New Mexico Bureau of Mines & Mineral Resources

Open-File Report 90

Descriptions of Sections Measured for Hydrogeologic Study of the San Juan Basin, Northwest New Mexico

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INTRODUCTION

Overview of Hydrogeologic Study

In July 1972, the New Mexico Bureau of Mines and Mineral Resources undertook a study of the ground-water resources in the New Mexico portion of the San Juan Basin to determine the availability of water supplies for coal surface mining. The initial project was funded in part through a grant from the New Mexico Water Resources Research Institute and by contributions from El Paso Natural Gas Company, Peabody Coal Company, and Western Coal Company. The scope of the project was expanded in 1974 to include the entire water-resource/energy spectrum in the area, and the study was continued as a cooperative effort of the Bureau, the Water-Resources Division of the U.S. Geological Survey, and the New Mexico State Engineer's Office.

In the present study the Bureau is responsible for characterizing the geologic framework of the Basin and helping evaluate the extent to which this framework controls the ground-water system(s) operative there. To accomplish this the Bureau part of the study has involved:

1. Preparation of maps showing elevation of top (structure), depth to top, and total thickness for all potential aquifers in the Basin.
2. Construction of a series of geologic cross sections to show the position, structure, thickness, and lateral continuity of Jurassic and younger strata in the Basin.

3. Field measurement, description, and selective sampling of representative stratigraphic sections for major rock units in the Basin.
4. Analysis of the petrography (texture, porosity, and composition) of major aquifers and selected confining layers in the Basin.

Purpose of This Report

Although much useful hydrogeologic information has already been compiled by both the U.S. Geological Survey and the Bureau, the project was scheduled to run for 5 years, and final reports will not appear before 1980. Presently there is considerable resource-development activity in the San Juan Basin, and the need for hydrogeologic information is urgent. To assure that interested parties have ready access to at least the basic data of our study prior to the completion of the final report, it was decided that a series of Open-File Reports be prepared: the Survey would report the basic hydrologic data (well records and water chemistry) and the Bureau would give the basic geologic data. As outlined above, the Bureau's geologic effort has included surface and subsurface stratigraphic studies as well as various petrographic analyses. The purpose of this report is to release the results of the Bureau's surface stratigraphic study of the San Juan Basin. Results of the subsurface stratigraphic study are reported in OF-89 (Stone and Mizell, 1978). Petrographic data are presented in OF-91.

The San Juan Basin

The San Juan Basin is a Laramide depression at the eastern edge of the Colorado Plateau. The Basin covers about 30,000 mi^2 in northwestern New Mexico and southwestern Colorado (figure 1). Structural relief in the Basin amounts to about 6,000 ft; monoclines are the most prominent structures. Faults are known to be abundant along the southern margin of the Basin, but the occurrence of soft shales at the surface of much of the area hinders field recognition of faulting outside this area.

The hydrogeologic study of the San Juan Basin has focused mainly on the Morrison Formation (Jurassic) and overlying rock units because 1) except in a narrow belt near the outcrop, underlying deposits are generally too deep in most of the Basin to be economically useful as aquifers, 2) the hydrologic and geologic characteristics of the deeper units are too poorly known, and 3) present energy development, specifically uranium mining, directly involves no units deeper than the Morrison. The stratigraphic framework and nomenclature of the deposits of interest in the present study are given in figure 2. In general, this sequence of deposits reflects a shift from largely continental deposition in Triassic and Jurassic times, to alternating marine/nonmarine shorezone deposition in Cretaceous time, then back to strictly, non-shorezone, continental deposition in Tertiary time.

More specifically, the Entrada-Todilto-Sumerville-Zuni/Bluff/Cow-Springs interval probably represents deposition in various desert environments (eolian dune field, inland sebkha,

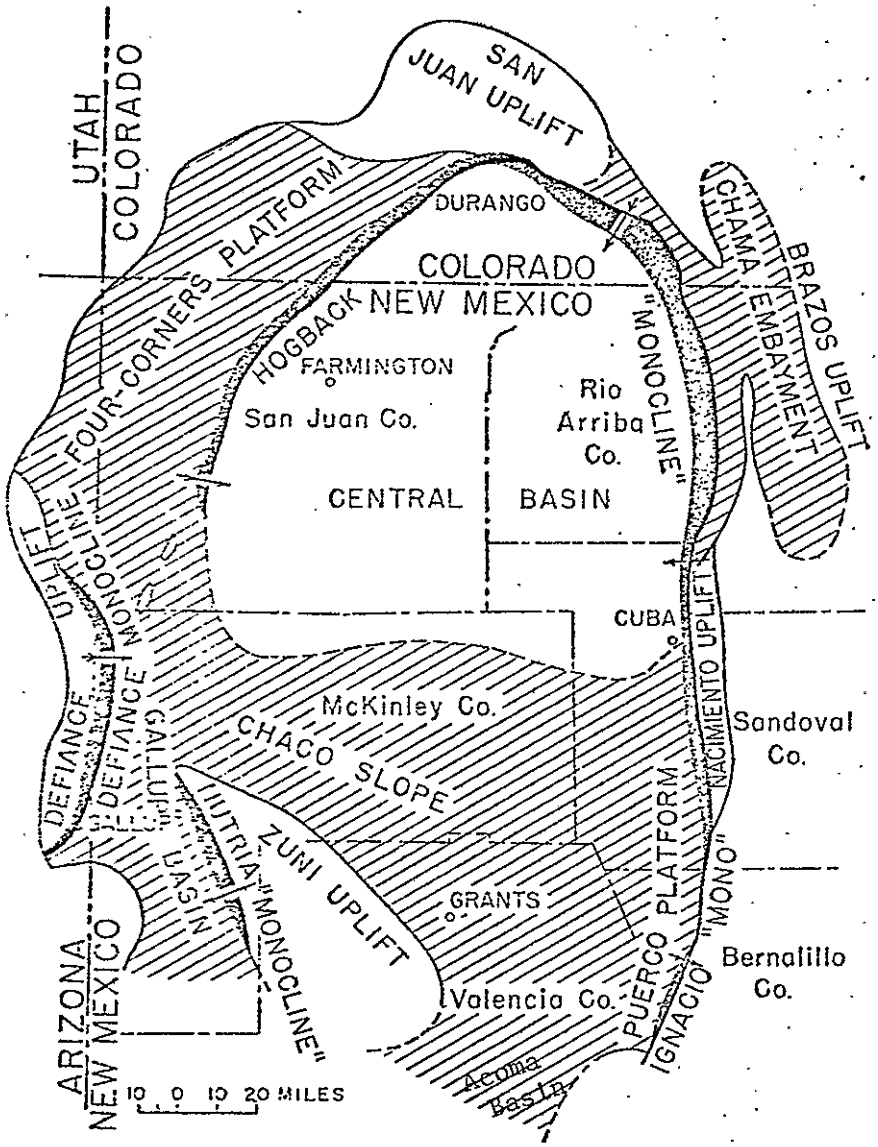

Figure 1. Location and structural elements of the San Juan Basin (as modified from Kelley, 1951, by Beaumont and others, 1976).

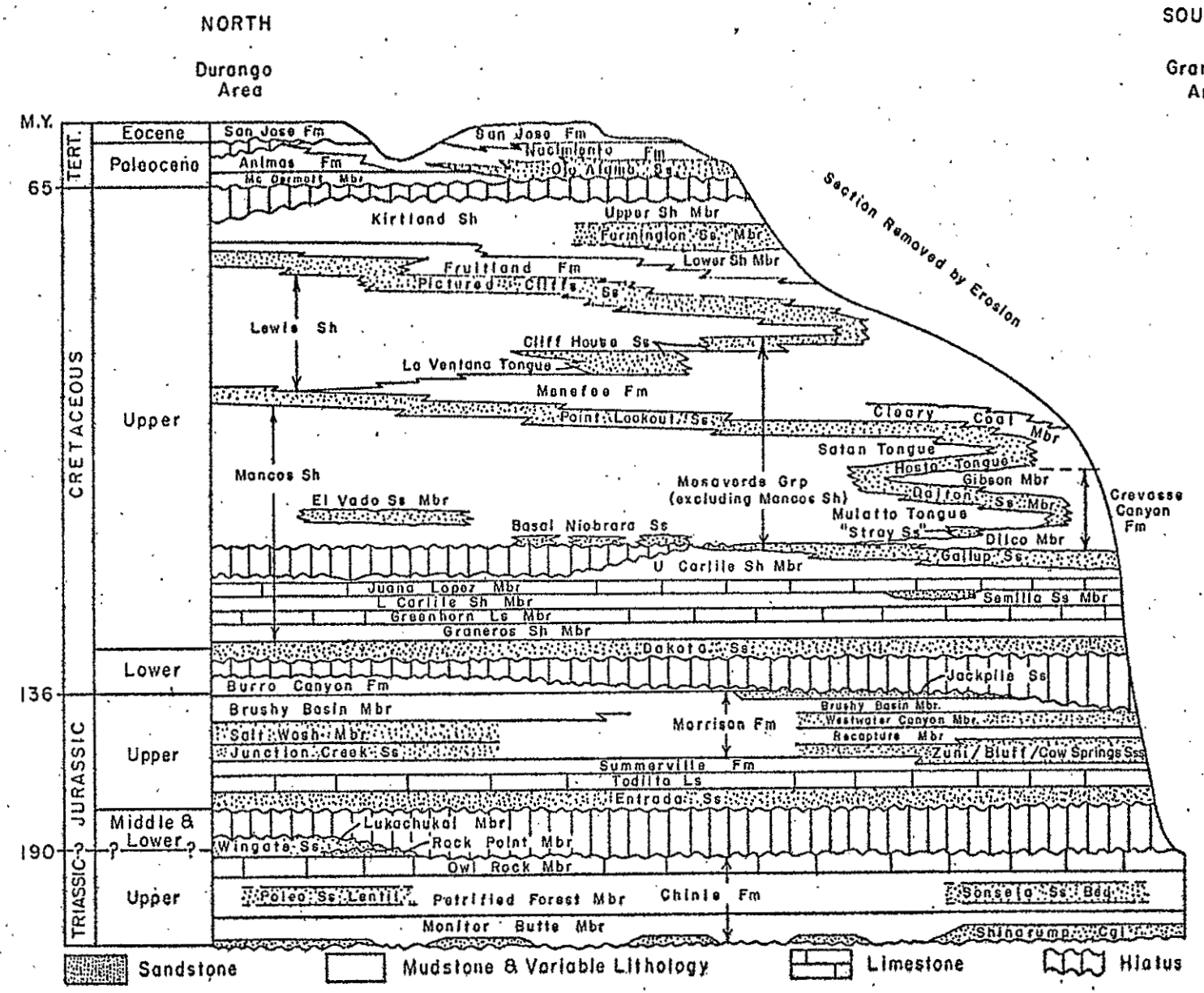

Figure 2. Time-stratigraphic framework and nomenclature, Triassic through Tertiary, San Juan Basin (modified from Molenaar, 1977).

lake). The Morrison Formation represents depositions under wetter conditions, perhaps alternating meandering/braided fluvial stream systems. The Dakota Sandstone records the initial invasion of this portion of North America by the vast Cretaceous seaway which extended from the Arctic Ocean to the Gulf of Mexico some 135 million years ago. The Mesaverde Group of the San Juan Basin records the alternating transgressive/regressive shorezone deposition that characterized this sea. Transgressions are represented by the Dakota Sandstone, Borrego Pass Lentil of the Crevasse Canyon Formation, Hosta Tongue of the Point Lookout Sandstone, and the Cliff House Sandstone. Regressions are documented by the Gallup Sandstone, Dalton Sandstone Member of the Crevasse Canyon Formation, the main body of the Point Lookout Sandstone, and the Pictured Cliffs Sandstone. With the final retreat of the sea, marked by the deposition of the Pictured Cliffs Sandstone, nonmarine conditions returned and prevailed throughout Paleocene and Eocene time. To date no Oligocene deposits have been found in the Basin proper, suggesting they have been subsequently eroded or that the modern erosional cycle was initiated as early as Oligocene time.

Previous Stratigraphic Work

Although it is beyond the scope of this report to review the vast amount of stratigraphic work that has been done over the years on the San Juan Basin, it is appropriate to identify for the reader selected references which also contain detailed

measured-section descriptions. Most of these works contain excellent bibliographies which give additional references. Numerous stratigraphic reports were also cited in Open-File Report 89 (Stone and Mizell, 1978).

Sections of uppermost Triassic and Jurassic deposits were given by Renick (1931), Allen and Balk (1954), Harshbarger and others (1957), and Cooley and others (1964). Smith (1954), Freeman and Hilpert (1956), and Hutson (1958) described sections of the Morrison Formation. Hutson (1958), Owen (1963, 1966), and Landis and others (1973) gave measured sections of the Dakota Sandstone. Sections of various parts of the Mesaverde Group were presented by Gardner (1909), Pike (1947), Allen and Balk (1954), Dane and others (1957, 1966, 1968), Hutson (1958), Mannhard (1976), and Shetiwy (1978). Dilworth (1960) described sections for the Farmington Sandstone Member of the Kirtland Shale. Sections of the Tertiary deposits of the basin were given by Sinclair and Granger (1914), Reeside (1924), Simpson (1948), Baltz and others (1966), Baltz (1967), Powell (1972), and Brown (1976).

Acknowledgements -- A number of the sections were measured by or with the assistance of geoscience graduate students at New Mexico Tech, while Bureau research assistants under my supervision. These include Scott Anderholm, Bob Brod, Dan Brown, Steve Craigg, and Lou Fleischhauer. Terry Siemers and Bob Osburn assisted in measuring one section during a class field trip. The identity of the

person(s) who measured a given section is indicated in the heading portion of the description.

MEASURED SECTIONS

Approach and Methods

Stratigraphic sections were measured in conjunction with the hydrogeologic study in order to provide detailed information on the lithology of the major aquifers and adjacent strata. Although the number and location of sections measured do not permit detailed regional correlation, the sections selected are believed to be representative of the strata in the area involved.

Sections were generally measured by means of a Jacob's staff and Abney level, adjusted for local dip. Where this method was not feasible, such as across steep cliffs, a steel tape was employed. The thickness of extensive intervals of shale, especially where they occupy broad valley floors, was determined by geometric means (Compton, 1962, Fig. 12-21, 12-22).

Bedding size was measured with Jacob's staff, steel tape, or pocket ruler. Grain sizes were measured with a pocket ruler or estimated from comparison with a sand card. Sorting was estimated using Folk's (1974) sorting images. Roundness of grains was determined by comparison with examples on a sand card or Powers (1953) chart. Mineralogy, matrix, and cement were determined by hand lens and acid (dilute HCl) bottle.

Format and Terminology

The descriptions which follow start at the top of the section and proceed downward, down the page. Numbering of field units was from the base of sections upward. The format used in describing the units is generally as follows:

> GENERAL ROCK TYPE--color; bedding/internal structure; other primary structures; texture; composition, matrix, cement; special constituents, concretions/nodules, fossils; contact with above.

The source and definition of all descriptive terms used in the descriptions are given in the Appendix.

Using This Report

Measured sections of interest may be identified in either of two ways: by stratigraphic unit or by locality. The distribution of sections by unit is shown in Table 1. The section number is a key to the county in which the section is located and thus identifies the area under which it is described: SJ in the number indicates San Juan County (Area 1), MK = McKinley County (Area 2), RA = Rio Arriba County, S = Sandoval County, and V = Valencia County (all in Area 3). Coverage by locality is shown on Plate 1 and cataloged in Tables 2 - 4.

Table 1. List showing distribution of measured sections by stratigraphic unit; Trc = Chinle Fm., Trw = Wingate Ss., Je = Entrada Ss., Jt = Todilto Ls., Js = Summerville Fm., Jb = Bluff Ss., Jcs = Cow Springs Ss., Jm = Morrison Fm., Kd = Dakota Ss., Km = Mancos Sh., Kg = Gallup Ss., Kcc = Crevasse Canyon Fm., Kpl = Point Lookout Ss., Kmf = Menefee Fm., Kch = Cliff House Ss., Kpc = Pictured Cliffs Ss., Kf = Fruitland Fm., Kk = Kirtland Sh., Ta = Animas Fm., Toa = Ojo Alamo Ss., Tn = Nacimiento Fm., Tsj = San Jose Fm., Qal = alluvium, Qat = terrace gravel

Unit	Measured Sections Covering Unit
Qal/Qat	SJ1W - 3,4A,5,6,7; SJ1E - 1; SJ2 - 6
Tsj	SJ2 - 7
Tn	SJ2 - 6,7
Toa	SJ1W - 4B; SJ2 - 5,6; RA - 3
Ta	SJ1W - 4B
Kk	SJ1W - 4A,4B,5; SJ2 - 4; RA - 3
Kf	SJ2 - 3B; RA - 3
Kpc/Kl	SJ1W - 3; SJ2 - 3A; RA - 3
Kch	SJ1W - 2B; SJ2 - 1,2; S - 2; RA - 2
Kmf	SJ1W - 2B; SJ2 - 1; S - 2; RA - 2
Kpl/Km	SJ1W - 1,2A; MK3W - 1E; MK3E - 1,3; RA - 2
Kcc/Km	MK3W - 1C,1D,1E; MK3E - 1,3
Kg/Km	SJ3 - 4,5; MK3W - 1C; MK3E - 1,2; V-1
Kd/Km	SJ3 - 2,3; MK3W - 1A,1B; MK3E - 1,2; S - 1; RA - 1
Jm	SJ3 - 1,3; MK3W - 1A; MK3E - 1,2; RA - 1
Jb/Jcs	SJ3 - 1; MK3W - 1A; MK3E -1,2
Js	SJ3 - 1; MK3W - 1A; MK3E - 1,2
Jt	MK3W - 1A; MK3E - 1,2; S - 3
Je	SJ3 - 1; MK3W - 1A; MK3E - 1,2; S - 3
Trw	MK3E - 1,2
Trc	MK3E - 2; S - 3

AREA 1 SECTIONS (San Juan County)

The first area covered in the hydrogeologic study was San Juan County. This area is important in that it is the site of two major coal mines, is crossed by the San Juan River, and includes the northwestern discharge point of the deep ground-water flow system. It is also unique in that all of the major rock units covered by the project crop out within its boundaries. Sections were selected for measurement so as to cover as many of these units as possible. Table 2 lists sections measured by location, gives the stratigraphic intervals covered, and identifies the pages where the descriptions may be found.

Table 2. Catalog of sections measured in Area 1 (San Juan County) by location; parentheses indicate location based on projected land grid. Abbreviations for units same as in Table 1.

