the southern part of the San Juan Basin. In the Laguna area, as shown in figure 2, Hunt (1936, text) applied the name Dakota(?) to a basal unit composed dominantly of sandstone and recognized a "lower part of the Mancos shale" made up of three units composed mostly of shale and three units composed mostly of sandstone. He suggested (p. 40) that "it seems probable that the Dakota(?) sandstone west of Mount Taylor is at the horizon of one of these sandstones, and therefore that the Dakota(?) sandstone west of Mount Taylor is younger than the sandstone called by the same name east of the mountain." This relationship was perhaps also implied by Hunt's selection (1936, geol. map) of Kd_1 and Kd_2 as the map designations for units composed of sandstone and shale in the lower part of the Mancos Shale.

Nine 7½-minute quadrangles were mapped as a part of a study of the uranium resources of the Laguna district. (See citations p. J2.) In the Laguna quadrangle, Moench (1963a) recognized and mapped subdivisions of the Dakota and Mancos similar to the subdivisions described by Hunt (1936, text), and the same scheme was used throughout the mapped area and in text discussion (Moench and Schlee, 1967). (See fig. 2.)

Both Hunt (1936) and Moench and Schlee (1967) recognized that the upper part of the Oak Canyon Member of the Dakota contained marine shale, siltstone, and limy beds, in contrast to the lower part of the Oak Canyon, which is composed mainly of sandstone and siltstone that is generally carbonaceous and is probably of paralic origin. Presumably for this reason, Moench and Schlee mapped the upper part of the Oak Canyon as a shale unit in the lower part of the Mancos Shale and mapped the lower part of the Oak Canyon Member as the Dakota Sandstone. Hunt (1936,

p. 39) pointed out that the restricted Dakota, as later mapped by Moench and Schlee and as designated the lower part of the Oak Canyon Member in the present report, is absent in places; perhaps for this reason, he mapped a unit, identified as Dakota(?) Sandstone on his map, that is essentially the Oak Canyon Member of the present report.

GRANTS AND MOUNT POWELL AREAS

The Dakota and Mancos in the Grants area are similar to the sequence at Laguna, though they are somewhat different in thickness and lithology. All the named rock units of the Laguna area are recognized at Grants, but some units, particularly the Clay Mesa Shale Tongue of the Mancos and the upper part of the Oak Canyon Member of the Dakota, are coarser grained and less fossiliferous than they are at Laguna. This lithologic difference is expectable because both of the cited units lose their lithologic identity farther west, between Grants and Mount Powell (figs. 1 and 3). During geologic mapping in the Grants area, Thaden, Merrin, and Raup (1967) recognized five informally designated mappable units in the Dakota-Mancos sequence (fig. 2). Earlier, Thaden, Santos, and Ostling (1966) had found that northwest of Grants the Dakota-Mancos sequence consisted of only four mappable units (fig. 2), and in the Mount Powell area and westward, we, together with J. F. Robertson and M. W. Green, found that only three mappable parts of the sequence are present (fig. 3).

Grants measured section

[SE¼ sec. 4 and NE¼NE¼ sec. 9, T. 10 N., R. 9 W., Grants SE 7½-minute quadrangle, Valencia County, N. Mex. Measured by C. H. Dane and E. R. Landis, Oct. 2, 1967]

	Ft	in
Top of measured section.		
Mancos Shale, main body (incomplete):		
1. Shale, very dark gray; contains "*Gryphaea*" *newberryi* (broad form) and *Exogyra levis*. USGS Mesozoic loc. D6216	5+	0
2. Bentonite		8
Total Mancos Shale, main body (incomplete)	5	8+
Twowells Sandstone Tongue of the Dakota Sandstone:		
3. Sandstone, yellowish-gray, soft; weathers back from underlying unit; contains *Exogyra* sp. USGS Mesozoic loc. D6215	5	0
4. Sandstone, yellowish-gray; forms resistant ledge	3	0
5. Sandstone, pale-yellowish-gray; softer than adjacent beds	7	6
6. Sandstone, pale-yellowish-gray to gray, mostly fine grained; forms massive ledge; gradational to underlying unit. Brown-weathered limy concretionary parts as much as 5 ft thick and 8 ft long in upper part.		

	Ft	in
Twowells Sandstone Tongue of the Dakota Sandstone — Con.		
Pinna sp. and *Inoceramus* sp. in lower part. USGS Mesozoic loc. D6214	29	6
Total Twowells Sandstone Tongue of the Dakota Sandstone	45	0
Whitewater Arroyo Shale Tongue of the Mancos Shale:		
7. Siltstone, pale-yellowish-gray, and about 25 percent very fine grained 1- to 12-inch-thick sandstone beds; forms soft slope	28	0
8. Covered; soft slope	50	0
Total Whitewater Arroyo Shale Tongue of the Mancos Shale	78	0
Paguate Sandstone Tongue of the Dakota Sandstone:		
9. Sandstone, yellowish-gray; massive to beds as much as 2 ft thick; forms ledge; has brown-weathered limy concretions as much as 4 ft thick and 5 ft long that contain *Exogyra* sp., *Idonearca* sp., and gastropods. USGS Mesozoic loc. D6213	36	0
10. Sandstone, silty, yellowish-gray; forms massive soft slope	11	0
11. Sandstone, pale-yellowish-gray; forms massive soft slope; has reddish-brown-weathering limy beds a few inches to 1 ft thick in upper part	10	0
Total Paguate Sandstone Tongue of the Dakota Sandstone	57	0
Clay Mesa Shale Tongue of the Mancos Shale:		
12. Shale, silty, medium-gray; forms soft slope	19	0
13. Covered; forms soft slope	30	0
Total Clay Mesa Shale Tongue of the Mancos Shale	49	0
Cubero Sandstone Tongue of the Dakota Sandstone:		
14. Sandstone, pale-reddish-gray, fine to very fine grained; massive to beds as much as 2 ft thick; forms ledge	29	0
15. Sandstone, pale-reddish-gray, fine to very fine grained, massive; softer than overlying unit	8	0
16. Sandstone, pale-yellowish-gray, very fine to fine-grained, massive, soft	3	0
17. Sandstone, silty, pale-olive-gray, very fine grained; poorly bedded in beds a few inches thick; forms soft slope	13	0
18. Sandstone, pale-yellowish-gray, fine to very fine grained; forms massive weak ledge; silty in lower 3 ft as it grades into underlying unit	8	0
Total Cubero Sandstone Tongue of the Dakota Sandstone	61	0
Oak Canyon Member of the Dakota Sandstone:		
Upper part:		
19. Shale, silty, medium-gray	12	0
20. Sandstone, silty, yellowish-gray; interbedded with me-		