Location (sec., T, R)	Section No.	Units Covered	Page
AREA 1 WEST--north of San Juan River, west of La Plata River			
(7, 31N, 16W)	SJ1W - 1	Km, Kpl	13
5, 29N, 16W	SJ1W - 2A	Kpl	15
4, 29N, 16W	SJ1W - 2B	Kmf, Kch	17
32, 30N, 15W	Sj1W - 3	Kl, Kpc, Qat	24
31, 30N, 13W	SJ1W - 4A	Kk, Qat	27
24, 30N, 14W	SJ1W - 4B	Ta, Toa	29
7, 29N, 13W	SJ1W - 5	Kk, Qat	32
10, 29N, 14W	SJ1W - 6	Qat	33
33, 30N, 15W	SJ1W - 7	Qat	34
AREA 1 EAST--north of San Juan River, east of La Plata River			
22, 29N, 13W	SJ1E - 1	Qat	35
Additional sections measured in this area for the hydrogeologic study were presented by Brown (1976).			
AREA 2--south of San Juan River, east of US 666			
27 & 33, 21N, 10W	SJ2 - 1	Kmf, Kch	36
13, 22N, 13W	SJ2 - 2	Kch	38
(14, 28N, 16W)	SJ2 - 3A	Kpc	40
(14, 28N, 16W)	SJ2 - 3B	Kf	42
21, 29N, 13W	SJ2 - 4	Kk	45
29, 29N, 13W	SJ2 - 5	Toa	47
36, 29N, 13W	SJ2 - 6	Toa, Tn, Qat	48
7 & 18, 27N, 10W	SJ2 - 7	Tn, Tsj	52
AREA 3--south of San Juan River, west of US 666			
11, 30N, 21W	SJ3 - 1	Je, Js, Jb, Jm	53
27, 30N, 20W	SJ3 - 2	Kd	56
34, 28N, 20W	SJ3 - 3	Jm, Kd	57
21, 30N, 19W	SJ3 - 4	Kg	60
17, 27N, 19W	SJ3 - 5	Kg	62

SECTION SJ1W-1, MONUMENT ROCKS (Chimney Rock 15' Quad.). West-facing slope along east side of dirt road which climbs southward onto mesa top just east of Atlantic Richfield Many Rocks Gallup well no. 3 (NE¼, NW¼, sec. 7, T31N, R16W, San Juan County); about 11 air miles northeast of junction of US 550 and US 666 in Shiprock, 8½ miles due east of US 666, and about 2 miles due west of boundary between Navajo and Southern Ute Indian Reservations; section measured by William J. Stone and Daniel R. Brown, 15 July 1975.

Unit	Lithology	Thickness: m(ft)
POINT LOOKOUT SANDSTONE		
2	SANDSTONE--very pale orange (10 YR 8/2) - grayish orange (10 YR 7/4) weathered and fresh, some weathers dark reddish brown (10 R 3/4); beds medium - very thick, regular, even, with thin planar - wavy, continuous, parallel - converging laminae; symmetrical ripple marks in base of first thick sandstone interval above base of section with crest orientations of S 65° E and S 63° E at 2 horizons 3 dcm apart; large-scale, concordant, low-angle, grouped, trough cross bedding in thicker beds; the bases of some beds reveal tool marks; orientations of S 10° W and S 25° W were measured from bases of separate sand bodies; grains fine, moderately - well sorted, subangular - subrounded; composed mainly of quartz with clay matrix and calcite cement; in lower part interbedded with thin - thick, regular, uneven beds of carbonaceous siltstone with climbing ripples and carbonaceous shale; in the sandstone, some flat feeding trails(?) observed on bedding surfaces and small, vertical, smooth burrows observed locally; basal surfaces of sandstones and siltstones sharp, locally disconformable.	75.5 (249.2)
MANCOS SHALE		
1	SILTSTONE AND SHALE SILTSTONE--very pale orange (10 YR 8/2) - grayish orange (10 YR 7/4) weathered and fresh, some also weathers dark reddish brown (10 R 3/4); beds thin - medium, regular, even with thin planar - wavy,	25.4 (83.8)

continuous, parallel to convergent laminae; climbing ripple marks in wavy bed about 3 dcm thick; very calcareous; carbonaceous plant debris abundant, muscovite minor; basal contacts of beds sharp, erosional(?) but upper contacts of beds gradational.

SHALE--yellowish gray (5 Y 7/2) - light olive gray (5 Y 6/1) weathered, yellowish gray - medium gray (N5) fresh; beds thin, regular, even, with planar, continuous, parallel laminae; not calcareous; contains carbonaceous plant debris; basal contacts of beds gradational but upper contacts sharp, erosional.

Contact of unit 1 with unit 2 above is sharp, erosional.

Total section thickness = 100.9 (356.4)

The base of the Mancos Shale is not exposed at this locality; measurement was begun at the base of the cliff south of Salt Creek and proceeded up the road.

SECTION SJ1W-2A, THE HOGBACK (Chimney Rock 15' Quad.). West-facing slope just south of unnamed arroyo cut through west edge of hogback about ½ mile due north of US 550; 8 air miles southeast of jct of US 550 and US 666 in Shiprock; NW¼, SE¼, sec. 5, T29N, R16W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 15 July 1975.

Unit	Lithology	Thickness: m(ft)
POINT LOOKOUT SANDSTONE		
4	SANDSTONE--pinkish gray (5 YR 8/1) weathered and fresh; beds thick - very thick, irregular, uneven, with thin, curved, discontinuous, converging laminae; large-scale, concordant - tangential, low-angle, grouped, trough cross bedding; grains medium, very well sorted, subrounded - rounded; composed mainly of quartz, with little if any matrix, not calcareous; some spherical, iron-stained concretions up to 1 dcm or so in diameter; where measured, contact with overlying Menefee Formation coincides with north-south dirt road which passes dump and old coal mines.	7.1 (23.4)
3	COVERED INTERVAL--may consist of soft, platy sandstone based on small exposure north of where measured or may be sandstone like unit 2 based on exposures to south where unit 2 is continuous to base of unit 4.	8.2 (27.1)
2	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, irregular, uneven, with thin curved - planar, continuous - discontinuous, parallel - converging laminae; vague suggestion of cross bedding locally; grains very fine - fine at base and medium at the top, well sorted, subrounded - rounded; composed mainly of quartz, with little matrix, calcareous; top covered.	18.3 (60.4)
1	ALTERNATING SANDSTONE AND SHALE SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds medium - very thick, regular, uneven, with thin, planar - wavy, continuous, parallel - convergent laminae; some small scale ripple bedding; grains very fine, well sorted, subrounded	59.7 (197.0)

- rounded; composed mainly of quartz with limonitic staining in some laminae and clay matrix, calcareous.

SHALE--light brownish gray (5 YR 6/1) - grayish orange (10 YR 7/4) weathered and fresh, beds very thin, irregular, uneven.

Contact of unit 1 with overlying unit is sharp, conformable(?)

Total section thickness = 93.3 (307.9)

Measurement began at top of Mancos Shale (base of lowest sandstone on west slope of hogback). Overlying units at this locality described in section SJ1W-2B.

SECTION SJ1W-2B, THE HOGBACK (Chimney Rock 15' Quad.). West-facing slopes of central and eastern part of hogback about 1/4 mile due north of US 550; about 8 air miles southeast of junction of US 550 and US 666 in Shiprock; SW¼, SW¼, sec. 4, T29N, R16W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 16 July 1975.

Unit	Lithology	Thickness: m(ft)
	CLIFF HOUSE SANDSTONE	
48	SANDSTONE--very pale orange (10 YR 8/2) - grayish orange (10 YR 7/4) weathered and fresh, some weathers pale yellowish orange (10 YR 6/6); beds medium - very thick, fairly regular, uneven, with thin, planar - wavy, continuous - discontinuous, parallel - convergent laminae; symmetrical straight-crested, ripple marks in upper part having a crest height of 6 mm and a wave length of 6 cm; grains very fine, very well sorted, subrounded - rounded; composed mainly of quartz with little matrix, calcareous; some horizontal burrows in lower part; contact with overlying Lewis Shale concealed by colluvium east of steep dip slope on east side of hogback. Lower 40.8 m taped; rest measured by Jacob's staff and Abney level.	128.9 (425.4)
47	SHALE AND SANDSTONE:	74.6 (246.2)
	SHALE--olive gray (5 Y 3/2) - medium dark gray (N4) weathered and fresh; as below.	
	SANDSTONE--unit is largely shale but contains a few beds of sandstone like unit 46.	
	Contact with above sharp; measured up to base of first thick sandstone (unit 48); locally there are sandstones like unit 48 lower but these are discontinuous.	
46	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh, some weathers dark yellowish orange (10 YR 6/6); beds medium - very thick, regular, uneven, with thin planar, continuous, parallel laminae; hint of cross bedding in places; grains very fine, very well sorted; subrounded - rounded; composed mainly of quartz with little matrix, slightly calcareous; knobby weathering near base; contact with above sharp.	21.9 (72.3)

MENEFEE FORMATION

45	CARBONACEOUS SHALE--olive gray (5 Y 3/2) - brownish black (5 YR 2/1) weathered and fresh; as below with thin sandy zones.	12.7 (41.9)
44	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds medium - thick, irregular, uneven, with thin, curved, discontinuous, convergent laminae; some contorted and ripple bedding; grains very fine - fine, well sorted, subrounded - rounded; composed mainly of quartz, calcareous; contact with above sharp.	2.7 (8.9)
43	CARBONACEOUS SHALE--like unit 41 below	13.6 (44.9)
42	SANDSTONE--grayish orange (10 YR 7/4); beds thin - medium, irregular, uneven, with thin, curved, discontinuous, convergent laminae; grains fine, well sorted, subrounded - rounded; composed mainly of quartz, slightly calcareous; rusty stain locally; contact with above sharp.	1.0 (3.3)
41	CARBONACEOUS SHALE--olive gray (5 Y 3/2) - brownish black (5 YR 2/1) weathered and fresh; as below with thin sandy zones.	23.1 (76.2)
40	LIMY SANDSTONE--moderate yellowish brown (10 YR 5/4) weathered, grayish orange (10 YR 7/4) fresh; beds medium, irregular, uneven, with thin, curved, discontinuous, convergent laminae; grains very fine to fine, well sorted, subrounded - rounded; composed of quartz and large amount of calcite; contact with above sharp.	2.4 (7.9)
39	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - brownish black (5 YR 2/1) weathered and fresh; as below.	8.3 (27.4)
38	SANDSTONE--grayish orange (10 YR 7/4) - very pale orange weathered and fresh; beds medium - thick, irregular, uneven, with thin, curved, discontinuous, convergent laminae; grains fine - medium, well sorted, subrounded - rounded; composed mainly of quartz, calcareous; contact with above sharp.	3.1 (10.2)
37	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) and brownish black (5 YR 2/1) weathered and fresh; contains several COAL beds a few dcm thick; contact with above sharp.	22.1 (72.9)

36	SANDSTONE--grayish orange (10 YR 7/4) weathered and very pale orange (10 YR 8/2) fresh; beds thick, irregular, uneven, with thin, curved, discontinuous, convergent laminae; grains fine - medium, well sorted, subrounded - rounded; composed mainly of quartz, slightly calcareous; rusty stain throughout, upper part platy; contact with above sharp.	3.9 (12.9)
35	CARBONACEOUS SHALE--grayish orange pink (10 YR 7/4) - grayish orange (10 YR 7/4); as below.	7.2 (23.8)
34	SANDSTONE--grayish orange (10 YR 7/4) weathered and moderate brown (10 YR 5/4) fresh; beds medium, irregular, uneven, with medium, curved, discontinuous, convergent laminae; grains very fine - fine, well sorted, subrounded - rounded; composed of quartz with large amount of calcite; contact with above sharp.	1.6 (5.3)
33	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - olive gray (5 Y 3/2) weathered and fresh; contains 1-m thick COAL bed near top.	18.2 (60.1)
32	SANDSTONE--grayish orange (10 YR 7/4) weathered and very pale orange (10 YR 8/2) fresh; beds medium - thick, irregular, uneven, with thin planar - curved, discontinuous, parallel - convergent laminae; grains fine, well sorted, subrounded - rounded; composed mainly of quartz, little matrix, not calcareous; rusty staining in places, very platy at top; contact with above sharp.	1.5 (5.0)
31	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - grayish orange (10 YR 7/4) weathered and fresh; as below.	4.9 (16.2)
30	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds medium - thick, irregular(?), uneven(?), thin, curved, discontinuous, convergent laminae; grains fine, well sorted, subrounded - rounded; composed mainly of quartz, little matrix, not calcareous; iron stained; not well exposed.	1.3 (4.3)
29	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) weathered and fresh; as below.	3.8 (12.5)

28	SANDSTONE--grayish orange pink (10 YR 7/2) weathered and very pale orange (10 YR 8/2) fresh; beds thick, irregular, uneven, with thin, curved, discontinuous, convergent laminae; grains fine - medium, well sorted, subrounded - rounded; composed mainly of quartz, little matrix, calcareous; contact with above sharp.	5.1 (16.8)
27	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - very pale orange (10 YR 8/2) weathered and fresh; as below.	4.3 (14.2)
26	SANDSTONE--grayish orange pink (10 YR 7/2) weathered and very pale orange (10 YR 8/2) fresh; beds medium - thick, regular, even, with thin, curved, discontinuous, convergent laminae; grains fine, well sorted, subrounded - rounded; composed mainly of quartz, minor clay matrix, slightly calcareous; ironstone concretions up to a few cms in diameter; contact with above sharp.	2.4 (7.9)
25	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - grayish orange pink (5 YR 7/2) weathered and fresh; as below.	5.1 (16.8)
24	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thin - medium, irregular, uneven, massive; grains fine - medium, moderately to well sorted, subrounded - rounded; composed mainly of quartz with plant debris and mud chips, not calcareous; contact with above sharp.	1.3 (4.3)
23	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - olive gray (5 Y 3/2) weathered and fresh; as below.	4.2 (13.9)
22	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thick, irregular, uneven, with thin, curved, discontinuous, convergent laminae; grains fine - medium, well sorted, subrounded - rounded; composed mainly of quartz, little matrix, calcareous; contact with above sharp.	0.6 (2.0)
21	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - dark yellowish brown (10 YR 4/2) weathered and fresh; as below but silty, platy in basal m; some sandstone lenses (<4 dcm thick) also occur within unit; cone-in-cone structure noted in layer near top.	13.3 (43.9)

20	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds medium, regular, even, with thin planar, continuous, parallel laminae; grains very fine - medium, well sorted, subrounded - rounded; composed mainly of quartz with little matrix, slightly calcareous; contact with above sharp.	1.0 (3.3)
19	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) weathered and fresh; as below.	5.2 (17.2)
18	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thick, irregular, uneven, with thin, curved, discontinuous, convergent laminae; grains medium, well sorted, subrounded; composed mainly of quartz and a fair amount of calcite; ironstone concretions up to a few cm in diameter, carbonate concretions up to 4 dcm in diameter; contact with above sharp.	3.5 (11.6)
17	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - olive gray (5 Y 3/2); as below but with thin poor-quality COAL near base; 2 sandstone bodies seem to occur within this interval to the north; poorly exposed.	13.6 (44.9)
16	SANDSTONE--grayish orange (10 YR 7/4) - dark yellowish brown (10 YR 4/2) weathered and very pale orange (10 YR 8/2) fresh; beds thick - very thick, irregular, uneven, with thin, curved, discontinuous, convergent laminae; large-scale, concordant, high-angle, grouped, trough cross bedding (22° S 45° E and 12° due E measured in 2 approximate trough axes); grains fine, well sorted, subrounded - rounded; composed mainly of quartz, little matrix, not calcareous; contact with above concealed.	5.6 (18.5)
15	CARBONACEOUS SHALE--moderate brown (5 YR 4/4) weathered and yellowish gray (5 Y 7/2) fresh; as below but poorly exposed; contact with above sharp.	10.2 (33.7)
14	LIMY SANDSTONE - SANDY LIMESTONE--grayish orange (10 YR 7/4) weathered and fresh in lower 2/3, dark yellowish brown (10 YR 4/2) weathered and fresh in upper 1/3; beds medium-thick, irregular, uneven, with thin, planar - curved, discontinuous, parallel - convergent laminae in the lower	7.6 (25.1)

	2/3, and thin - medium, irregular, uneven with thin, curved, discontinuous, convergent laminae in the upper 1/3; both parts contain large-scale, concordant - tangential, low-angle, grouped, trough cross bedding; grains medium, well sorted, subrounded - rounded; lower part composed mainly of quartz but upper part contains large amount of calcite; ironstone concretions having diameters up to 1 dcm in lower part; has platy weathering habit in upper part; contact with above concealed.	
13	CARBONACEOUS SHALE--moderate brown (5 YR 4/4) weathered and yellowish gray (5 Y 7/2) fresh; as below; thickness varies as a function of depth of scour by unit 14 above; 4-5 m thicker to north of where measured; contact with above sharp.	12.2 (40.3)
12	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thick - very thick, irregular, uneven, with thin, planar - curved, discontinuous, parallel - convergent laminae; large-scale, concordant - tangential, low-angle, grouped, trough and tabular cross bedding (1 trough-axis measurement gave 6° N 70° W; 3 measurements of tabular sets in cross section gave 11°, 12°, and 12° N 30° W); grains fine, well sorted, subrounded; composed mainly of quartz with carbonaceous plant debris along some laminar surfaces, clay matrix, not calcareous; ironstone concretions with diameters up to 5 cm; contact with above poorly exposed.	6.6 (21.8)
11	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) - olive gray (5 Y 3/2) weathered and fresh; as below; largely covered; contact with above sharp, disconformable.	11.7 (38.6)
10	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thick, irregular, uneven, with thin obscure laminae; grains fine, well sorted, subrounded; composed mainly of quartz, slightly calcareous; poorly exposed.	1.0 (3.3)
9	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) weathered and fresh; as below but with 5-dcm-thick COAL at top; contact with above sharp.	8.7 (28.7)

8	LIMY SANDSTONE - SANDY LIMESTONE--grayish orange (10 YR 7/4) weathered and fresh; beds medium-thick; irregular, uneven, with thin obscure laminae; grains fine, well sorted, subrounded; composed of nearly equal amounts of calcite and quartz; platy weathering at top; contact with above concealed.	4.3	(14.2)
7	COVERED INTERVAL	4	(13.2)
6	CONCRETION LAYER--grayish orange (10 YR 7/4) weathered and fresh; fairly continuous layer of carbonate concretions; appears at first to be sandstone.	0.7	(2.3)
5	CARBONACEOUS SHALE AND COAL		
5c	COVERED INTERVAL	1.6	(5.3)
5b	COAL--shaly, poor quality.	3.0	(9.9)
5a	CARBONACEOUS SHALE--yellowish gray (5 Y 7/2) weathered and fresh; mostly covered.	3.6	(11.9)
	Total Section Thickness = ~~497.2~~ 496.5		(1640.8)

Measurement began east edge of dirt road north of dump and north of Quaternary terrace gravel remnants. Underlying strata (Point Lookout Sandstone) described in section SJ1W-2A.

SECTION SJ1W-3, SHUMWAY ARROYO (Waterflow 7½' Quad.). West-facing cliff east of Shumway Arroyo and road to San Juan Generating Station, on James Dunlap place at west end of type area of Pictured Cliffs Sandstone; about .3 miles due north of US 550 and about 2 air miles northwest of Zia Trading Post; SW¼, SW¼, sec. 32, T30N, R15W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 12 July 1975.

Unit	Lithology	Thickness: m(ft)
	SAN JUAN RIVER TERRACE DEPOSIT	
11	GRAVEL--well rounded cobbles of siliceous? and volcanic rocks; largest observed approximately 4 dcm in diameter.	6.6 (21.8)
	PICTURED CLIFFS SANDSTONE	
10	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, irregular, uneven, with thin, planar, iscontinuous, parallel laminae; large-scale, concordant, low-angle, grouped, wedge(?) and trough cross bedding (measurement of 1 trough axis gave 12° S 30° W); grains fine, well sorted, subangular - subrounded; composed mainly of quartz, minor clay matrix, slightly calcareous; branching, horizontal burrows and mold of Ophiomorpha on bedding plane about 2 m below beginning of cobble-strewn slope; contains .5 m SHALE and friable SAND about 5 m above base; contact with above concealed.	24.9 (82.2)
9	COVERED INTERVAL	4.1 (13.5)
	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thin - medium, irregular, uneven, with very thin, planar, discontinuous, convergent laminae; ripple marks seen in float blocks probably from this unit but none seen in place; large-scale, concordant, low-high angle, grouped, trough (some wedge?) cross bedding in upper part (measurements along 3 trough axes yielded 9° S 45° W, 9° N 45° E, and 13° N 78° E); grains fine, well sorted, subangular-subrounded; composed mainly of quartz, some clay matrix; contact with above concealed.	1.8 (5.9)

7	COVERED INTERVAL--small exposures at mid thickness and upper 1.5 m reveal thin - medium beds of thinly laminated very fine sandstone or siltstone interbedded with shale.	3.0 (9.9)
6	LIMY SANDSTONE-SANDY LIMESTONE--moderate yellowish brown (10 YR 5/4) weathered and pale yellowish brown (10 YR 6/2) fresh; beds thin, irregular, uneven, massive; grains very-fine-sand - silt size, well sorted, subangular - subrounded; composed of nearly equal amounts of calcite and quartz sand or silt; very platy and brittle; contact with above concealed.	2.0 (6.6)
5	COVERED INTERVAL	2.8 (9.2)
4	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, regular, may be single bed, with very thin to medium laminae (thicker size at top), internal structure obscure; grains very fine, well sorted, subangular - subrounded; composed mainly of quartz, minor clay matrix, not calcareous; contains minor carbonaceous plant debris; contact with above concealed.	3.0 (9.9)
3	ALTERNATING SANDSTONE AND SHALE	3.3 (10.9)
	SANDSTONE--grayish orange (10 YR 7/4) - dark yellowish orange (10 YR 6/6) weathered and fresh; beds thin, regular, even in lower part, uneven above, with very thin - thin, planar, continuous, parallel laminae; one bed within a few dcm of top displays scour to depth of about 1.5 m down into zone of interbedded sandstone and shale and has very irregular base throughout exposure; straight, narrow sole marks on base of this bed indicate transport direction of approximately N 30° E; some load features (ball and pillar) also associated with scour; contains carbonaceous plant debris.	
	SHALE--grayish orange (10 YR 7/4) weathered and pale yellowish orange (10 YR 6/2) fresh; some small fragments of carbonaceous plant debris on bedding surfaces.	
	Contact of unit 3 with above sharp.	

2	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, regular, may be single bed (?), with very thin to thin laminae; internal structure obscured by case hardening; grains very-fine-sand - silt size, well sorted, subangular - subrounded; composed mainly of quartz, minor clay matrix, slightly calcareous; contact with above fairly sharp, may be gradational (?).	3.6 (11.9)

LEWIS SHALE

1	COVERED INTERVAL--in upper few dcm shale is exposed; contact with above sharp.	4.1 (13.5)

Total section thickness = 59.20 (195.4)

Measurement was begun at base of cliff at edge of arroyo.

SECTION SJ1W-4A, COTTONWOOD ARROYO (Farmington North 7½' Quad.). West-facing slope of second prominent knob on northeast side of dirt road that parallels arroyo (on northeast) from a point on NM 17 about 2¼ highway miles north of US 550; in "The Badlands" southeast of Piñon Mesa, southwest of Jackson Lake; and east of the La Plata River; NW¼, NE¼, NE¼, sec. 31, T30N, R13W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 13 July 1975.

Unit	Lithology	Thickness: m(ft)
QUATERNARY TERRACE DEPOSIT		
6	GRAVEL AND GRAVEL-STREWN SLOPE -- color variable; bedding indistinct; well rounded cobbles of various igneous and metamorphic rock types; only upper 1-2 m probably in place.	3.8 (12.5)
KIRTLAND SHALE		
5	SANDSTONE AND SHALE	
5e	INTERBEDDED SANDSTONE AND SHALE -- like 5a below; difficult to cross; contact with above concealed.	6.8 (22.4)
5d	SHALE -- dark yellowish brown (10 YR 4/2) weathered and fresh; composed of swelling clay and weathers with a "popcorn-like" surface; this is the dark shale marker bed used to tie this section to Section 4B to northeast.	2.0 (6.6)
5c	INTERBEDDED SANDSTONE AND SHALE -- same as 5a below.	12.0 (39.6)
5b	SANDSTONE -- very pale orange (10 YR 8/2) weathered and fresh; beds thick; irregular, uneven with thin, curved, discontinuous, convergent laminae; cross bedded; grains fine - medium, well sorted, subrounded - rounded; composed mainly of quartz with clay matrix (altered feldspar), not calcareous; thin dark shale bed occurs near middle of unit; contact with above concealed.	1,5 (5,0)
5a	INTERBEDDED SANDSTONE AND SHALE -- grayish orange (10 YR 7/4) weathered and fresh; poorly exposed sequence of alternating dark, swelling-clay shale and white - rust, slope-forming sandstone; weathering	7.0 (23.1)

of soft sandstones gives "popcorn-like" surface of shales sandy appearance; patches of dark reddish brown (10 R 3/4) concretions occur at places on slopes.

4	SANDSTONE -- grayish orange (10 YR 7/4) weathered and fresh; beds thick - very thick, irregular, uneven with thin curved, discontinuous, convergent laminae; large-scale, concordant, high-angle, grouped, trough and wedge(?) cross bedding; grains medium - coarse, fairly - well sorted, subrounded - rounded; composed mainly of quartz with clay matrix (altered feldspar?), not calcareous; carbonate concretions up to 1m in diameter occur locally; contact with above concealed.	8.9 (29.4)
3	INTERBEDDED SANDSTONE AND SHALE	17.1 (56.4)
	SANDSTONE -- grayish orange (10 YR 7/4) - yellowish gray (5 Y 7/2) weathered and fresh, some thin sandstones grayish olive (10 Y 4/2); beds thick, irregular, uneven with thin, curved, discontinuous, convergent laminae; large-scale, concordant, mostly high-angle, grouped, trough cross bedding; grains medium, well sorted, subrounded - rounded; composed mainly of quartz with clay matrix (altered feldspar?), not calcareous.	
	SHALE -- yellowish gray (5 Y 7/2); beds thick - very thick, regular, uneven; sandy; swelling, weathers with "popcorn-like" surface.	
	Contact with above concealed.	
2	SANDSTONE -- grayish orange (10 YR 7/4) weathered and fresh; beds thin - thick, irregular, uneven with thin, curved, discontinuous, convergent laminae; large-scale, concordant, mostly high-angle, grouped, trough cross bedding; grains fine, well sorted, subrounded; composed mainly of quartz with little matrix, not calcareous, contact with above concealed.	2.0 (6.6)
1	COVERED INTERVAL -- obscured by alluvium and soft sand.	3.6 (11.9)
	Total section thickness =	64.7 (213.5)

Base is floor of arroyo.

SECTION SJlW-4B, PIÑON MESA (Youngs Lake 7½' Quad.). South-facing slope near head of Cottonwood Arroyo at southern edge of mesa; NW¼, NE¼, sec. 25, NE¼, SW¼, sec. 24, T30N, R14W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 13 July 1975.

Unit	Lithology	Thickness: m(ft)
	OJO ALAMO SANDSTONE	
4	CONGLOMERATIC SANDSTONE -- grayish orange (10 YR 7/4), light brown (5 YR 5/6), and grayish brown (5 YR 3/2) weathered, very pale orange (10 YR 8/2) and grayish orange (10 YR 7/4) fresh; beds medium - very thick, irregular, uneven with thin, curved, discontinuous, convergent laminae; large-scale, concordant, high-angle, grouped, trough (some wedge-planar) cross bedding; grains consist of medium - very coarse, well sorted, subrounded - subrounded sand and pebbles; sand composed mainly of quartz, minor clay matrix, not calcareous; overlain by thin veneer of eolian sand.	26.1 (86.1)
	ANIMAS FORMATION	
	MCDERMOTT MEMBER	
3	SANDSTONE/SHALE COUPLET -- like 2a below; contact with above sharp, erosional.	5.1 (16.8)
2	INTERBEDDED SANDSTONE AND SHALE	
2d	SANDSTONE -- grayish orange (10 YR 7/4), very pale orange (10 YR 8/2) and dark yellowish orange (10 YR 6/6) weathered and fresh; beds thick, fairly regular, uneven with medium, curved, discontinuous, convergent laminae; cross bedded; grains fine - medium, fairly sorted, subrounded; composed mainly of quartz with much clay matrix, not calcareous; contact with above concealed.	3.0 (9.9)
2c	SANDSTONE/SHALE COUPLET -- like 2a below except grains fine - medium; contact with above concealed.	16.8 (55.4)
2b	SANDSTONE -- grayish orange (10 YR 7/4); beds thick, irregular, uneven with thin	2.0 (6.6)

laminae; cross bedded; grains consist of medium - coarse, well sorted, subrounded - rounded, sand and pebbles; composed mainly of quartz with clay matrix, not calcareous; thickness ranges from 1 - 4 m where measured; contact with above concealed.

2a SANDSTONE/SHALE COUPLET 1.7 (5.6)

SHALE -- grayish orange (10 YR 7/4) weathered and fresh; beds very thin, poorly exposed; not calcareous; contact with above sharp, erosional(?).

SANDSTONE -- very pale orange (10 YR 8/2) weathered and fresh; beds thick(?), indistinct with thin laminae; grains fine, well sorted, subrounded; composed mainly of quartz with clay matrix and clay pebbles, not calcareous; contact with shale gradational(?).

KIRTLAND SHALE

1 INTERBEDDED SANDSTONE AND SHALE 21.4 (70.6)

1c SANDSTONE, SILTSTONE, AND SHALE

SANDSTONE -- very pale orange (10 YR 8/2) weathered and fresh; beds generally indistinct owing to soft character; few ledge-forming beds; some thin, "purple" (dusky red - moderate red; 5 R 3/4 - 5 R 4/6), SILTSTONE beds; contacts with shales above poorly exposed but seem to be gradational.

SHALE -- pale red (6 R 6/2) weathered and pale red - blackish red (5 R 2/2) fresh; beds very thin, indistinct; contact with overlying sandstones erosional(?).

1b SANDSTONE -- very pale orange (10 YR 8/2) weathered and fresh; represents single(?) medium (.15 m; .5 ft), irregular, uneven bed; cross bedded(?); grains very fine - fine, fairly sorted, subrounded with clay matrix; composed mainly of quartz(?).

1a	SHALE -- very pale orange (10 YR 8/2) weathered and grayish orange (10 YR 7/4) fresh; beds very thin, indistinct; contact with above sharp, erosional(?).	
	Total section thickness =	76.1 (251.1)

Base of section is top of dark shale marker bed traced from Section 4A.

SECTION SJ1W-5, LA PLATA GRAVEL PIT (Farmington South 7½' Quad.) West edge of gravel pit in low terrace on east side of the La Plata River; .65 air mile northeast of US 550, across river from asphalt plant; NE¼, NE¼, sec. 7, T29N, R13W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 14 July 1975.

Unit	Lithology	Thickness: m(ft)
	QUATERNARY TERRACE DEPOSIT	
3	SANDY GRAVEL AND SAND SANDY GRAVEL -- color variable; beds medium - thick with excellent imbrication of gravel clasts and possibly frequency grading(?); gravel consists of well rounded cobbles and boulders of various igneous and metamorphic rock types with a sand matrix; maximum diameter observed about 3 dcm. SAND -- occurs as discrete, medium beds within gravel and as a single, very thick bed overlying gravel at top of unit in places.	4.0 (13.2)
	KIRTLAND SHALE	
	FARMINGTON SANDSTONE MEMBER	
2	SANDSTONE -- grayish orange (10 YR 7/4) weathered and fresh; beds thick, irregular, uneven with thin, curved, discontinuous, convergent laminae; crossbedded; grains medium, well sorted, subrounded - rounded; composed mainly of quartz with clay matrix, not calcareous; carbonaceous material common on laminar surfaces, clay pebbles along some beds; contact with above sharp, erosional.	2.0 (6.6)
1	INTERBEDDED SHALE AND SILTSTONE -- light gray (N7) - yellowish gray (5 Y 8/1) weathered and fresh; beds very thin - thin, irregular, even with thin laminae; contact with above sharp, erosional.	4.6 (15.2)
	Total thickness =	10.6 (35.4)

Base of section is surface of dirt road which fords La Plata River here.

SECTION SJ1W-6, HIGHWAY GRAVEL PIT (Kirtland 7½' Quad.). North of new Farmington-Shiprock highway, about 3.5 air miles east of Kirtland, 1 air mile southeast of the Twin Mounds, in terrace on divide between Dain and Locke Arroyos; near C, sec. 10, T29N, R14W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 17 July 1975.

Unit	Lithology	Thickness: m(ft)
	QUATERNARY TERRACE DEPOSIT	
6	SOIL -- stripped from gravel where measured.	0.2 (.7)
5	SANDY GRAVEL -- as below but bedding indistinct; cobbles coated with carbonate; maximum clast size about 3 dcm.	1.3 (4.3)
4	SAND -- probably single thin bed with thin, planar, continuous, parallel laminae; large-scale, concordant - tangential, low- to high-angle, grouped, trough cross bedding; grains fine - medium, some coarse, fairly - well sorted, subrounded; composed mainly of quartz with little matrix, calcareous; contact with above sharp, erosional.	1.3 (4.3)
3	SANDY GRAVEL -- color variable; beds thick, displaying size grading with coarse sandy gravel at base and fining and cleaning upward; maximum clast size about 3 dcm; contact with above sharp, erosional.	2.8 (9.2)
2	SAND -- probably single thick bed with thin, planar, curved, parallel laminae; grains fine - medium, well sorted, subrounded - rounded; composed mainly of quartz with little matrix, calcareous; varies in thickness laterally as a function of scour at base of gravel above; contact with above sharp, erosional.	0.6 (2.0)
1	COVERED INTERVAL -- consists of talus from units above; probably gravel based on exposure to east along pit face (where all but lower part of section removed); maximum clast size is 3 dcm.	2.0 (6.6)
	Total section thickness =	8.2 (27.1)

Base of section is pit floor which probably corresponds to the top of bedrock (Kirtland Shale).

SECTION SJ1W-7, SAN JUAN MINE GRAVEL PIT (Water Flow 7½' Quad.). Highest terrace south of San Juan Coal Mine and north of type locality for Pictured Cliffs Sandstone; about .7 air miles north of US 550, 1.7 air miles northeast of intersection of US 550 and road to San Juan Generating Station, and .9 air miles northwest of Zia Trading Post; west of dirt road which intersects US 550, 15 miles west of Zia Trading Post; SE¼, NW¼, sec. 33, T30N, R15W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 17 July 1975.

Unit	Lithology	Thickness: m(ft)
	QUATERNARY TERRACE DEPOSIT	
4	SOIL -- brownish,very-fine grained upper horizon and a white lower horizon grading into gravel below.	0.8 (2.6)
3	SANDY GRAVEL -- color variable; bedding indistinct; maximum clast size about 3 dcm; not calcareous.	2.1 (6.9)
2	GRAVEL -- color variable; maximum clast size 2 dcm, finer and cleaner at top, not calcareous; large block of Fruitland Formation occurs near base (maximum dimension 8 dcm); contact with above sharp, erosional.	1.1 (3.6)
1	COVERED INTERVAL -- consists mainly of talus from above but in a few places a few dcm of noncalcareous gravel with sand lenses are exposed between talus and unit 2 above.	1.4 (4.6)
	Total section thickness =	5.4 (17.8)

Base of section is floor of gravel pit. Patches of coaly material on this surface suggest the base of excavation is the top of the Fruitland Formation.

SECTION SJ1E-1, PENINSULA GRAVEL PIT (Farmington South 7½' Quad.). Low terrace on north side of San Juan River about 1 air mile due east of its confluence with the Animas River and about 1 air mile southeast of the Farmington Hospital; western face of new gravel pit opened east of dirt road extending south from Sycamore Avenue and east of gravel pit shown on topographic map; SW¼, NW¼, sec. 22, T29N, R13W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 14 July 1975.

Unit	Lithology	Thickness: m(ft)
	QUATERNARY TERRACE DEPOSIT	
4	SOIL -- weak, horizons poorly developed but probably in place.	0.4 (1.3)
3	SANDY GRAVEL -- color variable; no structures apparent.	2.2 (7.3)
2	INTERBEDDED SAND AND GRAVEL	0.9 (3.0)
	SAND -- color variable; beds thin - medium with thin laminae; grains fine - medium, well sorted, subangular - rounded; composed mainly of quartz, slightly calcareous.	
	GRAVEL -- color variable; beds thin - medium, interfinger with sand, laterally discontinuous.	
	Contact with above sharp, erosional.	
1	COVERED INTERVAL -- consists of talus from units above; one boulder seen measured 6 dcm in diameter.	2.1 (6.9)
	Total section thickness =	5.6 (18.5)

Base is floor of gravel pit.

SECTION SJ2-1, CHACRA MESA (Pueblo Bonito 7½' Quad.). North-facing slope just east of northwest end of the mesa and opposite Gallo Campground in Chaco Canyon National Monument; SW¼, SW¼, sec. 27 to NE¼, NE¼, sec. 33, T21N, R10W, San Juan County; section measured by William J. Stone, 24 July 1975.

Unit	Lithology	Thickness: m(ft)
CLIFF HOUSE SANDSTONE		
6	MOSTLY COVERED INTERVAL -- loose sand at surface except for lower 4-5 m where a ledge-forming SANDSTONE crops out; some small patches of SANDSTONE also crop out locally in slope above; upslope from National Park Service marker, a small exposure of variegated SHALE was seen.	52.8 (174.2)
5	COVERED INTERVAL -- loose sand at surface.	5.2 (17.2)
4	SANDSTONE	
4b	MOSTLY COVERED INTERVAL -- small exposure of SANDSTONE as below occurs at top.	13.8 (45.5)
4a	SANDSTONE -- color as below; beds thick - very thick, regular, even with thin, planar, continuous, parallel laminae; large-scale, concordant - tangential, low-angle, grouped, trough cross bedding; grains fine, well sorted, subrounded - rounded; composed mainly of quartz with minor clay matrix, calcareous, iron stained; contains spherical ironstone concretions up to 1 dcm in diameter and Ophiomorpha (horizontal and vertical, branching and nonbranching types seen. Contact with above concealed.	3.0 (9.9)
3	SANDSTONE -- like unit 2 below; poorly exposed, upper 1/3 is covered slope; contact with above concealed.	18.1 (59.7)
2	SANDSTONE AND SHALE	
2b	SANDSTONE -- grayish orange pink (5 YR 7/2) - moderate orange pink (5 YR 8/4) weathered and light brown (5 YR 6/4) fresh; beds very thick, regular, even with thin, planar, continuous, parallel laminae; cross bedded; grains	22.2 (73.3)

fine, well sorted, subrounded - rounded; composed mainly of quartz with clay matrix (altered feldspar), not calcareous; is first main cliff-forming sandstone in Cliff House; contact with above gradational.

2a	INTERBEDDED SANDSTONE AND SHALE -- sandstone like that in 2b above; shale contains carbonaceous plant debris like Menefee below; contact gradational.	3.2 (10.6)

MENEFEE FORMATION

1	CARBONACEOUS SHALE, COAL, AND SANDSTONE	
1b	SANDSTONE -- moderate orange pink (5 YR 8/4) weathered and very pale orange (10 YR 8/2) fresh; large-scale, concordant - tangential, low-angle, grouped, trough cross bedding; grains very fine - fine, fairly - well sorted, subrounded; composed mainly of quartz with considerable clay matrix (altered feldspar?), not calcareous; may be Cliff House(?); contact with above sharp.	8.5 (28.1)
1a	CARBONACEOUS SHALE, SANDSTONE, AND COAL -- shale is pale yellowish brown (10 YR 6/2) weathered and pale brown (5 YR 5/2) fresh; sandstones have erosional bases and are laterally discontinuous; minor thin beds of coal; contact with above sharp.	38.4 (126.7)

Total section thickness = 165.2 (545.2)

Base is base of lowest exposed Menefee Formation to east of small gully; base is about 5 m above main canyon floor.