	Ft	in
Oak Canyon Member of the Dakota Sandstone — Con.		
Upper part — Con.		
dium- to light-gray silty shale in beds ½–2 in. thick	10	0
21. Shale, silty, olive-gray	12	0
Total upper part	34	0
Lower part:		
22. Sandstone, grayish-orange, medium-grained; crossbedded at angles up to 45° in subparallel wedges as much as several feet thick; forms ledge	25	0
23. Shale, carbonaceous, medium-brown; interbedded with white very fine grained silty sandstone in beds 2–6 in. thick	2	0
24. Sandstone, pale-brownish-gray, fine to very fine grained; laminated to bedded (2- to 3-in.-thick beds) in upper part; has ½- to 1-in.-thick partings of silty shale and siltstone; forms ledge	7	0
25. Shale, pale-brown; silty and carbonaceous in upper part; 8-in.-thick lenticular very fine grained white sandstone near top	3	0
26. Sandstone, grayish-orange to grayish-red; mostly fine grained but some coarse grains in uppermost 1 ft; even bedded in beds a few inches to 2 ft thick in lower part; crossbedded in upper part; carbonaceous in lower 6–12 in.; forms ledge	21	0
27. Shale, carbonaceous, silty, dark-gray		7
Total lower part	58	7
Total Oak Canyon Member of the Dakota Sandstone	92	7
Morrison Formation:		
28. Claystone, green	Unmeasured	

Mount Powell measured section

[E½NW¼ sec. 8, T. 14 N., R. 13 W., Thoreau 7½-minute quadrangle, McKinley County, N. Mex. Measured by E. R. Landis and W. A. Cobban, with J. F. Robertson and M. W. Green, Oct. 7, 1969, and by E. R. Landis and W. A. Cobban, May 25, 1970]

Top of measured section.

	Ft	in
Mancos Shale, main body (incomplete):		
1. Shale, limy, medium-gray; interbedded with platy laminated light-gray limestone that weathers grayish yellow and contains *Inoceramus labiatus*	8+	0
2. Shale, limy, medium-gray	7	6
3. Limestone, light-gray; weathers to hard chips and flakes		6
4. Shale, limy, medium gray; contains "*Gryphaea*" *newberryi* in lower half	8	6
5. Bentonite		4
6. Shale, limy, medium-gray	5	0
7. Limestone, light-gray; weathers white, soft, and rounded; contains *Sciponoceras gracile*, "*Gryphaea*" *newberryi*, *Exogyra levis*, *Psilomya* sp., *Allocrioceras annulatum*, *Kanabiceras septemseriatum*, and *Metoicoceras whitei*.		

	Ft	in
Mancos Shale, main body (incomplete) — Con.		
USGS megafossil loc. D7342 from this unit and the underlying unit		3
8. Shale, limy, medium-dark-gray; contains *"Gryphaea" newberryi*	9	6
9. Shale, limy, medium-dark-gray; about 1 ft above base is a 2-in.-thick lenticular bed of flaky and chippy light-gray limestone	14	0
Total Mancos Shale, main body (incomplete)	53	7+
Twowells Sandstone Tongue of the Dakota Sandstone:		
10. Sandstone; weathers grayish yellow; fine to medium grained, mostly subrounded grains; silty at base, coarser upward; massive at base, poorly laminated at top; forms massive ledge. *"Gryphaea" newberryi* (broad form) throughout but abundant at top; none of the broad form observed above this unit. USGS megafossil loc. D7341	5	0
11. Sandstone, silty, carbonaceous; weathers very light gray; very fine to fine grained, subangular to subrounded; forms soft slope. May have *"Gryphaea" newberryi* (broad form) in uppermost part	3	5
12. Sandstone, silty, slightly carbonaceous; weathers grayish yellow; very fine grained; forms soft ledge	3	1
13. Sandstone, light-gray, fine-grained, massive; harder than adjacent units; forms ledge		5
14. Sandstone, silty, slightly carbonaceous; weathers grayish yellow; very fine grained; forms soft ledge	2	4
Total Twowells Sandstone Tongue of the Dakota Sandstone	14	3
Whitewater Arroyo Shale Tongue of the Mancos Shale:		
15. Siltstone, sandy; grades rapidly downward to silty shale, which forms bulk of unit; medium-dark-gray shale at base; a 2-in-.-thick bentonite about 22 ft above base; forms soft slope. Basal 10 ft contains *Exogyra* sp. USGS megafossil loc. D7340	37	0
16. Sandstone, silty; weathers yellowish gray; very fine grained, subangular to subrounded; poorly laminated to chunky; forms soft ledge. USGS megafossil loc. D7339: *Acanthocardia tritis*, *"Mantelliceras"* cf. *"M" canitaurinum*, *Gryphaea* sp., *Pinna* sp., *Inoceramus* sp., *Exogyra* sp., and *Camptonetes* sp	2	0
17. Shale, silty, medium-gray	10	0
18. Partly covered; mostly medium-gray shale, partly silty throughout but becoming siltier and sandier downward. Contains yellow-orange-weathered limestone concretions as much as 4 ft long and 2 ft thick with poorly developed cone-in-cone structure. Concretions are developed along bentonite beds, one of which is several inches thick and is 3 ft below top of unit.		