SECTION SJ2-2, TSAYA CANYON (Tanner Lake 7½' Quad.). Southeast-facing slope northwest of road from Bisti to Lake Valley; 6.25 road miles northeast of Lake Valley, .75 road miles northeast of Tsaya; NE¼, SE¼, sec. 13, T22N, R13W, San Juan County; section measured by William J. Stone and Henry L. Fleischhauer, 24 August 1976.

Unit	Lithology	Thickness: m(ft)
	CLIFF HOUSE SANDSTONE	
	"CHACRA" or "TSAYA" TONGUE	
5	SANDSTONE -- grayish orange (10 YR 7/4) weathered and very pale orange (10 YR 8/2) fresh; large-scale trough cross bedding in lower half; Ophiomorpha present, uppermost .7 - .8 m contains abundant bivalves and is very calcareous.	7.9 (26.1)
4	SHALE (tongue of Menefee Formation?) -- grayish orange pink (5 YR 7/2) weathered and dark yellowish brown (10 YR 4/2) fresh; largely covered except for upper 1.5 m; carbonaceous, contains jarosite, sandy at top; contact with above sharp but gradational; offset to high knob to north for unit 5.	8.0 (26.4)
3	SANDSTONE -- mottled grayish orange (10 YR 7/4), dark yellowish orange (10 YR 6/6), and very pale orange (10 YR 8/2) weathered and fresh; large-scale, trough cross bedding in places with ripples oriented vertically on trough slopes; poorly exposed on irregular slope, some SHALE interbeds(?); contact with above concealed.	17.9 (59.1)
2	SANDSTONE -- very pale orange (10 YR 8/2) - grayish orange (10 YR 7/4) weathered and fresh; contains large-scale, trough cross bedding throughout; a wedge of rust-colored (dark yellowish orange, 10 YR 6/6, weathered and fresh) sandstone containing abundant Ophiomorpha occurs in the lower half of the unit; wedge-shaped beds pinch out (few meters thick - 0) toward the north; contact with above sharp.	14.1 (46.5)

1	SANDSTONE -- grayish orange (10 YR 7/4) and very pale orange (10 YR 7/4) weathered and fresh; beds medium - very thick, irregular, uneven with thin laminae; Ophiomorpha present locally; contact with above sharp, erosional(?).	25.0 (82.5)
	Total section thickness =	72.9 (240.6)

Base is base of Cliff House Sandstone at the spectacular sandstone pinchout or "end of a coal bed" as illustrated in Fig. 28 of Bureau Circular 154 (Beaumont and others, 1976).

SECTION SJ2-3A, CHINDE WASH (Fruitland 7½' Quad.). Exposures along bed and banks of wash at and southeast of the point where northeast - southwest dirt road from Navajo-Mine/Four-Corners-Power-Plant offices crosses it; about 3.5 road miles southwest of intersection with road to Power Plant; SW¼, NE¼, sec. 14, T28N, R16W, Navajo Indian Reservation, San Juan County; section measured by William J. Stone and Daniel R. Brown, 30 July 1975.

Unit	Lithology	Thickness: m(ft)
PICTURED CLIFFS SANDSTONE		
7	SANDSTONE -- very pale orange (10 YR 8/2) weathered and fresh; some weathers dark yellowish orange (10 YR 6/6); beds medium - very thick, irregular, uneven with thin, curved, discontinuous, convergent laminae; large-scale, tangential, high-angle, grouped, trough cross bedding; grains very fine - fine, well sorted, subrounded - rounded; composed mainly of quartz with little matrix, calcareous in places; weathers with rounded convex-upward slopes; nothing overlies unit 7 at this point; to south Fruitland caps bluffs somewhat above this horizon.	8.6 (28.4)
6	LIMY SANDSTONE - SANDY LIMESTONE -- like unit 3 below; contact with above sharp.	0.4 (1.3)
5	SANDSTONE -- very pale orange (10 YR 8/2) - grayish orange (10 YR 7/4) weathered and fresh; beds thick, regular, even with thin, planar, continuous - discontinuous, parallel laminae; vague hint of cross bedding; grains fine, well sorted, subrounded - rounded; composed mainly of quartz and feldspar (altered) with clay matrix, not calcareous, friable; upper 1.2 m less resistant to erosion; contact with above sharp.	5.4 (17.8)
4	COVERED INTERVAL -- largely concealed but patches of SHALE and SANDSTONE occur locally; contact with above concealed.	3.4 (11.2)
3	LIMY SANDSTONE - SANDY LIMESTONE -- moderate yellowish brown (10 YR 5/4) weathered and medium light gray (N6) fresh; large-scale, tangential, low-angle, grouped, trough cross bedding; grains fine,	1.5 (5.0)

well sorted, subangular - subrounded; composed of quartz and calcite, no matrix; contact with above concealed.

2	SANDSTONE -- very pale orange (10 YR 8/2) - grayish orange (10 YR 7/4) weathered and fresh; beds medium - thick, irregular, uneven with thin - medium, planar - curved, discontinuous, convergent laminae; cross bedded; grains very fine - fine, well sorted, angular - subangular; composed mainly of quartz with little matrix, calcareous; contains scattered spherical carbonate concretions up to 2 cm in diameter; contact with above sharp.	7.1 (23.4)
1	INTERBEDDED SANDSTONE AND SHALE	11.4 (37.6)

SANDSTONE -- yellowish gray (5 Y 7/2) weathered and fresh; beds thin - medium, irregular, uneven with thin laminae which are most distinct where carbonaceous debris is abundant; contains straight, asymmetrical ripple marks with amplitudes of 4 - 5 mm and wave lengths of 5 - 7 cm and oriented N70°W; grains very fine - fine, well sorted, subangular - subrounded; composed mainly of quartz with little matrix, slightly calcareous; about 6 dcm below ripples, horizontal, branching Ophiomorpha observed; float block with ripple marks probably from this unit displayed 2 Rhizocorallium; upper 8 m poorly exposed, less resistant to erosion; contact with above sharp.

SHALE -- medium dark gray (N4) weathered and light gray (N7) fresh; beds thin, irregular, even; contains small carbonaceous plant fragments.

Total section thickness = 37.8 (124.7)

Base is base of exposure in Chinde Wash, 3.4 m below road to northwest. The transition zone at base of Pictured Cliffs (represented by unit 1) is not completely exposed here. About 5.5 m of covered slope lie between the top of section SJ2-3A and the base of section SJ2-3B. The amount of this interval assignable to the Pictured Cliffs is uncertain.

SECTION SJ2-3B, CHINDE WASH (Fruitland 7½' Quad.). Northwest-facing slope between prominent bench of Pictured Cliffs Sandstone and bluffs of Fruitland Formation to southeast; about 1/2 mile southeast of point where dirt road from Navajo Mine/ Four Corners Power Plant crosses wash; NE¼, SE¼, sec. 14, T28N, R16W, Navajo Indian Reservation, San Juan County; section measured by William J. Stone, Henry L. Fleischhauer, Jr., Glenn R. Osburn, and W. Terry Siemers, 6 November 1975.

Unit	Lithology	Thickness: m(ft)
FRUITLAND FORMATION		
13	SANDSTONE -- pale yellowish brown (10 YR 6/2) weathered and fresh; beds thin - medium, irregular, uneven with very thin - thin, planar, continuous - discontinuous, parallel - convergent; large- to small-scale, concordant, low-angle, grouped planar cross bedding; grains fine, moderately sorted; composed mainly of quartz.	8.0 (26.4)
12	SANDY MUDSTONE -- very pale orange (10 YR 8/2) weathered and fresh; beds medium, irregular, uneven; sand is very fine; contains siderite nodules up to about 3 dcm in diameter; disrupted by slumping into roadcut; contact with above sharp.	5.7 (18.8)
11	COVERED INTERVAL -- about 1 m below top is 2-m thick bed of clinker; contact with above concealed.	8.0 (26.4)
10	SANDSTONE -- pale reddish brown (10 R 5/4) weathered and moderate orange pink (10 R 7/4) fresh; beds thin - medium, regular, uneven with thin, wavy - planar, continuous, parallel laminae; grains fine, moderately sorted, subangular; composed mainly of quartz, not calcareous; some clay galls.	1.4 (4.6)
9	SHALE -- light gray (N7) weathered and fresh; beds very thin, irregular, uneven with very thin, curved, discontinuous, convergent laminae; not calcareous.	1.3 (4.3)
8	SILTSTONE -- grayish brown (5 YR 3/2) weathered and dusky brown (5 YR 2/2) fresh; beds medium, regular with medium, wavy, continuous, parallel laminae; not calcareous.	0.3 (1.0)

7		SILTSTONE AND SHALE -- like unit 3d below.	0.6	(2.0)
6		COAL -- black (N1) weathered and fresh; beds very thin, regular, even with very thin, planar - wavy, continuous, parallel laminae; small patches of resin locally.	0.6	(2.0)
5		SANDSTONE, SILTSTONE, AND SHALE		
	5b	SILTSTONE AND SHALE -- like unit 3d below.	0.2	(0.7)
	5a	SANDSTONE -- light brown (5 YR 6/4) weathered and fresh; single, very thick, regular bed with medium, planar, continuous, parallel laminae; grains very fine, very well sorted; composed mainly of quartz, not calcareous; contains carbonaceous plant fragments.	1.0	(3.3)
4		COAL -- black (N1) weathered and fresh; beds very thin, regular, uneven with very thin, planar, continuous - discontinuous, parallel - convergent laminae.	0.2	(0.7)
3		SANDSTONE, SILTSTONE, SHALE, AND COAL		
	3d	SILTSTONE AND SHALE -- grayish brown (5 YR 3/2) weathered and fresh; beds very thin, irregular, even with curved, discontinuous, convergent laminae; not calcareous; contains carbonaceous plant fragments.	0.3	(1.0)
	3c	SANDSTONE -- light gray (N7) weathered and fresh; beds thin, regular, uneven with medium, wavy, continuous, parallel laminae; grains fine, well sorted, subangular; composed mainly of quartz, not calcareous; contains carbonaceous plant debris.	0.6	(2.0)
	3b	SILTSTONE AND SHALE -- light gray (N7) - dark reddish brown (10 R 3/4) weathered and light gray - pale red (10 R 6/2) fresh; beds thin, regular, even with very thin, wavy, continuous - discontinuous, convergent laminae; not calcareous; contains carbonaceous plant fragments.	0.6	(2.0)
	3a	COAL -- black (N1); beds very thin, regular, even with planar, continuous, parallel laminae.	0.3	(1.0)

2	SILTSTONE -- moderate reddish brown (10 R 4/6) weathered and dark reddish brown (10 R 3/4) fresh; beds very thin, irregular, uneven with thin, curved, discontinuous, convergent laminae; not calcareous; contains carbonaceous plant debris.	0.7 (2.3)
1	SANDSTONE -- grayish orange (10 YR 7/4) weathered and very pale orange (10 YR 8/2) fresh; beds thin - medium, regular, uneven with thin, wavy, continuous - discontinuous, parallel laminae; small-scale, concordant(?), low-angle, grouped, wedge-planar cross bedding; grains fine, well sorted, subangular; composed mainly of quartz, not calcareous; contains clay galls and carbonaceous plant fragments; contact with above sharp.	2.0 (6.6)
	Total section thickness =	31.8 (105.0)

Base is base of unit 1 which is slightly above road level. About 5.5 m of covered slope lie between top of section SJ2-3A and base of section SJ2-3B. The amount of this interval assignable to the Fruitland is uncertain.

SECTION SJ2 - 4, SAN JUAN RIVER BLUFFS (Farmington South 7½' Quad.). North-facing slope of bluff rising from the floodplain, south side of San Juan River, south of Farmington, east of confluence with Animas River; about 1 air mile southeast of San Juan Mission and 1 air mile slightly east of south of the Farmington Hospital; SE¼, SW¼, sec. 21, T29N, R13W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 29 July 1975.

Unit	Lithology	Thickness: m(ft)
OJO ALAMO SANDSTONE (described in section SJ2-5)		
KIRTLAND SHALE UPPER SHALE MEMBER		
3	SANDSTONE AND SHALE	
3c	SHALE--pale olive (10 Y 6/2) - light olive gray (5 Y 5/2) weathered and fresh, grayish orange (10 YR 7/4) at the top; beds very thin; contact with above sharp, erosional.	7.4 (24.4)
3b	SANDSTONE--very pale orange (10 YR 7/4) - grayish orange (10 YR 7/4) weathered and fresh; beds thin; large-scale, tangential, low-angle, grouped, trough cross bedding; grains fine - medium, moderately well sorted, subangular - subrounded; composed mainly of quartz, much mud matrix, not calcareous; contains medium laminae of clay granules; contact with above gradational(?).	9.2 (30.4)
3a	COVERED INTERVAL--probably consists of soft sand and shale as above.	20.7 (68.3)
KIRTLAND SHALE FARMINGTON SANDSTONE MEMBER		
2	SANDSTONE	
2c	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh in lower and upper cliff-forming parts and grayish yellow green (5 GY 7/2) in middle slope-forming part; beds medium, irregular, uneven with thin laminae in lower part and medium laminae in middle part; large scale, tangential, low-angle, grouped, trough cross bedding in lower and middle	20.4 (67.3)

parts with an axis orientation in the middle SANDSTONE of N 6°W; grains medium, fairly - well sorted, subangular - subrounded; composed mainly of quartz with much clay matrix, not calcareous; upper part characterized by pitted weathering, middle and upper parts variable in resistance to erosion; contact with above covered.

2b	COVERED INTERVAL--in upper few meters alternating beds of SANDSTONE AND SHALE like unit 1 below are exposed.	8.3 (27.4)
2b	SANDSTONE--very pale orange (10 YR 8/2) - grayish orange (10 YR 7/2) and light brown (5 YR 5/6) locally weathered and fresh; beds medium - thick; large- and minor small-scale, concordant, low-angle, grouped, trough (some tabular?) cross bedding; grains medium, well sorted, rounded; composed mainly of quartz, slightly calcareous; gypsum on fracture surfaces; contact with above covered.	8.5 (28.1)
1	ALTERNATING SANDSTONE AND SHALE--SANDSTONE moderate brown (5 YR 4/4) - very pale orange (10 YR 8/2) weathered and fresh; beds medium - thick, regular, even, with thin planar, continuous, parallel laminae; cross bedded; grains very fine - fine, fairly - well sorted; composed mainly of quartz, with much clay matrix, slightly - not calcareous; gypsum and jarosite present; largely covered except upper and lower 5 m, contact with above sharp.	20.4 (67.3)
	Total section thickness =	94.9 (313.2)

Base is floodplain of San Juan River at Wildlife Refuge below dirt road along bluffs.

SECTION SJ2 - 5, HIGHWAY 371 ROADCUT (Farmington South 7½' Quad.). West-facing sides of roadcut, where highway crosses Ojo Alamo Sandstone south of San Juan River; about 1½ air miles southwest of Farmington hospital; NE¼, NW¼, sec. 29, T29N, R13W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 29 July 1975.

Unit	Lithology	Thickness: m(ft)
	OJO ALAMO SANDSTONE	
3	CONGLOMERATIC SANDSTONE--as below; seen to merge with or closely overlie unit 1 in bluffs on west side near mouth of Head Canyon to southeast of where measured; sandstones above this, poorly exposed along highway but clearly shown in Head and Stewart Canyons, are apparently tongues of Ojo Alamo within Nacimiento Formation.	16.6 (54.8)
2	SHALE--medium light gray (N6) weathered and dark gray (N3) fresh; silty; may be tongue of Nacimiento Formation(?);	4.1 (13.5)
1	CONGLOMERATIC SANDSTONE--very pale orange (10 YR 8/2) - grayish orange (10 YR 7/4) weathered and fresh; beds medium - thick, irregular, uneven with thin - medium curved, discontinuous, convergent laminae; cross bedded; grains medium - very coarse, well sorted, subrounded - rounded; composed mainly of quartz, little matrix, not calcareous, friable; contains oxidized logs, mud boulders, and plant fragments; gravel distribution variable, occurs as thin stringers and beds up to about 3m in thickness;	310.0 (1023.0)
	Total section thickness =	330.7 (1091.3)

Base is base of first gravelly sandstone above Kirtland Shale (Kirtland Shale described in section SJ2 - 4). Top of section is below antennae and buildings at top of hill.

NACIMIENTO FORMATION

1	INTERBEDDED SANDSTONE AND SHALE--pale olive (10 Y 6/2) - medium light gray (N6) weathered and fresh; largely covered but digging revealed dirty sandstone and shale.	10.5 (34.7)
	Total section thickness =	73.4 (242.2)

Base of section is top of main Ojo Alamo Sandstone here; traced top in from east of dirt road.

SECTION SJ2 - 6, STEWART CANYON (Farmington South 7½' Quad.). East-facing slope, west side of canyon and west of dirt road which enters canyon from southwest near here; about 2 air miles south of San Juan River; NE¼, SW¼, sec. 36, T29N, R13W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 29 July 1975.

Unit	Lithology	Thickness: m(ft)
5	COVERED INTERVAL--mainly loose Quaternary dune sand.	2.7 (8.9)
	NACIMIENTO FORMATION	
4	SANDSTONE--very pale orange (10 YR 8/2) weathered and grayish orange (10 YR 7/4) fresh; like unit 2 below but divided approximately into thirds by 2 SHALE breaks.	24.3 (80.2)
3	INTERBEDDED SANDSTONE AND SHALE--like unit 1 below; SANDSTONE grayish orange (10 YR 7/4) both weathered and fresh; a 3-m thick bed occurs 6m below the top of unit in places but laterally discontinuous or laterally variable in resistance to erosion; SHALE pale olive (10 Y 6/2) weathered and fresh; both covered with thin veneer of dune sand and colluvium.	31.8 (104.9)
	TONGUE OF OJO ALAMO SANDSTONE	
2	SANDSTONE--very pale orange (10 YR 8/2) weathered and grayish orange (10 YR 7/4) fresh; beds medium - thick, irregular, uneven with thin - medium, curved, discontinuous, convergent laminae; cross bedded; grains coarse - very coarse, fairly to well sorted, subrounded; composed mainly of quartz with little matrix, not calcareous; gravelly in lower part with clast diameters averaging 1 cm and ranging to 4 cm; contact with above covered.	4.1 (13.5)

SECTION SJ2 - 7, HARRIS MESA (Bloomfield 15' Quad.). South-facing slope, head of Armenta Canyon at southwestern tip of Harris Mesa, northeast of dirt road to well; about 2.5 air miles northeast of Angel Peak and 4 air miles northwest of Huerfanito Peak; NE¼, NW¼, sec. 18 to SW¼, SE¼, sec. 7, T27N, R9W, San Juan County; section measured by William J. Stone and Daniel R. Brown, 28 July 1975.

Unit	Lithology	Thickness: m(ft)
SAN JOSE FORMATION (undivided)		
17	SANDSTONE AND SHALE--in steep cliff, could not climb; determined from topo sheet that SHALE at base is about 80 ft (24.2 m) thick and overlying SANDSTONE is about 100 ft (30.3 m) thick; lithologies appear similar to those of other units in San Jose below.	54.5 (180.0)
16	SANDSTONE--light brown (5 YR 5/6) grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2) weathered and fresh; lowermost 2 m (6.6 ft) characterized by flat bedding with thin - medium planar, continuous, parallel laminae displaying parting lineation on surfaces; grains in this lower part are very fine - fine, well sorted, subangular - subrounded; composed of quartz with little matrix, not calcareous; 1 m (3.3 ft) interval above this is very rubbly with clay galls (rip up) up to 1 dcm in diameter, similar rubbly zones occur above but are less continuous laterally, some consist of gravel and petrified wood blocks up to 5 dcm in diameter; beds of gravel up to 5 dcm thick also occur in unit; bulk of unit characterized by large scale, high angle, trough cross bedding; where cross bedded, grains are coarse, well sorted, subangular - subrounded with little matrix, not calcareous; top of unit forms broad bench (at an elevation of about 6800 ft) that extends back to cliffs formed by unit 17; contact with above concealed.	41.4 (136.6)
15	SHALE--olive gray (5 Y 3/2) - grayish olive (10 Y 4/2) - yellowish gray (5 Y 7/2) weathered and fresh; mostly covered.	10.2 (33.7)
14	SANDSTONE--grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2) weathered and	35.8 (118.1)

	fresh, light brown (5 YR 5/6) in places; beds thick to very thick, regular, even with thin, curved, discontinuous, convergent laminae; large-scale, low - high angle, trough cross bedding; grains coarse - very coarse, well sorted, subrounded - rounded; composed mainly of quartz, minor matrix, not calcareous; base very rubbly; contact with above concealed.		
13	SHALE--dark gray (N3); like unit 11 below.	6.9	(22.8)
12	SANDSTONE--grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2) weathered and fresh; beds very thick, regular, even with thin laminae; cross bedding(?); grains very fine - fine, fairly sorted, subangular - subrounded; composed mainly of quartz, considerable clay matrix, not calcareous; pitted weathering habit at top; contact with above concealed.	2.4	(7.9)
11	SHALE AND SILTSTONE--olive black (5 Y 2/1) - grayish red (5 R 4/2) - grayish yellow green (5 GY 7/2) weathered and fresh; SILTSTONE occurs as beds and lenses 3 - 6 dcm thick with large-scale trough cross bedding, tuffaceous(?); contact with above sharp.	22.1	(72.9)
10	SANDSTONE--grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2); like unit 8 below with SHALE partings; lacks gravel in upper few m.	17.6	(58.1)
9	SHALE--like unit 7 below, olive black (5 Y 2/1) in places.	11.0	(36.3)
8	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thick - very thick, regular, even with thin curved, discontinuous, convergent laminae; large-scale, tangential, high-angle(?), grouped, trough cross bedding; grains coarse - very coarse, well sorted, subrounded - rounded; composed mainly of quartz, minor clay, not calcareous; much pebble gravel, strikingly coarser than lower units; contact with above concealed.	2.5	(8.3)

NACIMIENTO FORMATION

7	SHALE--like unit 1 below.	4.0	(13.2)
6	SANDSTONE--like unit 2 below.	7.3	(24.1)
5	SHALE--like unit 1 below.	3.4	(11.2)
4	SANDSTONE--like unit 2 below; some pebbles.	4.6	(15.2)
3	SHALE--like unit 1 below.	13.6	(44.9)
2	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds thick - very thick, regular, even with thin, curved, discontinuous, convergent laminae; large-scale, tangential, high-angle(?), grouped, trough cross bedding; grains coarse - very coarse, well sorted, subrounded - rounded; composed mainly of quartz, minor clay matrix, not calcareous; ironstone concretions in places; contact with above concealed.	3.3	(10.9)
1	SHALE--olive gray (5 Y 3/2) - grayish olive (10 Y 4/2) weathered, yellowish gray (5 Y 7/2) fresh; largely covered, some poor exposures locally; noncalcareous concretions occur near top; contact with unit above sharp, erosional.	10.3	(34.0)
	Total section thickness =	250.9	(828.2)

Base is floor of small wash. Units 1 - 10 measured southeast of this wash; rest of section measured in slopes to northwest of wash.

SECTION SJ3 - 1, BIKLABITO DOME (Rattlesnake 15' Quad.). East facing slope of point projecting eastward from cliffs on west side of dirt road; about 2 air miles southwest of village of Biklabito and almost due west of center of dome; SE¼, SW¼, sec. 14, T30N, R21W, San Juan County; section measured by William J. Stone, 12 August 1975.

Unit	Lithology	Thickness: m(ft)
	MORRISON FORMATION SALT WASH MEMBER	
10	COVERED SLOPE AND SANDSTONE	
10c	COVERED SLOPE--much porphyritic andesite talus above unit 10b; top of section is broad bench extending westward to mountain front.	13.0 (43.0)
10b	SANDSTONE--pale reddish brown (10 R 5/4) - light brown (10 YR 6/4) weathered, pinkish gray (5 YR 8/1) fresh; like other "buff" sandstones below except distinctly cross bedded like unit 5a; upper and lower contacts concealed.	6.0 (20.0)
10a	COVERED SLOPE	5.0 (16.5)
	BLUFF SANDSTONE	
9	SANDSTONE--moderate reddish brown (10 R 4/6) weathered, moderate reddish orange (10 R 6/6) fresh; beds thick - very thick, regular, uneven with thin planar, continuous, parallel laminae; grains fine, moderately sorted, subrounded; composed mainly of quartz; irregular calcite fracture fillings form boxwork; contact with above concealed.	11.2 (37.0)
	SUMMERVILLE FORMATION	
8	COVERED INTERVAL AND SANDSTONE--mostly covered except for 1-m thick SANDSTONE in second interval above base (Jacob's staff intervals = 1.6 m each); pale red (10 R 6/2) weathered, pinkish gray (5 YR 8/1) fresh; like SANDSTONE in unit 7 below.	4.5 (14.9)

7	SANDSTONE--moderate red (5 R 5/4) - grayish red (5 R 5/2) weathered, pinkish gray (5 YR 8/1) - moderate red (5 R 5/4) fresh; beds medium - thick, regular, uneven - even with vague planar, continuous, parallel laminae; grains very fine, fair to very well sorted, subrounded - rounded; composed mainly of quartz, some clay matrix, calcareous; unit consists of knobby, dark red-weathering, red SANDSTONE interbedded with non-knobby, red-weathering, white SANDSTONE, like unit 5 below, and minor red SHALE; contact with above concealed.	10.0	(33.0)
6	COVERED INTERVAL	9.3	(30.7)
5	SANDSTONE		
5b	SANDSTONE--pale red (10 R 6/2) weathered, pinkish gray (5 YR 8/1) fresh; largely covered by talus from above; resembles unit 2.	1.0	(3.3)
5a	SANDSTONE--light gray (N7) weathered, pinkish gray (5 YR 8/1) fresh; beds medium - thick, irregular, uneven with very thin - thin planar, continuous, convergent laminae; large scale trough(?) cross bedding; grains fine, very well sorted, rounded; composed mainly of quartz with little matrix, calcareous; contact with 5b above gradational.	1.6	(5.3)
4	SILTSTONE--moderate red (5 R 5/4) weathered and fresh; beds thin, irregular, uneven with thin indistinct laminae (disrupted by calcareous fracture fillings); silt grains fairly well sorted, subrounded; composed mainly of quartz with clay matrix, calcareous in part; only upper 1 m exposed; contact with above sharp.	3.1	(10.2)

ENTRADA SANDSTONE

3	SANDSTONE--grayish orange pink (5 YR 7/2) - light brown (5 YR 6/4) weathered and fresh; beds medium, regular, uneven with thin planar continuous, parallel laminae; faint trough cross bedding on bedding surfaces; grains very fine - fine, fairly sorted, rounded; composed mainly of quartz, little matrix, calcareous; contact with above concealed.	1.5	(5.0)

2	SANDSTONE--moderate reddish orange (10 R 6/6) - pale reddish brown (10 R 5/4) weathered and fresh; beds medium - thick, regular, uneven with some dark streaks suggesting medium laminae; inconspicuous cross bedding in places; grains very fine, well sorted, subrounded; composed mainly of quartz with some clay matrix, calcareous; forms smooth convey upward cliff with red and white banding; contact with above concealed.	11.5 (38.0)
1	SANDSTONE--moderate red (5 R 5/4) - pale reddish brown (10 R 5/4) weathered and fresh, a few white mottles; beds medium - thick, irregular, uneven with vague hint of thin to medium laminae; grains very fine, well sorted, subrounded; composed mainly of quartz, some clay matrix, calcareous; white mottles are bleached patches, 1 - 2 dcm in diameter, both scattered and localized at selected horizons; contact with above gradational.	7.3 (24.1)
	Total section thickness =	85.0 (281.0)

Measurement began at top of sandstone by road on west side (Wingate Sandstone). Dip not corrected for; measured to be 3°W in upper beds (such as unit 9).

SECTION SJ3 - 2, RED WASH (Rattlesnake 15' Quad.). Along northernmost of two forks in small tributary wash which enters Red Wash from east side; about 6 air miles southeast of Biklabito; SW¼, NW¼, sec. 26, T30N, R20W, San Juan County; section measured by William J. Stone, 12 August 1975.

Unit	Lithology	Thickness: m(ft)
	MANCOS SHALE (not measured)	
	DAKOTA SANDSTONE	
3	SANDSTONE--grayish orange pink (5 YR 7/2) - light brown (5 YR 6/4) weathered, very pale orange (10 YR 8/2) - grayish orange pink (5 YR 7/2) fresh; beds medium, irregular, uneven with some indistinct thin laminae; ripple marks seen on float block to west that may be from this horizon, base irregular due to load structures; grains very fine - fine, well sorted, subrounded; composed mainly of quartz, clay matrix, calcareous; contact with above concealed; this unit may correspond to unit 8 of a more complete Dakota section measured in Red Wash by J.R. Kostura (a graduate student at Bowling Green, working with Don Owen).	7.4 (24.4)
2	COAL--pale yellowish orange (10 YR 8/6) - light brown (5 YR 5/6) weathered, dusky brown (5 YR 2/2) fresh; beds very thin, irregular, even, shaly; most low grade, dull, crumbly, some small vitreous blebs locally; contact with above sharp.	1.1 (3.6)
1	SILTSTONE--medium light gray (N6) streaked with dark gray (N3) weathered, light brown (5 YR 6/4) - moderate brown (5 YR 4/4) fresh; beds very thin - thin, irregular, uneven with thin irregular, discontinuous laminae; much fine carbonaceous detritus along laminae; not calcareous; contact with above sharp.	1.7 (5.6)
	Total section thickness =	10.2 (33.6)

Base is floor of wash. No lower sandstone beds encountered in spite of walking down wash a good distance, only more siltstone/shale like unit 1.

SECTION SJ3 - 3, MITTEN ROCK (Mitten Rock 7½' Quad.). Northwest-facing slope, east side Little Shiprock Wash, west side Mitten Rock; about 1 air mile due north of Red Rock Highway and about 15 highway miles west of U.S. 666; SE¼, SE¼, sec. 34, T28N, R20W, San Juan County; section measured by William J. Stone, 14 August 1975.

Unit	Lithology	Thickness: m(ft)
DAKOTA SANDSTONE		
10	SANDSTONE--grayish orange pink (5 YR 7/2) weathered, banded very pale orange (10 YR 8/2) and grayish orange (10 YR 7/4) fresh; beds medium - thick, irregular, uneven with thin - medium curved, discontinuous, convergent laminae; large-scale, high-angle, trough cross bedding; grains medium, well sorted, rounded; composed mainly of quartz, some clay matrix, slightly calcareous; nothing above this where measured.	2.0 (6.6)
9	COVERED SLOPES AND MUDSTONE	
9d	SILTSTONE--pale olive (10 Y 6/2) - yellowish gray (5 Y 7/2) weathered and fresh; beds indistinct and irregular; contains carbonaceous plant fragments up to a 10 cm long; contact with above sharp.	2.0 (6.6)
9c	COVERED SLOPE	8.0 (26.4)
9b	SANDSTONE--grayish orange pink (5 YR 7/2) weathered, very pale orange (10 YR 8/2) - light brown (5 YR 8/2) - light brown (5 YR 6/4) fresh; single medium bed; grains very fine, well sorted, subangular; composed mainly of quartz, some clay matrix, calcareous; contact with above concealed.	0.3 (1.0)
9a	COVERED SLOPE--gray - rust SHALE?	10.0 (33.0)
MORRISON FORMATION BRUSHY BASIN MEMBER		
8	SANDSTONE--light brown (5 YR 6/4) - grayish orange pink (5 YR 7/2) weathered, banded - mottled pale brown (5 YR 5/2) and pale yellowish brown (10 YR 6/2) fresh; beds obscure except where marked by	4.2 (13.9)

	pebbles; grains very fine - fine, moderately sorted, subangular with granules and pebbles up to 7 cm maximum diameter; composed mainly of quartz, clay matrix, calcareous; upper part contains voids which suggest former presence of plant debris and very euhedral quartz grains; contact with above concealed.	
7	COVERED INTERVAL	7.3 (24.1)
6	MUDDY SANDSTONE--light brown (5 YR 6/4) weathered, grayish orange pink (5 YR 7/2) - light brown (5 YR 6/4) fresh; beds indistinct, irregular, uneven with vague thin laminae; hint of cross bedding in places; grains fine - very coarse, poorly sorted, subangular - rounded; composed mainly of quartz but some mafic minerals also present, much clay matrix (most grains "float"), not calcareous; contact with above concealed; upper part oxidized more than lower.	2.4 (7.9)
5	COVERED INTERVAL--may be interbedded SANDSTONE AND SHALE.	27.6 (91.1)
4	SANDSTONE--very pale orange (10 YR 8/2) - grayish orange pink (5 YR 7/2) weathered, white (N) - grayish orange pink (5 YR 7/2) fresh; beds medium - thick, regular, uneven with thin(?) inconspicuous laminae, possibly cross bedded(?); grains fine - medium, well sorted, subrounded; composed mainly of quartz, very little clay, lower part friable and calcareous, upper part dense and completely cemented by siliceous material; dense part covered by heavy coat of desert varnish; contact with above concealed.	5.1 (16.8)
3	COVERED INTERVAL	8.7 (28.7)
2	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds medium, regular, uneven with planar, continuous, parallel laminae of uncertain thickness; grains fine - medium, moderately sorted, clay matrix, calcareous; contact with above concealed.	4.2 (13.9)

1	SHALE--pale yellowish brown (10 YR 6/2) weathered and fresh; concretionary; poorly exposed.	12.0 (39.6)
	Total section thickness =	96.0 (316.8)

Base is road along south bank of Little Ship Rock Wash. Dip of 20° S80°E measured in unit 4; Abney level set for 20° in measuring units 5 through 10.

SECTION SJ3 - 4, BIKLABITO ROAD (Rattlesnake 15' Quad.). South-facing bank of Ship Rock Wash(?); north side of NM 504; 9 air miles west of town of Shiprock; NW¼, NW¼, sec. 21, T30N, R19W, San Juan County; section measured by William J. Stone, 11 August 1975.

Unit	Lithology	Thickness: m(ft)
GALLUP SANDSTONE		
4	SANDSTONE--grayish orange pink (5 YR 7/2) - very pale orange (10 YR 8/2) weathered, very pale orange (10 YR 8/2) fresh; beds thick, irregular, uneven, laminae indistinct, bedding surfaces planar - curved, discontinuous, convergent; cross bedded as in unit 3 below; grains medium, well sorted, subrounded; composed mainly of quartz, little matrix, not calcareous; overlain by .1 - .3 m Quaternary dune sand.	2.7 (8.9)
3	SANDSTONE--grayish orange pink (5 YR 7/2) weathered, very pale orange (10 YR 8/2) fresh; beds thin - medium, irregular, uneven, laminae indistinct, bedding surfaces planar - curved, discontinuous, parallel - convergent; large-scale, tangential, high-angle, grouped, cross bedding type uncertain owing to exposure, beds separated in places by thin shale partings; grains medium - coarse, well sorted, subrounded - rounded; composed mainly of quartz, little matrix, calcareous; contains burrows; contact with above gradational.	2.8 (9.2)
2	SANDSTONE--grayish orange pink (5 YR 7/2) weathered, very pale orange (10 YR 8/2) fresh; beds medium, regular, uneven, laminae indistinct, bedding surfaces planar, continuous, parallel - convergent; large-scale, tangential, low-angle, grouped trough cross bedding in lower and upper parts, missing in middle due to bioturbation(?); grains medium, well sorted, rounded, pebbles at base like at top of unit 1; composed mainly of quartz with little matrix, calcareous in part; contains smooth-walled burrows and shell fragments; contact with above gradational.	2.6 (8.6)

1	SANDSTONE--grayish orange pink (5 YR 7/2) weathered, very pale orange (10 YR 8/2) fresh; beds thin - medium, regular, uneven, vertically variable in resistance to erosion (may be controlled by variation in bioturbation); grains fine - medium, fairly sorted, subrounded - rounded, upper few dcm contain clasts up to 1 cm in diameter; composed mainly of quartz with clay matrix, calcareous; only upper .5 m exposed in undercut beneath unit 2; contact with above sharp.	1.5 (5.0)
	Total section thickness =	9.6 (31.7)

Base is arroyo floor 10 - 15 m northwest of culvert at highway. Dip is low (3° N60°E), not corrected for. Slope of arroyo floor and dip similar so walking downstream revealed only slightly lower beds; base of Gallup Sandstone never encountered.

SECTION SJ3 - 5, ROCK RIDGE (Mitten Rock 7½' Quad.). Southeast-facing cliff, northwest side of stream and road cut through Rock Ridge; 3 3/4 air miles southeast of Mitten Rock, about 1 air mile northwest of Big Gap Reservoir; NW¼, sec. 17, T27N, R19W, San Juan County; section measured by William J. Stone, 15 August 1975.

Unit	Lithology	Thickness: m(ft)
MANCOS SHALE (not measured)		
GALLUP SANDSTONE		
7	SANDSTONE--pale brown (5 YR 5/2) weathered, very pale orange (10 YR 8/2) fresh; beds thin - medium, regular, even with indistinct laminae; vague, large-scale, trough cross bedding; grains medium, well sorted, subrounded; composed mainly of quartz, some clay matrix (from feldspar weathering), calcareous; lower 3 m covered, slope forming; appears to be top of Gallup Sandstone.	8.0 (26.4)
6	SANDSTONE--light brown (5 YR 6/4) - pale brown (5 YR 5/2) weathered, grayish orange (10 YR 7/4) fresh; beds thick regular, even with thin - medium, curved, continuous, convergent laminae; large-scale, tangential, trough cross bedding; grains medium to very coarse, well sorted within laminae, subrounded - rounded; composed mainly of quartz, little clay matrix, not calcareous; contains small diameter, straight, smooth-walled burrows; contact with above concealed.	1.6 (5.3)
5	COVERED INTERVAL (SHALE?)	8.0 (26.4)
4	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds medium - thick; large-scale trough cross bedding; grains medium, well sorted, subrounded; composed mainly of quartz, clay matrix, not calcareous; contact with above concealed.	12.8 (42.2)
3	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds thin - medium, regular, even; small - large-scale, trough cross bedding; grains fine - medium, moderately sorted, subrounded - rounded; composed mainly of	3.2 (10.6)

quartz, clay matrix, slightly calcareous; minor muscovite; contact with above sharp.

2	SANDSTONE--grayish orange (10 YR 7/4) weathered, pale yellowish orange (10 YR 8/6) fresh; beds medium - thick, regular, even; conspicuous large-scale, trough cross bedding; grains medium - coarse, moderately sorted, subrounded - rounded; composed mainly of quartz, some clay matrix, not calcareous; contact with above sharp.	9.0 (29.7)
1	SANDSTONE--light brown (5 YR 6/4) weathered, grayish orange (10 YR 7/4) fresh; beds thick, regular, uneven with thin planar, continuous, parallel laminae; grains fine - medium, moderately sorted, subrounded - rounded; composed mainly of quartz, clay matrix, not calcareous; contact with above sharp.	16.0 (52.8)
	Total section thickness =	58.6 (193.4)

Base is contact with Mancos Shale below as seen in wash on north side of road. Measured with Abney level set for 8^{o} dip but dip may flatten out somewhat in uppermost beds (units 6 and 7).