	Ft	in
Whitewater Arroyo Shale Tongue of the Mancos Shale — Con.		
USGS megafossil loc. D7338 is from float about 10 ft above base of unit: *Exogyra* sp., *Turritella* sp., and *Acanthocardia* sp	45	0
Total Whitewater Arroyo Shale Tongue of the Mancos Shale	94	0
Dakota Sandstone, main body:		
19. Sandstone, very silty; weathers yellowish gray; slightly carbonaceous; fine grained, subrounded to subangular; forms soft slope	5	0
Section offset northward.		
20. Partly covered; seems to be all sandstone similar to the underlying sandstone unit; has brown-weathered hard rounded concretionary limy parts several feet thick and as much as 10 ft in diameter that weather to very angular plates. Thickness approximate	4	0
21. Sandstone, grayish-olive to dusky-brown, calcareous; mostly fine grained to very fine grained; upper part has angular to subangular hard rock fragments of sand to pebble size along with fossils, which are mostly *Ostrea beloiti* but also *Inoceramus rutherfordi*, *Tellina* sp., and *Cymbophora* aff. *C. securis*. USGS Mesozoic locs. D7336 and D7337	1	3
22. Limestone, light-gray; weathers brown; hard; has wavy contact with underlying unit		3
23. Sandstone; weathers grayish yellow; calcareous; very fine grained, subrounded to subangular, subspherical; some carbonaceous streaks; in beds 2 to 3 in. thick; weathers to soft rounded edge; plates and cobbles	1	4
24. Covered; soft slope; very silty and sandy	4	6
25 Sandstone; similar to unit 28 below; a 2- to 6-in.-thick yellow-weathered laminated silty recess former near middle causes unit to weather to two ledges; some low-angle (few degrees or less) cross-lamination	1	11
26. Partly covered; soft slope; nearby exposures show unit to be interbedded grayish-orange to yellowish-gray very fine grained silty sandstone in beds as much as 3 in. thick and yellow to white laminated and cross-laminated carbonaceous-streaked sandy siltstone	6	0
27. Partly covered; seems to be similar to underlying unit	2	6
28. Sandstone, silty; weathers grayish yellow to grayish orange; very fine grained, subangular to subrounded, subspherical; horizontal beds ½–2 ft thick, some low-angle cross-lamination within beds; forms smooth-faceted angular ledge	3	9
29. Partly covered; soft slope; may be mostly yellow-weathered siltstone and sandstone	8	6
30. Sandstone; weathers light yellowish gray to grayish orange; fine grained, subangular to subrounded quartz, subspherical; mostly massive but has some weak horizontal beds ½–3 ft thick; breaks into slabs 3 ft wide		

	Ft	in
Dakota Sandstone, main body — Con.		
by 6–10 ft long. This forms the uppermost strong resistant ledge in the Dakota	8	0
31. Sandstone; weathers yellowish brown with red iron streaks; fine grained, subrounded, subspherical; horizontal beds 2–3 in. thick, some current ripples ½ in. deep, 3 in. long; unit grades upward but is softer than overlying unit, so it commonly forms a recess	1	2
32. Partly covered; seems to be all carbonaceous siltstone and shale in upper part; coaly in upper 1 ft and white clayey siltstone in uppermost 2 in	4	6
33. Sandstone; weathers yellowish gray to grayish orange; fine grained, subrounded quartz; poor horizontal bedding; forms massive bold ledge — the "Dakota main ledge"	38	0
34. Sandstone; weathers moderate reddish orange; fine grained, subrounded; massive; faint traces of bedding near top result in break between this unit and the overlying unit; forms bold cliff	14	6
35. Siltstone, light-gray, laminated, soft		1
36. Sandstone, pebbly; weathers moderate reddish orange to moderate reddish brown; mostly very fine and fine grained but poorly sorted, so grains as large as medium and coarse are abundant; most grains are subrounded; unit includes as much as 25 percent rounded granules and pebbles of quartz and as much as 30 percent dark igneous(?) rocks in lenticular bodies within the otherwise massive, faintly crossbedded, resistant ledge former	2	1
37. Sandstone; silty, as in underlying unit; interbedded with laminated clayey carbonaceous siltstone and carbonaceous silty shale; soft; forms recess; top contact even but sharp	3	8
38. Sandstone, silty; weathers grayish orange; fine to very fine grained, subangular to subrounded; crosslaminated; forms massive soft ledge	1	4
39. Siltstone, sandy; weathers light gray; laminated and crosslaminated; platy; forms soft slope	4	0
40. Sandstone; weathers grayish yellow; fine grained, subangular to subrounded; in horizontal beds ½–3 ft thick that are crosslaminated and crossbedded; forms ledge	10	0
41. Sandstone, silty, carbonaceous, fine grained to very fine grained, subangular to subrounded, massive, soft; grades in upper part to carbonaceous sandy siltstone; sharp wavy contact with overlying unit; forms soft recess	4	9
42. Sandstone; weathers light gray to orange; very fine to fine grained, subangular to subrounded; sparse plant debris throughout; silty in lower 2 in. and upper 4 in.; soft	1	0