AREA 2 SECTIONS (McKinley County)

The second area covered was McKinley County. The uranium mines at Ambrosia Lake and Church Rock, as well as the McKinley coal mine, lie within its boundaries. Although the Tertiary sedimentary units are not present, the Jurassic rocks and the Crevasse Canyon Formation of the Mesaverde Group (Cretaceous) are best developed in this area. Outcrops along the northern flank of the Zuni Mountains provide an excellent opportunity to measure fairly complete stratigraphic sections through the Jurassic and Cretaceous deposits of the southern part of the basin. Sections measured and the intervals covered in each are given in Table 3.

Table 3. Catalog of sections measured in Area 2 (McKinley County) by location; abbreviations for units same as in Table 1.

Location (sec., T, R)	Section No.	Units Covered	Page
AREA 3 EAST--east of NM 57, south of Torreon Road, west of county line			
17, 20, 24, 14N, 11W to 4, 9, 21, 15N, 11W	MK3E - 1	Je, Jt, Js, Jb, Jm, Kd, Kg, Kcdi, Kcb, Kcda, Kcg, Kpl	84
11, 13, 18, 13N, 10, 11W	MK3E - 2	Je, Jt, Js, Jb, Jcs, Jm, Kd	94
19, 14N, 10W	MK3E - 3	Kg, Kcdi, Kcb	99
Additional sections measured for this area in the hydrogeologic study will appear in New Mexico Tech M.S. thesis by R.C. Brod.			
AREA 3 WEST--west of NM 57, south of Navajo 7, east of US 666			
11, 15N, 17W to 36, 16N, 17W	MK3W - 1A	Je, Jt, Js, Jcs, Jm, Kd	66
23, 27, 16N, 17W	MK3W - 1B	Kd	72
23, 14, 16N, 17W	MK3W - 1C	Kg, Kcdi	74
2, 16N, 17W	MK3W - 1D	Kcdi, Kcda	77
19, 30, 17N, 16W	MK3W - 1E	Kcg, Kpl	81

SECTION MK3W - 1A, CHURCH ROCK ROAD (Church Rock 7½' Quad.). Measured exposures along Church Rock Mine road between base of Entrada Sandstone cliffs north of village of Church Rock, past Kit Carson Cave, to top of Dakota Sandstone where it caps mesa that lies 1/2 air mile southwest of Springstead Trading Post and between Church Rock Mine Road and Pinedale Road; section extends from SE¼, sec. 11, T15N, R17W to SE¼, NE¼, sec. 36, T16N, R17W, McKinley County; section measured by William J. Stone and Robert C. Brod, 10 June 1977.

Unit	Lithology	Thickness: m(ft)
DAKOTA SANDSTONE		
16	SANDSTONE AND SHALE--grayish orange (10 YR 7/4) and some dark yellowish orange (10 YR 6/6) weathered, mattled dark yellowish orange (10 YR 6/6) and light greenish gray (5 G 8/1) fresh; beds medium, irregular, even(?) with thin planar, discontinuous, parallel laminae; large-scale, low-high angle, concordant - tangential, grouped, trough - tabular-planar cross bedding in middle and top; float blocks of unit display tool marks on soles of beds; grains medium - very coarse, moderately - well sorted, subrounded - rounded; composed mainly of quartz, not calcareous; carbonaceous SHALE interbeds up to a few m thick.	10.2 (33.7)
15	CARBONACEOUS SHALE AND COAL--brownish black (5 YR 2/1), dark yellowish orange (10 YR 6/6), and all shades of gray (N-3 - N-8) weathered and fresh; beds indistinct; mostly covered; contact with above sharp.	4.7 (15.5)
14	SANDSTONE--dark yellowish orange (10 YR 6/6) - pale yellowish orange (10 YR 8/6) weathered, yellowish gray (5 Y 7/2) fresh; beds thin, irregular, uneven with indistinct thin laminae; grains medium - very coarse, fairly - moderately sorted, subrounded with gravel up to a few cm in diameter; composed mainly of quartz, not calcareous; contains carbonaceous stringers and trash; contact with above concealed.	3.7 (12.2)

MORRISON FORMATION
BRUSHY BASIN MEMBER(?)

13 SHALE--white (N9), bluish white (5 B 9/1) weathered, very light gray (N8), pale purple (5 P 6/2) fresh, some pale yellowish orange (10 YR 8/6) - dark yellowish orange (10 YR 6/6) both weathered and fresh; beds indistinct, largely covered; contact with above sharp. 4.7 (15.5)

MORRISON FORMATION
WESTWATER CANYON MEMBER

12 SANDSTONE--grayish orange pink (5 YR 7/2) weathered and fresh, some grayish orange pink (10 R 8/2) fresh; beds thick - very thick, irregular, uneven with thin, curved laminae; cross bedding similar to that in unit 10 below; grains medium - very coarse, moderately sorted, subrounded with pebble gravel; composed of quartz and feldspar with clay matrix, not calcareous; base irregular, unit thickens and thins laterally; contact with above concealed. 16.6 (54.8)

MORRISON FORMATION
RECAPTURE MEMBER (TONGUE)

11 MUDSTONE AND SANDSTONE 19.4 (64.0)

11d SHALE--pale olive (10 Y 6/2) - dusky yellow (5 Y 6/4) weathered and fresh; mostly covered.

11c SANDSTONE--yellowish gray (5 Y 8/1) weathered, very light gray (N8) - light greenish gray (5 GY 8/1) fresh; beds thin, irregular, uneven with very thin(?); planar laminae; grains very fine - fine, moderately sorted, subrounded; composed mainly of quartz, clay matrix, calcareous; contact with above concealed.

11b SILTSTONE--yellowish green (5 Y 8/1) - light greenish gray (5 G 8/1) weathered, yellowish green (5 Y 8/1) - white (N9) fresh; beds thin, irregular, uneven with thin(?) planar laminae; slightly calcareous;

contains light greenish gray (5 GY 8/1) - greenish gray (5 GY 6/1) clay chips along bedding surfaces; contact with above concealed.

11a MUDSTONE--grayish red (5 R 4/2) - pale olive (10 Y 6/2) - dusky yellow (5 Y 6/4) weathered and fresh; beds thin, irregular, uneven, massive; mostly clay with floating coarse - very coarse rounded, quartz sand grains, not calcareous; contact with above sharp.

On slope to west of where measured, top of unit 11 is lower and 2 red-white-green (ascending order) mudstone intervals like that described here are present above and below a tongue of sandstone like unit 10. Abrey changed to 3½° prior to measurement of unit 12.

MORRISON FORMATION
WESTWATER CANYON MEMBER

10 SANDSTONE--grayish orange pink (5 YR 7/2) weathered and fresh; some grayish orange pink (10 R 8/2) fresh; beds thick, irregular, uneven with thin curved, discontinuous, convergent laminae; large-scale, tangential, high-angle, grouped, trough cross bedding; grains fine - medium, moderately sorted, subrounded - rounded with gravel up to 2 cm in diameter; sand composed of quartz and feldspar, locally altered to clay, gravel consists of quartz, K feldspar, claystone, clay matrix, not calcareous, contact with above sharp. 21.4 (70.6)

Units 11 through 17 measured SE¼, NE¼, sec. 36, T16N, R17W.

MORRISON FORMATION
RECAPTURE MEMBER

9 SANDSTONE--very similar to unit 8 below. Overlain by Westwater Canyon Member of Morrison; offset to north (sec. 36) for Westwater Canyon Member of Morrison and higher units. 21.3 (70.3)

COW SPRINGS SANDSTONE (TONGUE)

8	SANDSTONE--grayish orange pink (5 YR 7/2) weathered, very pale orange (10 YR 8/2) fresh; beds thick - very thick, irregular, uneven with thin indistinct laminae; large-scale, high-angle, trough cross bedding; grains fine, well sorted, subrounded; composed mainly of quartz; little matrix, not calcareous; forms large "hoodoos" east of road at curve (SW¼, NE¼, sec. 1, T15N, R17W; traced from there to lower part of cliffs south of Kit Carson Cave where units 9 and 10 measured (SE¼, NE¼, sec. 1).	11.0 (36.3)

MORRISON FORMATION
RECAPTURE MEMBER

7	SANDSTONE--pale olive (10 Y 6/2) weathered, pale yellowish green (10 GY 7/2) - light greenish gray (5 GY 8/1) fresh with resistant blebs pale brown (5 YR 5/2) weathered, light brown (5 YR 6/4) fresh; only hint of bedding or internal structure is given by horizons of elongate cavities and resistant blebs; grains fine, moderately sorted, mostly quartz; contact with above sharp.	39.5 (130.4)
6	INTERBEDDED SANDSTONE AND MUDSTONE--; SANDSTONE is moderately orange pink (5 YR 8/4) - very pale orange (10 YR 8/2) weathered, light greenish gray (5 GY 8/1) - white (N9) fresh; MUDSTONE is dark reddish brown (10 R 3/4) - grayish red (10 R 4/2) weathered, mottled grayish red (10 R 4/2) and grayish green (5 GY 6/1) fresh; SANDSTONE intervals range from 0.5 - 5.0 m in thickness, thickest at the top of unit, more or less structureless; Mudstone consists of SILTSTONE and a few good clay SHALES up to 5 dcm thick; contact with above may be erosional(?); Crossed highway for upper part and unit 7.	83.5 (275.6)

COW SPRINGS SANDSTONE

5	"BANDED" SANDSTONE--grayish orange pink (5 YR 7/2) weathered, grayish orange pink	79.5 (262.4)

(5 YR 7/2) - light brown (5 YR 6/4) fresh; beds thick - very thick, regular, uneven massive, mostly indistinct; vague large-scale, trough cross bedding, some deformed(?) in upper part; grains silt - fine sand, moderately sorted, subrounded - rounded; composed mainly of quartz, slightly calcareous; color banding less distinct in upper 5 - 10 m; contact with above farily sharp.

SUMMERVILLE FORMATION

4	SILTSTONE--poorly exposed.	1.7	(5.6)

TODILTO LIMESTONE

3	LIMESTONE--pinkish gray (5 YR 8/1) - yellowish gray (5 Y 8/1) grayish orange pink (10 R 8/2) weathered, pinkish gray (5 YR 8/1) - light greenish gray (5 GY 8/1) fresh; beds thin - very thin, irregular, uneven with thin - very thin wavy, discontinuous, parallel(?) laminae; pull-apart structure apparent locally; microcrystalline; contact with above concealed.	0.6	(2.0)

ENTRADA SANDSTONE
UPPER MEMBER

2	SANDSTONE--pale brown (5 YR 5/2) - light brown (5 YR 6/4) weathered, light brown (5 YR 5/6) fresh; beds very thick, regular, uneven with very thin - thin planar - curved, discontinuous, convergent laminae; conspicuous large-scale, tangential, high-angle, grouped, trough cross bedding; grains fine - medium, well sorted, well rounded; composed of quartz and minor amount of unidentified dark mineral, calcareous; contact with above marked by interval of sandstone, possibly reworked from Entrada, characterized by small-scale, tangential, low-angle, grouped, trough cross bedding; overlain by thin layer of gravel up to 3 cm in diameter.	50.5	(166.7)

ENTRADA SANDSTONE
MIDDLE SILTSTONE MEMBER

1	SILTSTONE--mottled pale reddish brown (10 R 5/4) - moderate orange pink (10 R 7/4) and very light gray (N8) - white (N9) weathered, mottled moderate reddish brown (10 R 4/6) - pale reddish brown (10 R 5/4) and pinkish gray (5 YR 8/1) - white (N9) fresh; beds thin - very thick (most medium), regular, uneven with very thin - thin, planar and wavy, discontinuous(?), parallel laminae; grains silt - medium sand (most silt or very fine sand), well sorted, subrounded; composed mainly of quartz, iron stained, calcareous; knobby or "rock-baby" weathering habit; contact with above sharp due to lithologic break and associated "alkali" zone. Abney set for 1½° based on dip here. Unit only partially exposed.	21.4 (70.6)
	Total section thickness =	389.7 (1286.0)

Base is base of exposed middle Entrada; ground surface covered with modern dune sand.

SECTION MK3W - 1B, SOUTH OF NOSE ROCK POINT (Church Rock 7½' Quad.). Dakota Sandstone bench that forms northwest bank of Puerco River; exposures just east of Hard Ground Flats road and outcrops at top of bench to northeast, about 1 air mile slightly west of south of Nose Rock Point and about 2½ air miles west northwest of Springstead Trading Post; W½, SW¼, sec. 23 and NW¼, NE¼, NE¼, sec. 27, T16N, R17W, McKinley County; section measured by William J. Stone and Robert C. Brod, 13 July 1977.

Unit	Lithology	Thickness: m(ft)
	DAKOTA SANDSTONE TWO WELLS MEMBER	
3	SANDSTONE--color not recorded; beds indistinct except at top where thin and platy; grains fine - medium, coarser than main body of Dakota below; top characterized by smooth-walled, vertical and horizontal, sand-filled burrows; described from scattered outcrops at top of bench, lies well above main Dakota, poorly exposed.	? (?)
	DAKOTA SANDSTONE (main body)	
2	SANDSTONE--grayish orange (10 YR 7/4) - pale yellowish orange (10 YR 8/6) and light brown (5 YR 5/6) mottled with yellowish gray (5 Y 7/2) - greenish gray (5 GY 6/1) weathered, very pale orange (10 YR 8/2) fresh, local iron staining is dark yellowish orange (10 YR 6/6); beds thin - medium, irregular, uneven with thin, planar-continuous-parallel, wavy-discontinuous-parallel, and curved-discontinuous-convergent laminae; abundant symmetrical (minor asymmetrical), straight and sinuous ripple marks in upper half of unit, crest heights up to 1 cm, wave lengths up to 1 dcm, striking northwesterly to northeasterly, locally these orientations form interference ripple marks; minor large-scale, tangential - concordant, high-angle, solitary, tabular-planar cross bedding; grains very fine, very well sorted, rounded; composed mainly of quartz, calcareous; at top is horizon with horizontal, branching, smooth-walled, filled burrows, 1-2 cm in diameter; forms ledge and cliff, is uppermost unit next to road, to north is overlain by tongue of Mancos Shale.	2.25 (7.4)
1	SHALE--color not recorded; carbonaceous with thin coaly horizons.	7.0 (23.1)

Another SANDSTONE (probably also Dakota) lies below the coaly interval based on a few poor exposures; not measured or described.		
Total section thickness	=	9.3 (30.5)

Base is road level at base of west-facing slope just east of road. Dip is 4^{o} toward northwest. Thickness of unit 1 determined by Jacob's Staff; thickness of unit 2 measured with a tape.

SECTION MK3W - 1C, NOSE ROCK POINT (Church Rock 7½ Quad.). Southwest-facing slope at southwestern point of mesa between the valley of the Puerco River and Hard Ground Canyon; about 3 air miles northwest of Springstead Trading Post and 2 air miles north of junction of drainage from Hard Ground Canyon and the Puerco; NW¼, NW¼, NW¼, sec. 23 and SW¼, SW¼, SW¼, sec. 14, T16N, R17W, McKinley County; section measured by William J. Stone and Robert C. Brod, 13 June 1977.

Unit	Lithology	Thickness: m(ft)
CREVASSE CANYON DILCO MEMBER (not measured)		
GALLUP SANDSTONE		
21	SANDSTONE--moderate orange pink (5 YR 8/4) weathered, grayish orange pink (10 R 8/2) fresh; beds medium - very thick, regular(?), uneven with thin, planar - curved, discontinuous, convergent laminae or massive; small-scale, tangential(?), low-angle, grouped, wedge-planar, cross bedding; grains fine, well sorted, subrounded; composed mainly of quartz, clay matrix, not calcareous; log type carbonate concretions, plant trash on bedding at some horizons; contact with above inaccessible, forms steep cliff at top of mesa, uppermost Gallup ("Torrivio Member") lies above so not observed; thickness estimated from topo sheet.	60.0? (198.0?)
20	SANDSTONE--grayish orange (10 YR 7/4) - grayish orange pink (5 YR 7/2) weathered, light greenish gray (5 GY 8/1) fresh; beds thick at base, thin at top, irregular, uneven with thin - medium, planar, discontinuous, convergent laminae or massive; vague small-scale, low-angle, solitary trough cross bedding; grains very fine - fine, well sorted, subrounded; composed mainly of quartz, very calcareous with luster mottling; contains interbeds up to a few dcm thick of dirty, carbonaceous, very fine SANDSTONE; forms slope; contact with above sharp.	9.7 (32.0)
19	SANDSTONE--like unit 11 below but contains log type carbonate concretions; forms cliff; contact with above marked by change in slope.	16.7 (55.1)

18	SHALE--like unit 2 below; carbonaceous; contains layers of very fine, medium laminated SANDSTONE; contact with above gradational.	19.4	(64.0)
17	SANDSTONE--like unit 11 below.	9.1	(30.0)
16	SHALE--like unit 2 below.	4.0	(13.2)
15	SANDSTONE--like unit 11 below except beds medium, irregular, uneven with thin - medium (top), planar - curved, discontinuous, parallel laminae; vague cross bedding; contact with above sharp.	0.3	(1.0)
14	SHALE--like unit 2 below.	18.4	(60.7)
13	SANDSTONE--like unit 11 below.	1.6	(5.3)
12	SHALE--like unit 2 below.	2.0	(6.6)
11	SANDSTONE--mottled grayish orange (10 YR 7/4) and very pale orange (10 YR 8/2) weathered and fresh; single thick bed with thin - medium (top), planar, continuous, parallel laminae; grains very fine, well sorted, subrounded; composed mainly of quartz, not calcareous; forms ledge.	.8	(2.6)
10	SHALE--like unit 2 below.	4.0	(13.2)
9	SANDSTONE--like unit 7 below except consists of single medium bed with thin - medium, planar, continuous, parallel laminae.	0.5	(1.7)
8	SANDSTONE--plant debris near top, poorly exposed, forms slope.	2.0	(6.6)
7	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds thin - thick, irregular, uneven with thin - medium (top) curved, discontinuous, convergent laminae; large-scale, concordant, trough cross bedding; grains very fine, well sorted, subrounded; composed mainly of quartz, very calcareous with luster mottling; contact with above concealed.	0.6	(2.0)
6	SHALE--like unit 2 below.	0.9	(3.0)
5	SANDSTONE--grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2) weathered and fresh; beds thin - medium, irregular, uneven with	1.1	(3.6)

	thin, planar, discontinuous, convergent laminae; vague cross bedding at top; grains like unit 1 below; contact with above concealed.	
4	SHALE--like unit 2 below; forms cliff; conspicuously fractured like Mancos Shale below unit 1.	18.4 (60.7)
3	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; most beds thin, some thick, regular, even with vague thin planar laminae; grains very fine, well - very well sorted; composed mainly of quartz, calcareous; forms ledge; contact with above concealed.	1.0 (3.3)
2	SHALE--yellowish gray (5 Y 7/2) weathered, pale olive (10 Y 6/2) fresh; beds thin, irregular, uneven with thin, planar, continuous, convergent laminae; ripple marks seen in cross section in interbedded thin beds of SANDSTONE like unit 1 below; carbonaceous; horizontal - branching, smooth-walled, sand-filled burrows; forms steep slope; contact with above sharp.	4.2 (13.9)
1	SANDSTONE--grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2) weathered and fresh; beds thick, indistinct in places, regular(?), even(?) with thin laminae - massive; grains very fine, well - very well sorted, subrounded - rounded; composed mainly of quartz, abundant carbonaceous debris, not calcareous; base characterized by load/ collapse structures; SANDSTONE content of Mancos Shale below increases upward toward base of unit 1 which is first thick SANDSTONE in sequence; forms cliff; contact with above concealed.	3.1 (10.2)
	Total section thickness =	177.8 (586.7)

Base is base of first thick sandstone in transition zone between Mancos Shale and Gallup Sandstone. Dips averaging 13° (northwesterly) measured in Mancos here; Abney set accordingly.