	Ft	in
Dakota Sandstone, main body — Con.		
43. Siltstone, sandy; increasingly carbonaceous upward; forms soft recess		11
44. Sandstone; weathers grayish yellow to grayish orange; mostly very fine to fine grained, subangular and subrounded; mostly poor horizontal beds 2 in. to 2 ft thick; massive to blocky; forms ledge	5	9
45. Sandstone, very silty; carbonaceous streaks; weathers yellowish gray to white; very fine grained, subangular; massive; soft; sharp irregular basal contact but gradational to overlying unit	1	10
46. Sandstone; weathers grayish orange to yellowish gray; fine to very fine grained, subangular; lower 3 ft is massive single ledge, upper 2½ ft is poorly bedded horizontally and has some cross-lamination and bedding; forms ledge	5	6
47. Sandstone, very silty; carbonaceous streaks; weathers yellowish gray to white, with iron streaks; mostly very fine grained, subangular; gradational upward and downward; soft unit at base of overlying ledge	1	6
48. Shale; increasingly carbonaceous upward; silty in upper 6 in	4	0
49. Partly covered; seems to be all carbonaceous shale	2	0
50. Partly covered; seems to be sandstone similar to underlying unit	6	0
51. Sandstone; weathers grayish yellow to grayish orange; mostly fine grained, subangular to subrounded; poor horizontal beds 2 in. to 10 ft thick, with low-angle internal crossbedding; breaks to blocky large boulders; forms rough ledge	17	0
Total Dakota Sandstone, main body	176	7
52. Covered; soft interval	12	0
Morrison Formation:		
53. Claystone, green and purple	Unmeasured	

GALLUP AREA

The section measured in Cliff Dwellers Canyon is generally representative of the Dakota-Mancos sequence throughout the Gallup area. In parts of the Gallup area and to the north and west of Gallup, the uppermost sandy part of the Twowells that characteristically contains abundant specimens of *"Gryphaea" newberryi* Stanton (broad form) — unit 1 of the Cliff Dwellers Canyon measured section — is separated from the main, underlying mass of the Twowells by shale and silty shale, and it seems to constitute a separate recognizable rock unit (Dane and others, 1971). Not enough is known about the distribution and character of this unit to justify a formal stratigraphic designation at this time.

Cliff Dwellers Canyon (Gallup) measured section

[NE¼ sec. 30, T. 16 N., R. 17 W., Gallup E 7½-minute quadrangle, McKinley County, N. Mex. Measured by C. H. Dane and G. O Bachman, May 25, 1957, and supplemented by C. H. Dane, E. R. Landis, and W. A. Cobban, Apr. 27, 1967]

	Ft	*in*
Top of measured section. Top of exposure.		
Twowells Sandstone Tongue of the Dakota Sandstone:		
1. Coquina of "*Gryphaea*" *newberryi* (broad form); has sandy calcareous matrix	4	8
2. Sandstone, medium- to fine-grained; silty in upper part; makes persistent ledge; contains some brown calcareous concretionary masses	44	0
Total Twowells Sandstone Tongue of the Dakota Sandstone	48	8
Whitewater Arroyo Shale Tongue of the Mancos Shale:		
3. Covered	5	6
4. Sandstone, hard, persistent; weathers orange and white..		9
5. Shale, gray; sandy in upper half	8	0
6. Sandstone, thin-bedded, gray	1	6
7. Shale, gray	6	0
8. Bentonite		6
9. Shale, gray; contains *Exogyra* sp. to within 3 ft of top..	18	0
10. Bentonite, thin; not measurable	....	....
11. Shale, gray; contains *Exogyra* sp. in upper 2 ft. USGS Mesozoic loc. D5765	14	0
Total Whitewater Arroyo Shale Tongue of the Mancos Shale	54	3
Dakota Sandstone, main body:		
12. Sandstone, yellowish-gray, fine-grained, calcareous; contains *Exogyra levis* in abundance. USGS Mesozoic loc. D5764	2	0
13. Shale, sandy, yellowish-gray; contains many thin beds of yellowish-gray fine-grained sandstone and a soft thin-bedded ripple-marked sandstone ½–3 ft thick whose base is 11½ ft above the base of the unit. This sandstone is overlain by some carbonaceous shale. A slope-forming unit	19	0
14. Sandstone, yellowish-gray, medium- to coarse-grained; forms prominent ledge; evenly bedded in basal 4 ft, strongly crossbedded above, especially in middle part. Top 10 ft is even bedded. About 20 ft above the base is a bed 2–3 ft thick of granule-sized conglomerate	52	0
15. Shale, dark-gray, carbonaceous to coaly	3	6
16. Sandstone, coarse-grained; contains lenses up to granule-sized grains; irregularly thin bedded; weathers brown on top	7	0
17. Shale, dark-gray; carbonaceous for the most part; poorly exposed in a slope	21	0
18. Sandstone; persistent dark-gray ledge capping very light gray to white medium-grained sandstone cliffs of Jurassic age. At the base is yellowish-red-weathering grit or coarse sandstone 6 in. thick that contains		

	Ft	in
Dakota Sandstone, main body — Con.		
a few pebbles, to ¾ in. in dimension, of chert, quartz, and quartzite. Basal contact irregular, with relief of 6 in. within 2–3 ft horizontally; contact is sharp, but probably not everywhere at same level. There is probably some reworking of the underlying sandstone into the basal Dakota in places, and locally the basal bed of the Dakota is gray shale. Bedding of the unit as a whole is irregularly and weakly parallel, but in part it is crossbedded	10	0
Total Dakota Sandstone, main body	114	6
Sandstone of Jurassic age	Unmeasured	

ACOMA AREA

The lower part of the Dakota-Mancos sequence caps mesas over a considerable part of the distance between Laguna and Acoma, but the upper part has been largely removed by erosion. The complete sequence crops out south of Acoma and is present at the surface over large areas between Acoma and the Rio Salado (fig. 1). As mentioned previously, the Paguate Sandstone Tongue, which is a prominent element of the sequence in the Laguna area, pinches out southwest of Laguna and is not present in the Acoma area and southward. The Cubero Sandstone Tongue of the Dakota Sandstone, units 13–17 of the Acoma measured section, has a softer, finer grained middle part (units 14–16). The Cubero becomes thinner south of the Acoma area and is not recognizable in the D Cross Mountain area (fig. 1). The Oak Canyon Member in the Acoma area is similar to the equivalent rocks in the Laguna area.

Acoma measured section

[SE¼SE¼ sec. 36, T. 8 N., R. 8 W., Blue Mesa and East Mesa 7½-minute quadrangles, Valencia County, N. Mex. Measured by C. H. Dane, E. R. Landis, and W. A. Cobban, Aug. 2 and 8, 1966]

	Ft	in
Top of measured section. Top of exposure.		
Twowells Sandstone Tongue of the Dakota Sandstone:		
1. Sandstone; weathers grayish orange; fine grained; crossbedded within horizontal beds as much as 4 ft thick; forms massive bold ledge	45+	0
Total Twowells Sandstone Tongue of the Dakota Sandstone	45+	0
Mancos Shale, lower part:		
2. Covered; uppermost part is silty shale and siltstone transitional to overlying unit, and lower part includes medium-gray shale	188	0
3. Bentonitic clay, light-gray to greenish-gray; locally contains cone-in-cone limestone concretions		8
4. Shale, medium- to dark-gray; *"Gryphaea"* cf. *"G." kel-*		

	Ft	in
Mancos Shale, lower part — Con.		
lumi as float in upper part of unit. USGS Mesozoic loc. D5393	14	0
5. Shale, medium- to dark-gray; has rounded brecciated and healed limestone concretions as much as 2 ft in diameter that contain *Acanthoceras alvaradoense.* USGS Mesozoic loc. D5332	4	0
6. Shale, medium- to dark-gray	17	0
7. Bentonite streak	----	----
8. Shale, medium- to dark-gray		6
9. Bentonite streak	----	----
10. Shale, medium- to dark-gray	3	0
11. Shale, dark-gray; contains limestone concretions, very dark gray, discoidal, and as much as 3 ft in diameter. *Ostrea beloiti, Acanthoceras* sp., *Plicatula* sp., *Veniella* sp., and *Tarrantoceras* sp. USGS Mesozoic loc. D5331		6
12. Shale, dark-gray	4	0
Total Mancos Shale, lower part	231	8
Cubero Sandstone Tongue of the Dakota Sandstone:		
13. Sandstone, clayey and partly silty, yellowish-gray, very fine grained; carbonaceous (plant) fragments; tracks, trails, and borings; in beds 1½–4 ft thick, thinnest in upper part; *Exogyra* sp. USGS Mesozoic loc. D5330	22	9
14. Siltstone, clayey, dark-gray, carbonaceous, lenticular	1	3
15. Sandstone, clayey, medium-gray, very fine grained, carbonaceous	1	0
16. Shale, very silty, carbonaceous, medium-gray	7	6
17. Sandstone, clayey, yellowish-gray, very fine grained; thin silty shale interbeds; in beds 1–4 ft thick, thickest beds toward top; forms weak ledge	11	0
Total Cubero Sandstone Tongue of the Dakota Sandstone	43	6
Oak Canyon Member of the Dakota Sandstone:		
Upper part:		
18. Shale, very silty, dark-gray	5	0
19. Siltstone, calcareous, gray to brown, lenticular, fossiliferous; contains *Exogyra columbella, Plicatula arenaria, Psilomya levis, Turritella* sp., *Psilomya* aff. *P. concentrica, Pinna* sp., and *"Gryphaea"* sp. USGS Mesozoic loc. D5329		8
20. Shale, silty, dark-gray	8	0
21. Bentonite		1
22. Shale, dark-gray	5	0
23. Bentonite; some soft white limy concretions		4
24. Shale, silty, dark-gray; carbonaceous (plant) fragments	20	0
25. Bentonite		1
26. Shale, medium-gray; has a white lenticular sandstone as much as 4 in. thick in upper part	2	5

	Ft	in
Oak Canyon Member of the Dakota Sandstone — Con.		
Upper part — Con.		
Total upper part	41	7
Lower part:		
27. Sandstone, yellowish-gray, very fine grained, soft and poorly bedded	1	2
28. Sandstone, clayey, carbonaceous, very dark gray	2	4
29. Sandstone, medium-gray, very fine grained; abundant carbonaceous fragments; forms persistent ledge	2	5
30. Shale, dark-gray		1
31. Sandstone, white, very fine grained		1
32. Shale, silty, carbonaceous, medium- to dark-gray; interbedded with siltstone and sandstone in beds <1 in. thick	15	3
33. Sandstone, white, very fine grained, hard		3
34. Shale, silty, dark-gray; siltstone beds <1 in. thick interbedded in upper part	6	5
35. Sandstone, light- to moderate-brown, coarse to very coarse grained; contains granules and small pebbles of quartz and both light- and dark-colored quartzite; in lenticular beds, internally crossbedded, <1–6 in. thick; hard ledge contrasting sharply with underlying soft white sandstone of Jurassic age; unit wedges out within 50 ft along outcrop and is intermittent in occurrence over an area of several square miles	2	10
Total lower part	30	10
Total Oak Canyon Member of the Dakota Sandstone	72	5
Sandstone of Jurassic age	Unmeasured	