SECTION MK3W - 1D, HARD GROUND CANYON (Hard Ground Flats 7½ Quad.). Southeast-facing cliffs on northwestern wall of canyon in area between Nose Rock Point and Hard Ground Flats; about 2 air miles slightly east of north of Nose Rock Point and about 2.5 air miles southwest of the center of Hard Ground Flats; SE¼, SW¼ -- W½, SE¼, sec. 2, T16N, R17W, McKinley County; section measured by William J. Stone and Robert C. Brod, 14 June 1977.

Unit	Lithology	Thickness: m(ft)
	CREVASSE CANYON FORMATION DALTON SANDSTONE MEMBER	
28	SANDSTONE--grayish orange (10 YR 7/4) and light greenish gray (5 GY 8/1) weathered, light greenish gray (5 GY 8/1) fresh; beds thin - very thick, irregular, uneven with very thin, planar, discontinuous, convergent laminae; large-scale, tangential, low-angle, solitary wedge-planar cross bedding; grains medium, well sorted, angular - rounded; composed mainly of quartz, clay matrix; pitted weathering habit, generally forms cliff; caps mesa, overlain by quartzite pebbles on soil surface.	9.1 (30.0)
27	SHALE--like unit 10 below.	0.8 (2.6)
26	SANDSTONE--grayish orange (10 YR 7/4) - light greenish gray (5 GY 8/1) weathered and fresh; beds medium, irregular, uneven with thin laminae; grains medium, well sorted, subrounded; composed mainly of quartz; not well expersed.	0.9 (3.0)
25	SHALE--like unit 10 below.	0.9 (3.0)
24	SANDSTONE--like unit 22 below except beds thin.	1.0 (3.3)
23	SANDSTONE--like unit 22 except not friable.	2.7 (8.9)
22	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds thick, regular(?), uneven with thin, planar, continuous, parallel laminae; grains very fine - fine, moderately sorted, subrounded; composed mainly of quartz, friable; pitted weathering habit, forms slope; contact with above sharp.	4.7 (15.5)
21	COVERED INTERVAL--small exposures of medium-bedded sandstone; otherwise thick talus.	10.2 (33.7)

20	SANDSTONE--like unit 19 below but forms slope.	2.3 (7.6)
19	SANDSTONE--grayish orange (10 YR 7/4) - grayish orange pink (5 YR 7/2) weathered and fresh; beds thick, irregular, uneven with thin, locally distorted, planar - curved laminae; vague, large-scale, trough cross bedding; grains fine - coarse, moderate sorting, fining upward, subrounded; composed mainly of quartz; forms overhanging ledge; contact with above marked by break in slope.	6.1 (20.1)
18	SHALE--like unit 10 below.	1.8 (5.9)
17	SANDSTONE--grayish orange pink (5 YR 7/2) weathered and fresh; beds medium, irregular, uneven with very thin planar, discontinuous, convergent laminae; large-scale, discordant, high-angle, solitary, tabular-planar cross bedding; grains fine, moderately sorted, subangular; composed mainly of quartz; contact with above sharp.	12.4 (40.9)
16	INTERBEDDED SANDSTONE AND SHALE--largely covered.	3.3 (10.9)
15	SANDSTONE--like unit 11 below.	0.5 (1.7)
14	SHALE--like unit 10 below.	1.0 (3.3)
13	SANDSTONE--like unit 11 below.	0.1 (0.3)
12	SHALE--like unit 10 below.	10.7 (35.3)
11	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds medium - thick, irregular, even(?) with thin - medium, planar - curved, continuous, parallel laminae; cross bedded; grains very fine, well - very well sorted, subrounded; composed mainly of quartz, calcareous; contact with above concealed.	7.1 (23.4)
10	SHALE--pale olive (10 Y 6/2) - yellowish gray (5 Y 7/2) weathered and fresh; beds very thin; contains thin SANDSTONE layers; contact with above gradational.	7.2 (23.8)

CREVASSE CANYON FORMATION
DILCO COAL MEMBER

9	SANDSTONE--like unit 7 below; contains deformed cross bedding; appears local, discontinuous laterally.	0.6	(2.0)
8	Shale--like unit 2 below.	7.7	(25.4)
7	Sandstone--light brown (5 YR 6/4) - grayish orange (10 YR 7/4) weathered and fresh; beds thick, irregular(?) uneven with thin, planar(?) laminae (difficult to see structure); grains very fine - fine, moderately - well sorted, subrounded; composed mainly of quartz, not calcareous; carbonaceous debris; contact with above largely concealed. Offset up canyon along top of this SANDSTONE for measurement of overlying units.	1.8	(5.9)
6	SHALE--like unit 2 below.	0.8	(2.6)
5	SANDSTONE--light brown (5 YR 6/4) - grayish orange pink (5 YR 7/2) weathered and fresh; beds thin - medium, irregular(?), uneven with thin planar - curved, discontinuous, convergent laminae; grains very fine, fairly - moderately sorted, subrounded; composed mainly of quartz, not calcareous; carbonaceous plant fragments and root-like rusty staining; contact with above concealed.	0.6	(2.0)
4	SHALE--largely covered, like unit 2 below.	6.1	(20.1)
3	SANDSTONE--grayish orange (10 YR 7/4) - light brown (5 YR 6/4) weathered and fresh; beds medium - thick, irregular, uneven with thin planar, discontinuous, parallel laminae; vague, large-scale, tangential(?), low-angle, grouped, wedge-planar, trough cross bedding; grains fine, moderately sorted, subrounded; composed mainly of quartz, some mud chips (rip up), abundant carbonaceous plant fragments, not calcareous; contact with above concealed.	0.5	(1.7)
2	SHALE--yellowish gray (5 Y 8/1) - brownish gray (5 YR 4/1) silty shale and dark greenish gray (5 GY 4/1) - brownish black (5 YR 2/1) carbonaceous shale; silty shale contains muscovite, carbonaceous shale contains thin coaly horizons; only lower few m exposed.	16.6	(54.8)

GALLUP SANDSTONE

1	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; characterized by conspicuous large-scale, trough cross bedding; grains very coarse - fine (fining upward); probably is "Torrivio Member" of Molenaar (1973); only partially exposed; contact with above sharp.	?
	Total section thickness =	117.5 (387.7)

Base is top of Gallup Sandstone. Dip there about 4° northeasterly; Abney level set accordingly.

SECTION MK3W - 1E, HARD GROUND FLATS (Hard Ground Flats 7½' Quad.). South-facing slope of mesa at north edge of Flats; about 1½ air miles slightly east of south of Red Water Pond, about 3/4 air mile northwest of windmill on flats; NW½, NE½, sec. 30(?) and SW½, SE½, sec. 19(?), T17N, R16W (based on extended land grid), McKinley County; section measured by William J. Stone and Robert C. Brod, 16 June 1977.

Unit	Lithology	Thickness: m(ft)
MENEFEE FORMATION (thin, not measured)		
POINT LOOKOUT SANDSTONE		
12	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds thin - thick, irregular, uneven with thin, wavy(?) laminaeu; large-scale, tangential, high-angle, solitary, trough cross bedding; grains very fine, well sorted, subrounded; composed mainly of quartz, clay matrix, calcareous; contains small plant fragments and local clay lenses; bedding surfaces near top show smooth-walled, horizontal, branching, filled burrows up to 1 cm in diameter; lack of distinct structure in rest may be due to bioturbation(?); forms cliff, caps mesa.	5.4 (17.8)
CREVASSE CANYON SANDSTONE GIBSON COAL MEMBER		
11	CARBONACEOUS SHALE--light - dark gray (N7 - N3) weathered, olive gray (5 Y 4/1) fresh; beds thin with thin laminae; some beds are silt - stone; carbonaceous plant fragments abundant throughout; contact with above sharp.	2.5 (8.3)
10	SANDSTONE--grayish pink (5 YR 7/2) weathered and fresh; single very thick bed, irregular with vague, thin - medium planar (?) laminae; grains very fine - fine, moderately sorted, subrounded; composed mainly of quartz, clay matrix, not calcareous; forms ledge.	2.9 (9.6)
9	MUDSTONE--mottled medium gray (N4) and light brown (5 YR 5/6) weathered and fresh; beds very thin with alternating thin laminae of very fine SANDSTONE and CLAYSTONE; contact with above sharp.	0.25 (0.8)

8	SANDSTONE--grayish orange (10 YR 7/4) weathered, pale yellowish orange (10 YR 8/6) - pale yellowish green (10 Y 8/2); beds thin - medium, irregular, uneven with thin - medium, planar, discontinuous, convergent and curved, discontinuous, parallel laminae; cross bedded; grains very fine - fine, well sorted, angular; composed mainly of quartz, clay matrix, not calcareous; ironstone concretions; contact with above sharp(?).	5.0 (16.5)
7	INTERBEDDED SILTSTONE AND SHALE--SILTSTONE is light gray (N7) with thick massive(?) beds, "baked" in places, contains ironstone concretions in lower part locally; SHALE is light - dark gray (N7 - N3) - black (N1), "baked" locally, light gray beds contain plant fragments; contact with above sharp.	27.3 (90.1)
6	SANDSTONE--grayish orange (10 Yr 7/4) weathered, pale yellowish orange (10 YR 8/6) and pale greenish yellow (10 Y 8/2) fresh; beds medium - thick, irregular, uneven with thin (same medium), planar, discontinuous, parallel laminae; large-scale, discordant - tangential, high-angle, solitary(?), trough(?) cross bedding; grains very fine - medium (varies bed - bed), moderately sorted, subrounded; composed mainly of quartz, clay matrix, nor calcareous; lower part contains abundant plant molds and mud chips or voids where weathered out; thin SHALE interbeds near middle; bed contacts quite irregular, erosional; contact with above sharp.	10.2 (33.7)
5	INTERBEDDED SANDSTONE AND SHALE--very pale orange (10 YR 8/2) - pale reddish brown (10 R 5/4) in upper part, brownish gray (5 YR 4/1) - dark yellowish brown (10 YR 4/2) in lower park; bed thin - medium, irregular, uneven with thin laminae; small- and large-scale trough cross bedding; sand grains fine - medium, moderately sorted, subrounded; composed mostly of quartz, clay matrix, not calcareous; SHALE dominant in lower half, small SANDSTONE ledge in middle, slope-forming SANDSTONE AND SHALE in upper half; contact with above sharp.	3.1 (10.2)
4	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds medium - thick, irregular, uneven with thin, planar, discontinuous, parallel laminae; large-scale, trough cross bedding; grains fine, moderately sorted, subrounded;	6.7 (22.1)

composed of quartz with minor amounts of mafic mineral(?), clay matrix, not calcareous; contains ironstone concretions and mud chips at base; this and units 1 and 3 die out to east, reach maximum thickness where measured; contact with above sharp.

3	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thin - medium, irregular, uneven with thin, planar, continuous, parallel laminae; vague cross bedding; grains fine - medium, moderately sorted; composed mainly of quartz, not calcareous; ironstone concretions near top; contact with above sharp, erosional.	1.2 (4.6)
2	SHALE--upper part carbonaceous, pale brown (5 YR 5/2) - grayish brown (5 YR 3/2) weathered and fresh; contains 4 dcm of coal near middle; lower part is noncarbonaceous, light olive gray (5 Y 5/2) - pale olive (10 Y 6/2) weathered and fresh; contact with above sharp, erosional.	3.7 (12.2)
1	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds medium (some thick), irregular, uneven with vague medium - thin, planar - curved, discontinuous, parallel laminae; large-scale, tangential, high-angle, grouped, trough and possibly wedge-planar cross bedding; grains fine, moderately sorted, subrounded; composed of quartz, clay matrix, not calcareous at base or top but in middle; middle part also iron stained, most prominent part of cliff; disconformably overlies a carbonaceous, silty shale sequence of uncertain thickness.	2.9 (9.6)
	Total section thickness =	71.4 (235.5)

Base is base of lowest SANDSTONE on left side of prominent cliff. Abney level set at 5° in accordance with several examples of northeasterly dip measured here.

SECTION MK3E - 1, BORREGO PASS (Casamero Lake and Borrego Pass 7½' Quads.). Measured outcrops along road from Prewitt to Borrego Pass Trading Post; line of section (from south to north) involves exposures in sec's. 24, 20, and 17, T14N, R11W and sec's. 21, 9, and 4, T15N, R11W, McKinley County; section measured by Robert C. Brod, 28 June - 1 July 1977.

Unit	Lithology	Thickness: m(ft)
	POINT LOOKOUT SANDSTONE HOSTA TONGUE	
54	SANDSTONE--grayish orange (10 YR 7/4) weathered, very light gray (N8) fresh; beds medium - thick, regular, even with thin planar, discontinuous, parallel laminae; large-scale, tangential, low-angle, grouped, tabular-planar cross bedding; grains fine, well sorted, subrounded; composed mainly of quartz, clay matrix, not calcareous; caps mesa.	50.3 (166.0)
53	SANDY SHALE--very light gray (N8) weathered, light greenish gray (5 GY 8/1) fresh; beds thin - medium, irregular, uneven with thin, planar laminae, interval structure poorly shown; grains include fine sand - silt, very poorly sorted, angular; composed mainly of quartz in silt and clay matrix; similar to unit 51 below; contact with above gradational, coarsening upward(?).	4.8 (15.8)
	CREVASSE CANYON FORMATION GIBSON COAL MEMBER	
52	CARBONACEOUS SHALE AND COAL--light gray (N7) - brownish black (5 YR 2/1) weathered and fresh; mostly covered, COAL exposed at base; contact with above sharp(?).	19.2 (63.4)
51	SANDY SILTSTONE--grayish orange (10 YR 7/4) weathered, dark yellowish orange (10 YR 6/6) fresh; sand occurs in SILTSTONE and as SANDSTONE lenses up to 1 dcm thick; sand grains fine - very fine, like unit 44 below; contact with above poorly exposed.	8.0 (26.4)
50	SHALE--some noncarbonaceous, light gray (N7), some carbonaceous, brownish black (5 YR 2/1); clinker lag on slope; contact with above covered.	14.3 (47.2)

49	COVERED INTERVAL	4.8 (15.8)

CREVASSE CANYON FORMATION
DALTON SANDSTONE MEMBER

48	SANDSTONE--grayish orange (10 YR 7/4) weathered, dusky yellow (5 Y 6/4) fresh; beds thick - very thick, regular, even with thin - medium, curved, discontinuous, parallel laminae; large-scale, tangential, low-angle, grouped, wedge-planar(?) cross bedding; grains fine sand and silt, very poorly sorted, angular; composed mainly of quartz with silt and clay matrix, not calcareous; contact with above sharp.	33.6 (110.9)

MANCOS SHALE
MULATTO TONGUE

47	COVERED SLOPE--SHALE(?); measured from topo sheet.	3.5 (11.6)

CREVASSE CANYON FORMATION
BORREGO PASS LENTIL (formerly "STRAY SANDSTONE")

46	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; mottled with light brown (5 YR 5/6) on fresh surfaces; beds medium - thick, regular, even with thin, planar, continuous, parallel laminae; large-scale, tangential - discordant, high-angle (some low-angle), grouped, tabular-planar (some trough) cross bedding displaying opposing dip directions in places; grains fine - medium, poorly sorted, subangular; composed mainly of quartz in silt - clay matrix, not calcareous; contact with above sharp.	17.6 (58.1)

CREVASSE CANYON FORMATION
DILCO COAL MEMBER

45	CARBONACEOUS SHALE--like unit 37 below.	1.8 (5.9)

44	SANDSTONE--grayish orange (10 YR 7/4) weathered, dark yellowish orange (10 YR 6/6) fresh; beds thin - medium, irregular, uneven with thin - medium, wavy, discontinuous, convergent laminae; small-scale, tangential, low-angle, solitary, tabular-planar cross bedding; grains fine - medium, poorly sorted, subangular; composed mainly of quartz in silt and clay matrix, not calcareous; numerous carbonaceous plant fragments; thin shale lenses in upper half; contact with above gradational.	1.4 (4.6)
43	INTERBEDDED CARBONACEOUS SHALE AND SANDSTONE--like unit 38 below.	1.2 (4.0)
42	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thin - medium, irregular, uneven with thin, curved, discontinuous, convergent laminae; large-scale, tangential, low-angle, grouped, trough cross bedding displaying opposing dips locally; grains medium, moderately sorted, angular; composed mainly of quartz with silt matrix, not calcareous; contact with above sharp.	7.2 (23.8)
41	CARBONACEOUS SHALE--like unit 37 below; contact with above gradational.	8.4 (27.7)
40	SANDSTONE--like unit 36 below.	1.0 (3.3)
39	CARBONACEOUS SHALE--like unit 37 below.	10.5 (34.7)
38	INTERBEDDED SANDSTONE AND SHALE--SHALE is like unit 37 below; SANDSTONE occurs as thin, irregular, uneven beds (up to 1 cm thick); forms cliff; contact with above sharp.	2.0 (6.6)
37	CARBONACEOUS SHALE--light bluish gray (5 B 7/1) weathered and fresh with dark greenish gray (5 G 4/1) carbonaceous plant material on laminar surfaces; contact with above sharp.	8.0 (26.4)
36	SANDSTONE AND CARBONACEOUS SHALE--SANDSTONE like unit 31 below but thinly bedded, occurs as 2 ledges: 0.7 m and 1.0 m thick; SHALE like unit 32 below, occurs in 2 slope-forming intervals: 0.9 m and 0.8 m thick; contact with above concealed.	3.4 (11.2)

35	SANDSTONE--like unit 27 below.	2.5 (8.3)
34	CLINKER--forms thin parting and produces lag on top of unit 33 below.	0.1 (0.3)
33	SANDSTONE--like unit 27 below.	1.5 (5.0)
32	CARBONACEOUS SHALE--color not recorded; contains few lenses of SANDSTONE like unit 31 below; largest seen approximately .5 m thick and 50 m across; contact with above sharp.	6.4 (21.1)

GALLUP SANDSTONE
GALLEGO SANDSTONE MEMBER(?)

31	SANDSTONE--grayish orange (10 YR 7/4) weathered, white (N9) fresh; beds medium - very thick (thicker at top), regular, uneven with thin, planar, continuous, parallel laminae; large-scale, tangential, low- and high-angle (mostly high-angle), solitary, tabular-planar cross bedding; grains fine, well sorted, subangular; composed mainly of quartz, clay matrix, not calcareous; contact with above sharp.	26.7 (88.1)

MANCOS SHALE
D-CROSS TONGUE(?)

30	SHALE--brownish gray (5 YR 4/1) - light brownish gray (5 YR 6/1) - medium gray (N5) weathered and fresh; carbonaceous with very thin lenses of well sorted SANDSTONE at top; mostly covered except at base of overlying unit; contact with above gradational.	27.8 (91.7)

GALLUP SANDSTONE
"BED A"(?)