THE NARROWS AREA

Southward from the Grants area the upper part of the Dakota-Mancos sequence — the Twowells Sandstone Tongue, the Whitewater Arroyo Shale Tongue, and the Paguate Sandstone Tongue — are recognizable as far as The Narrows area (fig. 1). The rocks equivalent to the Clay Mesa Shale Tongue of the Laguna area are closely similar to equivalent rocks in the Acoma area, but the Cubero Sandstone Tongue was not observed south of a point about 12 miles south of the Grants area. Therefore, the lower part of the sequence is divided into a unit designated the lower part of the Mancos Shale, which is equivalent to rocks included in other areas in the Clay Mesa Shale Tongue and the Cubero Sandstone Tongue, and into a unit designated the Dakota Sandstone, which is equivalent to rocks included in other areas in the lower part of the Oak Canyon Member of the Dakota Sandstone.

Lithogenetic equivalents of the upper part of the Oak Canyon Member were not recognized in The Narrows area, and the time relationship of the rocks in the lower part of the measured section are unknown. The thick sandstone units (units 30 and 31, The Narrows measured section) are probably equivalents of the lenticular sandstone that is the basal unit of the Acoma measured section.

The Narrows measured section

[NE¼ sec. 4 and NW¼ sec. 3, T. 7 N., R. 10 W., North Pasture 7½-minute quadrangle, Valencia County, N. Mex. Measured by C. H. Dane and E. R. Landis, Sept. 13, 1967, and by E. R. Landis and W. A. Cobban, Oct. 16, 1970]

	Ft	*in*
Top of measured section. Top of exposure.		
Twowells Sandstone Tongue of the Dakota Sandstone:		
1. Sandstone, yellowish-gray, soft	5+	0
2. Sandstone, yellowish-gray, calcareous, slabby-bedded	1	6
3. Sandstone, grayish-yellow, soft; contains *"Gryphaea" newberryi* (broad form), *Exogyra levis, Exogyra* sp., *Pinna* sp., *Acanthocardia tritis,* and *Pecten* (*Camptonectes*) sp. USGS Mesozoic loc. D6133	1	0
4. Sandstone, grayish-orange to pale-brown, fine-grained; forms massive cliff; upper part contains *Calycoceras obrieni, Acanthocardia tritis,* and *Exogyra levis.* USGS Mesozoic loc. D6132	25	0
5. Sandstone, silty, yellowish-gray, lumpy-bedded	2	6
6. Sandstone, silty, grayish-orange, slightly calcareous, very fine grained; in beds 4–8 in. thick; very fossiliferous, with *Exogyra levis, Exogyra* sp., *Acanthocardia tritis, Pinna* sp., and many others. USGS Mesozoic loc. D6131	6	0
Total Twowells Sandstone Tongue of the Dakota Sandstone	41+	0
Whitewater Arroyo Shale Tongue of the Mancos Shale:		
7. Shale, silty, dark-gray	5	0
8. Siltstone, yellowish-gray; forms weak ledge		9
9. Siltstone, yellowish-gray, clayey; interbedded gray silty shale	44	0
10. Shale, medium-gray	13	0
11. Bentonite		1
12. Shale, medium-gray, flaky	6	0
13. Bentonite		1
14. Shale, medium-gray	11	0
15. Limestone concretions, medium-gray, fractured; in medium-gray shale	1	0
16. Shale, medium-gray		9
17. Siltstone, clayey, light-gray	15	0
18. Covered; soft slope	45	0
Total Whitewater Arroyo Shale Tongue of the Mancos Shale	141	8
Paguate Sandstone Tongue of the Dakota Sandstone:		
19. Sandstone, yellowish-gray to pale-brown, fine-grained; massive to beds 2 ft thick in lower part, thinner bedded in upper part, with ripple marks; "trace fossils";		

	Ft	in
Paguate Sandstone Tongue of the Dakota Sandstone — Con.		
forms ledge	15	0
Total Paguate Sandstone Tongue of the Dakota Sandstone	15	0
Mancos Shale, lower part:		
20. Siltstone, clayey, light-olive-gray; sparse limy concretions	8	6
21. Shale, slightly silty, light-olive-gray	20	0
22. Shale, dark-gray	15	0
23. Bentonite	1	4
24. Shale, dark-gray	13	6
25. Shale, medium- to dark-gray	30	0
26. Shale, medium- to dark-gray; fractured gray limy concretions; has "*Gryphaea*" cf. "*G.*" *kellumi*	10	0
27. Covered; soft slope	28	0
Total Mancos Shale, lower part	126	4
Dakota Sandstone:		
28. Sandstone, pale-brown, fine-grained; in beds <1–3 in. thick, thicker beds in upper part	11	0
29. Partly covered; lower part is mostly dark-gray shale, upper part is light-gray shale and shaly siltstone; forms slope	18	0
30. Sandstone, white to brown; crossbedded, ledges 2–4 ft thick; softer in lower part; forms weak ledge	29	0
31. Sandstone, pale-brown, massive; rests with smoothly irregular contact on white "bleached" zone at top of underlying cliff-forming sandstone of Jurassic age	35	0
Total Dakota Sandstone	93	0
Sandstone of Jurassic age	Unmeasured	

ALAMO DAY SCHOOL AREA

The Dakota-Mancos sequence is poorly exposed southward from the Acoma area. Except for exposures in the Paradise Canyon area (fig. 1), only fragmental exposures were observed between Acoma and the Rio Salado. In the area of the Alamo Day School on the Alamo Navajo Reservation, the lower part of the Dakota-Mancos sequence is well exposed, but the upper part is commonly concealed. In the D Cross Mountain area, west of the Alamo Day School area, the rocks underlying the Twowells Sandstone Tongue of the Dakota Sandstone are soft dark shale and siltstone, and the unexposed parts of the Alamo Day School measured section are inferred to be similar rocks.

The Twowells Sandstone Tongue of the Alamo Day School area is silty, soft, and massive, and it crops out as a weak rounded nonobvious ledge. The Paguate Sandstone Tongue of the Dakota Sandstone in the Laguna area is not present in the Alamo Day

School area, and the unit designated the lower part of the Mancos Shale in figures 2 and 4 thus may include lithogenetic equivalents of the Whitewater Arroyo and Clay Mesa Shale Tongues of the Mancos and time equivalents of the Paguate Sandstone Tongue and, perhaps, the Cubero Sandstone Tongue of the Dakota Sandstone. The Dakota Sandstone at the base of the sequence includes lithogenetic equivalents of the lower part of the Oak Canyon Member of the Dakota Sandstone of the Laguna area, but it may be younger and not time equivalent.

Alamo Day School measured section—upper part

[SE¼SW¼ sec. 13, T. 3 N., R. 7 W., Table Mountain 7½-minute quadrangle, Socorro County, N. Mex. Measured by C. H. Dane, E. R. Landis, and W. A. Cobban, Apr. 29, 1967, and by E. R. Landis, June 13, 1968]

	Ft	*in*
Top of measured section.		
Mancos Shale, main body (incomplete):		
1. Shale, dark-gray; much selenite	5+	0
2. Bentonite; thickness approximate		4
3. Shale; weathers light gray and flaky	22	0
4. Bentonite; thickness approximate		2
5. Shale; weathers light gray and flaky	2	0
6. Interval unmeasured; thickness estimated	20	0
7. Bentonite		2
8. Shale; weathers light gray and flaky; has light-gray limestone nodules about 3 ft above base; "*Gryphaea*" *newberryi* in float	6	0
Total Mancos Shale, main body (incomplete)	55	8+
Twowells Sandstone Tongue of the Dakota Sandstone:		
9. Sandstone, silty, calcareous; weathers pale yellowish gray; very fine grained; mostly massive; soft. USGS Mesozoic loc. D5772 has *Plicatula* sp. and *Metoicoceras* sp	12	0
10. Concretions, limestone, silty to sandy; weathers pale yellowish gray	1	0
11. Sandstone, calcareous; weathers pale yellowish gray; very fine grained	10+	0
Total Twowells Sandstone Tongue of the Dakota Sandstone	23+	0
Mancos Shale, lower part (incomplete):		
12. Interval unmeasured; thickness estimated	115	0
Total Mancos Shale, lower part (incomplete)	115	0

Alamo Day School measured section — lower part

[SE¼NE¼ sec. 12, T. 3 N., R. 7 W., Pueblo Viejo Mesa 7½-minute quadrangle, Socorro County, N. Mex.]

	Ft	*in*
Top of measured section.		
Mancos Shale, lower part (incomplete):		
13. Shale, may not be in place; incomplete section	30±	0

	Ft	in
Mancos Shale, lower part (incomplete) — Con.		
14. Shale, gray; grades up into gray shaly siltstone or mudstone	55	0
15. Limestone, brownish-gray, very silty to sandy; weathers to brown angular fragments		11
16. Bentonite		1
17. Shale, dark-gray; 2½ ft below top are rounded medium-gray calcareous concretions that weather gray. USGS Mesozoic loc. D5771, from concretions, contains *Inoceramus rutherfordi, Ostrea beloiti, Acanthoceras amphibolum*, and *Tarrantoceras* sp	24	6
18. Shale, gray; upper 6 in. contains gray limy sandstone concretions that have tendency toward cone-in-cone structure	17	3
19. Bentonite		1
20. Shale, gray	1	8
21. Bentonite		2
22. Shale, silty, gray; lower part is soft, clayey, silty sandstone	7	6
23. Sandstone, silty, soft; carbonaceous in lower part; upper 1–3 in. is hard quartzitic ledge former with "trace fossils"	3	0
24. Partly covered; mostly gray shale	27	5
25. Bentonite		1
Total Mancos Shale, lower part (incomplete)	167	8
Dakota Sandstone:		
26. Partly covered; mostly sandstone that is silty, carbonaceous, and very fine grained; poor subparallel bedding; soft; weathers grayish orange	5	0
27. Partly covered; mostly sandstone that is silty, clayey, very carbonaceous, very fine grained, and soft	3	0
28. Sandstone, yellowish-gray, fine-grained; coarser upward; crossbedded in tabular sets a few inches to 1 ft thick; in some places upper few beds are coarse grained with granules and pebbles. Top few inches is a brown iron-stained cap	8	0
29. Sandstone, carbonaceous, fine-grained, soft; grades upward to overlying unit	1	0
Total Dakota Sandstone	17	0
Triassic rocks (incomplete):		
30. Claystone, pale-yellowish-green; a few inches of iron-stained clay at top	10+	0
Total Triassic rocks (incomplete)	10+	0

LA VENTANA AREA

The Dakota-Mancos sequence crops out in hogbacks along the west flank of the Sierra Nacimiento on the east side of the San Juan Basin near La Ventana. The exposures are incomplete and partly covered, but lateral tracing between nearby partial sections allows reasonable certainty about the sequence of rock units. The upper part of the Dakota-Mancos sequence is fairly well exposed in the Tafoya Dam section, and the lower part was examined where San Miguel Canyon cuts through the Dakota hogback northeast of La Ventana.

A sequence of soft limy sandstone about 12½ feet thick (units 19 and 20, Tafoya Dam section) probably represents the Two-wells Sandstone Tongue of the Dakota Sandstone. Some sandy shale and sandstone (units 25 and 26, Tafoya Dam section) may possibly be an extremely attenuated representative of the Paguate Sandstone Tongue of the Dakota Sandstone, but they are not so designated in the La Ventana area because rocks in the same stratigraphic position at other nearby places are all shale. The resistant ledge-forming sandstone part of the Dakota-Mancos sequence in the area (units 1 and 2, San Miguel Canyon section) may be the lateral equivalent of the Cubero Sandstone Tongue of the Dakota Sandstone, and the shale and sandstone sequence that underlies the ledge-forming sandstone may be equivalent to the Oak Canyon Member of the Dakota. However, the rocks in La Ventana area are not here so divided because the rocks in much of the outcrop area between La Ventana and the Rio Puerco are partly or wholly concealed or have not been examined in detail and because no fossils have been found that would aid in correlation.

Tafoya Dam measured section

[SW¼SE¼ sec. 14, T. 19 N., R. 1 W., La Ventana 15-minute quadrangle, Sandoval County, N. Mex. Measured by C. H. Dane, Oct. 1959, and by C. H. Dane, E. R. Landis, W. A. Cobban, E. G. Kauffman, and G. R. Paulson in 1963–65]

Top of measured section.

Mancos Shale, main body (incomplete):	*Ft*	*in*
1. Limestone; weathers very light gray	1	0
2. Shale, calcareous, medium-gray	9	0
3. Bentonite		2
4. Shale, calcareous, medium-gray	3	6
5. Bentonite		2
6. Shale, calcareous, medium-gray	6	0
7. Bentonite, iron-stained, gypsiferous		11
8. Shale, calcareous, medium-gray	7	10
9. Bentonite, gypsiferous		4
10. Shale, calcareous, medium-gray	10	0
11. Limestone, gray, concretionary; contains *Sciponoceras gracile*		6
12. Shale, calcareous, medium-gray	32	0
13. Bentonite		6
14. Shale, medium-dark-gray; calcareous in part	17	0
15. Bentonite		2

	Ft	in
Mancos Shale, main body (incomplete) — Con.		
16. Shale, medium-dark-gray	1	6
17. Bentonite		2
18. Shale, medium-dark-gray	10	6
Total Mancos Shale, main body (incomplete)	101	3
Twowells Sandstone Tongue of the Dakota Sandstone:		
19. Sandstone, light-yellowish-gray; clayey in part; has rounded limy concretionary masses as much as 8 in. thick and 1 ft long in the upper part	10	6
20. Concretions, limy, sandy; as much as 4 ft long; contains *"Mantelliceras" canitaurinum*	2	0
Total Twowells Sandstone Tongue of the Dakota Sandstone	12	6
Mancos Shale, lower part:		
21. Mostly covered; principally shale	3	6
22. Bentonite		1
23. Mostly covered; principally shale	40	0
24. Bentonite		1
25. Shale, silty, medium-gray; sandy in middle	1	10
26. Sandstone, glauconitic; mostly medium grained but has some coarse grains and some black and red siliceous granules; has *Inoceramus* cf *I. nahwisi* and *Metoicoceras praecox*		3
27. Shale, silty and sandy	1	2
28. Mostly covered; has thin (1-in.?) bentonite bed 2 ft above base	5	3
29. Sandstone, very limy, very light yellowish gray; interbedded with platy light-gray sandy limestone	1	5
30. Bentonite		2
31. Shale, dark-gray	4	8
32. Bentonite		1
33. Shale, very dark gray		9
34. Bentonite		11
35. Shale, very dark gray	2	4
36. Bentonite		1
37. Shale, dark-gray; has 1-in.-thick light-gray-weathering siltstone near middle	35	1
38. Limestone, black; weathers very light gray; lenticular		3
39. Shale, dark-gray	17	0
40. Sandstone, gray; abundant trails and borings; contains *"Gryphaea"* sp		4
41. Shale, dark-gray	17	10
Total Mancos Shale, lower part	133	1

Top of ledge-forming Dakota Sandstone.

San Miguel Canyon measured section

[Near line between secs. 1 and 2, T. 19 N., R. 1 W., La Ventana 15-minute quadrangle, Sandoval County, N. Mex. Measured by C. H. Dane and E. R. Landis, July 12, 1966]

Top of measured section.

	Ft	in
Dakota Sandstone, main body:		
1. Sandstone, silty, light-yellowish-gray; in beds as much as 2 ft thick alternating with 6-in.-thick beds of gray siltstone	11	0
2. Sandstone, light-gray; weathers pale red in upper part; in beds 8–20 in. thick; abundant borings and trails in upper part; upper 31 ft forms resistant ledge, lower part is softer, massive, light gray to white	66	0
3. Partly covered; seems to be all flaky light-brown-weathered shale	54	0
4. Sandstone, very light gray; weathers grayish orange to moderate brown; very fine grained; brown to black plant fragments and carbonaceous streaks and spots	2	8
5. Partly covered; seems to be all dark-gray shale	4	2
6. Bentonite	1	10
7. Shale, carbonaceous, silty, very dark gray to light-brown	7	5
8. Sandstone, very light gray, very fine grained; interbedded light-gray to white siltstone	2	5
9. Sandstone; weathers grayish yellow to pale brown; fine grained; some plant fragments in upper part; resistant beds as much as 2½ ft thick	6	0
Total Dakota Sandstone, main body	155	6
Morrison (?) Formation:		
10. Sandstone, white, mostly fine grained, crossbedded; some pebbly coarse-grained laminae	Unmeasured	

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[Letters designate the separately published chapters]

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