29	SANDSTONE--grayish orange (10 YR 7/4) weathered, light greenish gray (5 G 8/1) fresh; beds medium - thick, irregular, uneven with some thin, planar - curved, discontinuous, parallel - convergent laminae but mostly massive; small-scale,	13.1 (43.2)

	tangential, low-angle, solitary, trough cross bedding; some large-scale, high-angle, tabular-planar; in places opposing dips noted; grains fine, moderately sorted, angular; composed mainly of quartz, clay matrix, not calcareous; vertical burrows common, average diameter 1 cm; lower 2 m silty including thin, discontinuous lenses of siltstone; contact with above sharp.	
MANCOS SHALE (main body)		
28	SHALE--color not recorded; silty; contains lenses of SANDSTONE up to 1 dcm thick; contact with above gradational; thickness determined from topo sheet; Abney set at 3 3/4° for units 28 - 54.	53.3 (175.9)
DAKOTA SANDSTONE (undivided)		
27	SANDSTONE--light red (10 R 6/6) weathered, moderate orange pink (5 YR 8/4) fresh; beds medium, regular, even with obscure medium, wavy, discontinuous, convergent laminae; grains very fine, moderately sorted, angular; composed mainly of quartz, minor clay matrix(?), not calcareous; contact with above concealed.	2.7 (8.9)
26	COVERED SLOPE--SHALE(?)	6.4 (21.1)
25	SANDSTONE--like unit 23 below but cross bedding is high angle, discordant, grouped.	4.6 (15.2)
24	COVERED SLOPE--CARBONACEOUS SHALE(?)	3.5 (11.6)
23	SANDSTONE--moderate reddish orange (10 R 6/6) and moderate orange pink (10 R 7/4) weathered moderate orange pink (5 YR 8/4) fresh; beds medium - thick, irregular, uneven with thin, curved, continuous, parallel laminae; large-scale, tangential, low-angle, solitary, tabular-planar cross bedding; grains medium, well sorted, rounded; composed almost entirely of quartz, not calcareous; scattered wood fragments.	6.4 (21.1)

MORRISON FORMATION
BRUSHY BASIN MEMBER

22	COVERED SLOPE--small exposure of green SHALE.	30.1	(99.3)
21	SANDSTONE--grayish orange (10 YR 7/4) weathered, white (N9) fresh; beds medium - thick, irregular, uneven with thin - medium, planar, continuous, parallel laminae; large-scale, discordant, low-angle, solitary, tabular-planar cross bedding; grains fine, moderately sorted, subangular - angular; composed largely of quartz with a minor amount of some mafic mineral, not calcareous.	4.8	(15.8)
20	VARIEGATED SHALE--various shades of red, green, purple, and yellow; contact with above sharp.	8.0	(26.4)

MORRISON FORMATION
WESTWATER CANYON MEMBER

19	SANDSTONE--like unit 16 below; forms slope, mostly covered; contact with above sharp(?).	14.4	(47.5)
18	SANDSTONE--like unit 16 below; forms cliff; contact with above sharp.	10.4	(34.3)
17	SHALE--like unit 12 below; with SANDSTONE lenses up to .75 m thick.	13.8	(45.5)
16	SANDSTONE--moderate orange pink (10 R 7/4) weathered, pale reddish brown (10 R 5/4) fresh; beds medium - thick, irregular, uneven with medium, curved, discontinuous, convergent laminae; large-scale, tangential, low-angle, grouped, trough cross bedding; grains medium - coarse, poorly sorted, angular - rounded; composed of quartz and feldspar, not calcareous; arkosic gravel up to 1 cm in diameter associated with cross bed troughs; lenses of moderately sorted, medium, quartz SANDSTONE near top.	19.2	(63.4)
15	INTERBEDDED SANDSTONE, SILTSTONE, AND SHALE--colors as in units 12 and 14 below; all layers are discontinuous laterally; SANDSTONE beds range to 1 m in thickness, less abundant in middle 10 m of unit.	34.1	(112.5)

14	SANDSTONE--moderate orange pink (10 R 7/4) mottled with light greenish gray (5 GY 8/1) weathered and fresh; beds thin - thick, irregular, uneven with thin planar, continuous, parallel laminae; grains very fine - fine, poorly sorted, angular; composed of quartz and approximately 5% unidentified mafic mineral, not calcareous; contact with above sharp.	4.4 (14.5)
13	SHALE--red; like in unit 12 below; also includes lenses of fine SANDSTONE.	1.1 (3.6)
12	SANDSTONE AND SHALE--very light gray (N8) weathered, light greenish gray (5 GY 8/1) fresh; SANDSTONE consists of fine - medium (fines upward ?), poorly sorted, subangular, quartz grains; SHALE is dark reddish brown (10 R 3/4), occurs as lenses approximately 1 m long and 0.1 m thick, especially common in upper 10 m of unit; forms slope, largely covered.	32.0 (105.6)

BLUFF SANDSTONE

11	SANDSTONE--white (N9) - light gray (N7) weathered, white (N9) fresh; beds thin, irregular, uneven with thin - medium, planar, discontinuous(?), parallel laminae; small-scale, tangential(?), low-angle, solitary(?), tabular-planar cross bedding; grains medium, moderately sorted, rounded; composed of quartz with trace of black and orange grains, not calcareous; similar to white bands at top of unit below but parallel bedding more distinct in this unit.	3.0 (9.9)
10	"BANDED" SANDSTONE--white bands white (N9) - light gray (N7) weathered white (N9) fresh; 0.3 - 1.0 m thick; red bands pale reddish brown (10 R 5/4) weathered, moderate reddish orange (10 R 6/6) fresh; 1.0 - 5.0 m thick; beds thick - very thick, regular, uneven with thin - medium, curved, continuous, parallel laminae; conspicuous, large-scale, discordant and tangential, high-angle, grouped, tabular-planar cross bedding; grains in white bands medium - coarse, well sorted, subrounded - rounded; composed of quartz with trace of black and	45.8 (151.1)

	orange minerals, clay matrix, not calcareous, iron stained; small spherical concretions (average diameter 0.75 cm) form rough surface on uppermost red band; contact with above sharp.	
9	SANDSTONE AND MUDSTONE--like unit 7 below.	7.7 (25.4)
8	SANDSTONE--moderate orange pink (10 R 7/4) - pale yellowish orange (10 YR 8/6) weathered, moderate orange pink (5 YR 8/4) fresh; beds medium (regularity/eveness obscured) with thin - medium, planar, discontinuous, parallel or curved, discontinuous, convergent laminae; large-scale, tangential, high-angle, grouped, tabular(?)-planar cross bedding, dips opposed in places; grains fine, moderately sorted, subrounded; composed largely of quartz with trace of dark grains, no matrix, not calcareous; weathers like wrinkled skin; white chert nodules at basal contact; contact with above sharp.	2.4 (7.9)

SUMMERVILLE FORMATION

7	SANDSTONE--moderate orange pink (10 R 7/4) weathered, moderate orange pink (5 RY 8/4) fresh; beds medium - very thick, irregular, uneven with obscure thin, wavy, discontinuous, convergent laminae; grains fine - medium, well sorted, subangular - subrounded; composed of quartz with minor black grains(?), no matrix, not calcareous; high density of vertical joints and fine texture leads to Knobby weathering habit; contact with above sharp.	17.6 (58.1)
6	COVERED SLOPE	37.3 (123.1)

TODILTO LIMESTONE

5	LIMESTONE--light olive gray (5 Y 6/1) - medium light gray (N6) weathered, olive gray (5 Y 4/1) fresh; beds thin - medium, regular, uneven with thin planar, continuous, parallel or wavy discontinuous, convergent laminae; planar laminae occur between	3.6 (11.9)

massive beds in middle of unit, wavy laminae common at top and bottom of unit; microcrystalline with some silt; bioclastic fragments (?) associated with base of some beds locally. Abney set at 4.5° for units 5 - 27.

4	SILTSTONE--color not recorded; beds very thin - thin, irregular, uneven with thin, wavy, discontinuous, convergent laminae; symmetrical ripple marks (seen in cross section only); grains silt - fine sand, moderately sorted, subrounded; composed mainly of quartz, not calcareous; contact with above gradational.	1.6 (5.3)

ENTRADA SANDSTONE
UPPER SANDSTONE MEMBER

3	SANDSTONE--moderate orange pink (10 R 7/4) mottled with medium gray (N5) weathered, moderate reddish orange (10 R 6/6) - moderate orange pink (10 R 7/4) fresh; beds very thick, regular, even with thin, curved - planar, continuous, parallel laminae; very-large-scale, tangential, high-angle, grouped, trough cross bedding; grains fine, well sorted, rounded; composed exclusively of quartz, no matrix, calcareous; contact with above gradational.	41.1 (135.6)

ENTRADA SANDSTONE
MIDDLE SILTSTONE MEMBER

2	SILTSTONE--pale reddish brown (10 R 5/4) - moderate orange pink (10 R 7/4) weathered and fresh with some irregular blebs of light greenish gray (5 GY 8/1) fresh; beds medium - very thick, regular, uneven with some discernible thin laminae, mostly massive; grains silt, poorly sorted, angular; composed of quartz, calcareous; dense vertical joints yields Knobby weathering habit; contact with above sharp, irregular.	18.0 (59.4)

ENTRADA SANDSTONE
LOWER SANDSTONE MEMBER

1	SANDSTONE--moderate reddish brown (10 R 4/6) weathered and fresh; beds very thick(?), with thin, planar, continuous, parallel laminae (regularity/eveness of beds indistinct); very-large-scale, tangential, high-angle, grouped trough cross bedding; grains medium, well sorted, well rounded; composed of quartz, iron stained, calcareous; base covered by talus; contact with above sharp, marked by relatively resistant white clay(?) zone at top of lower Entrada.	12.4 (40.9)
	Total section thickness =	718.8 (2,372.1)

Base is base of exposed lower Entrada. Section traversed parallel to dip as determined from Dakota Sandstone in sec. 31, T15N, R11W: 4°, N48°E. Abney set accordingly.

MK3E - 2, HAYSTACK MOUNTAIN (Bluewater 7½' Quad.). West- and east-facing slopes of mesa; S½, SW¼, sec. 11 to C, W½, sec. 13, T13N, R11W and NW¼, sec. 18, T13N, R10W, McKinley County; measured by Robert C. Brod, 6 July 1977.

Unit	Lithology	Thickness: m(ft)
DAKOTA SANDSTONE		
21	SANDSTONE--like unit 19 below; SHALE lenses up to 2 dcm thick in lower 4 m; caps mesa, top has pitted surface.	33.5 (110.6)
20	CARBONACEOUS SHALE AND COAL--like unit 18 below.	1.7 (5.6)
19	SANDSTONE--light brown (5 YR 6/4) weathered, light brown (5 YR 5/6) fresh; beds thin - medium, regular, even with thin, planar, discontinuous, parallel laminae; small- and large-scale, tangential, low-angle, solitary, trough cross bedding; grains fine, well sorted, subangular - subrounded; composed mainly of quartz, trace of silt matrix, not calcareous; contact with above sharp.	1.9 (6.3)
MORRISON FORMATION BRUSHY BASIN MEMBER		
18	CARBONACEOUS SHALE AND COAL--color not recorded, iron stained, organic debris in partings.	4.0 (13.2)
17	SHALE--light greenish gray (5 GY 8/1) mottled with pale yellowish orange (10 YR 8/6) weathered and fresh; clay rich.	4.4 (14.5)
16	SILTSTONE, SANDSTONE, AND SHALE--color not recorded; beds medium, regular, even mostly massive, some thin, wavy, discontinuous, convergent laminae; sand grains fine, subrounded; composed of quartz and unidentified red and green grains, silt matrix, not calcareous; SHALE like unit 15 below occurs as 1 dcm-thick lens near middle; contact with above sharp.	4.8 (15.8)
15	SHALE--grayish yellow green (5 GY 7/2) weathered and fresh, red lenses at base; mostly covered; contact with above sharp.	13.3 (43.9)

MORRISON FORMATION
WESTWATER CANYON MEMBER

14	CONGLOMERATIC SANDSTONE--pale red (10 R 6/2) weathered, pale reddish brown (10 R 5/4) fresh; beds medium, irregular, uneven with medium, curved, discontinuous, parallel laminae; large-scale, tangential, mostly low-angle (a few high-angle), solitary, trough cross bedding; grains silt - gravel (up to 2 cm in diameter), very poorly sorted, subrounded - subangular; composed mainly of quartz with about 7% feldspar, silt and clay matrix, calcareous; gravel consists of chert, quartz, and feldspar, occurs throughout but especially abundant in lower 5 m; clay blebs up to 1 dcm long (rip-up) throughout; contact with above sharp.	12.8 (42.2)
13	SHALE--dark reddish brown (10 R 3/4), light brownish gray (5 YR 6/1) and yellowish gray (5 Y 7/2) weathered and fresh; contact with above sharp.	6.1 (20.1)
12	SANDSTONE--like unit 10 below; contact with above sharp.	19.2 (63.4)
11	SANDSTONE--like unit 10 below; contact with above gradational.	4.8 (15.8)
10	SANDSTONE--pale red (10 R 6/2) weathered, pale reddish brown (10 R 5/4) fresh; beds thin - medium, irregular, uneven with thin, planar and curved, discontinuous, convergent laminae; small-scale, tangential, low-angle, solitary, wedge-planar(?) cross bedding; grains fine - coarse, poorly sorted, rounded; composed mainly of quartz, silt and clay matrix, calcareous, some iron cement.	4.8 (15.8)

MORRISON FORMATION
RECAPTURE MEMBER

9	SANDY SILTSTONE--light greenish gray (5 GY 8/1) weathered and fresh; beds thin, irregular, uneven with thin, curved, discontinuous, convergent laminae; large-scale, tangentila, low-angle, solitary, wedge-planar cross bedding; grains silt - fine sand, very poorly sorted, subangular; composed of quartz, silt matrix, calcareous; lenses (up to 3 m thick) of dark reddish	54.4 (179.5)

brown (10 R 3/4) SHALE near upper and lower contacts; very friable, poorly exposed; contact with above gradational.

COW SPRINGS SANDSTONE

8	SANDSTONE--moderate orange pink (10 R 7/4) - pale red (10 R 6/2) weathered, moderate reddish orange (10 R 6/6) fresh; beds thin - medium, irregular, uneven with medium (a few thin), wavy, discontinuous, convergent laminae; grains fine, moderately sorted, subangular; composed mainly of quartz, not calcareous, iron cemented(?).	6.4 (21.1)

BLUFF SANDSTONE

7	SANDSTONE--moderate orange pink (5 YR 8/4) weathered, moderate reddish orange (10 R 6/6) fresh; beds medium - thick, regular, even with thin - medium, planar, discontinuous, mostly parallel laminae; small- and large-scale, tangential, high- and low-scale, grouped, tabular-planar cross bedding; grains silt - fine sand, poorly sorted, angular; composed mainly of quartz with 5 - 10% unidentified black grains; silt and minor clay matrix, not calcareous; contact with above difficult, gradational(?).	42.2 (139.3)

SUMMERVILLE FORMATION

6	INTERBEDDED SANDSTONE AND SILTSTONE--SANDSTONE grayish orange pink (10 R 8/2) weathered, white (N9) - very light gray (N8) fresh; beds thick - very thick, regular, uneven with thin, planar and curved, discontinuous, parallel laminae; small- and large-scale, tangential, low-angle, grouped, tabular-planar (some wedge-planar?) cross bedding; grains fine, well sorted, subangular; composed mainly of quartz and minor unidenfified black grains, clay matrix, not calcareous; SILTSTONE dark reddish brown (10 R 3/4) weathered and fresh; beds medium with vague internal structures; well indurated but not calcareous, possibly cemented by iron or silica(?); contact with above sharp.	34.6 (114.2)

5	COVERED INTERVAL	25.3 (83.5)

TODILTO LIMESTONE

4	LIMESTONE--very light gray (N8) weathered, medium light gray (N6) fresh; beds thin, regular, uneven (thicken toward top) with very thin - thin, planar, discontinuous, parallel laminae; small-scale, tangential, low-angle, solitary, trough cross bedding; microcrystalline; grayish red (5 R 4/2) SHALE occurs in lower 1 dcm, as interbeds with LIMESTONE, these decrease in abundance toward top but present throughout; dip at top of this unit is 3°, N45° - 50°E; Abney set accordingly for units above.	4.1 (13.5)

ENTRADA SANDSTONE
UPPER SANDSTONE MEMBER

3	SILTSTONE--moderate orange pink (5 YR 8/4) weathered and fresh; beds thin(?), irregular, uneven with thin, curved, discontinuous, convergent laminae; small-scale, tangential, low-angle, solitary, tabular-planar cross bedding, poorly exposed; grains silt - fine sand, poorly sorted, subangular; composed of quartz, no matrix(?), calcareous; contact with above sharp.	5.0 (16.5)
2	SANDSTONE--moderate orange pink (10 R 7/4) weathered and fresh; beds medium - very thick, irregular, uneven with thin, curved, continuous, parallel laminae; conspicuous large-scale, tangential, high-angle, grouped, trough cross bedding; grains mostly fine, poorly sorted, subrounded - rounded (some medium - coarse, well sorted, subangular sand scattered throughout most beds); composed mainly of quartz with trace of unidentified black grains and clay, clay and minor silt matrix, calcareous; contact with above sharp.	38.4 (126.7)

ENTRADA SANDSTONE
MIDDLE SILTSTONE MEMBER

1	SILTSTONE--moderate reddish orange (10 R 6/6) weathered, moderate reddish	3.0 (9.9)

brown (10 R 4/6) fresh; beds thick, irregular, uneven, mostly massive, some lenses with thin laminae locally; grains silt and minor fine sand, poorly sorted, angular; composed mainly of quartz, calcareous; small (< 1 cm in diameter) white blebs throughout, same lithology as surrounding rock; small (< .5 cm) crystalline nodules (gypsum?) common, especially in lower half; incomplete exposure; contact with above sharp; dips of 3° N70° - 85°E measured in Entrada; Abney set accordingly; tried to measure in a N77°E direction.

Total section thickness = 324.7 (1071.4)

Base is base of exposed middle Entrada, west of Haystack Mountain. Measured units 1 through 4 in sec . 11, T13N, R11W, units 5 through 8 in sec. 13, T13N, R11W, and remainder in sec. 18, T13N, R10W.

SECTION MK3E - 3, MESA REDONDA (Goat Mountain 7½' Quad.). South-facing slope on southernmost tip of mesa, north side of road; NE¼, sec. 19, T14N, R10W, McKinley County; section measured by Robert C. Brod, 8 July 1977.

Unit	Lithology	Thickness: m(ft)
	CREVASSE CANYON FORMATION BORREGO PASS LENTIL (formerly "STRAY SANDSTONE")	
13	SANDSTONE--moderate reddish orange (10 R 6/6) weathered, grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2) fresh; beds mostly thick (some thin in lower 4 m), regular, even with medium, planar, continuous, parallel laminae; conspicuous, large-scale, tangential, high-angle, grouped, tabular-planar cross bedding (some small-scale, low-angle, solitary in lower 4 m); ripple marks present on talus blocks from this unit; grains fine - medium, moderately sorted, angular; composed mainly of quartz, some black grains(?), silt matrix, calcareous; horizontal, smooth-walled, burrows 0.2 - 1 cm in diameter common in lower 4 m; forms cliff, inaccessible; thickness determined from geologic map (USGS GQ-518).	35.7 (117.8)

	CREVASSE CANYON FORMATION DILCO COAL MEMBER	
12	INTERBEDDED CARBONACEOUS SHALE AND SILTSTONE--like unit 10 below.	2.8 (9.2)
11	SILTSTONE--like that in unit 10 below; with about 33% CARBONACEOUS SHALE; contact with above sharp.	2.3 (7.6)
10	INTERBEDDED CARBONACEOUS SHALE AND SILTSTONE--colors not recorded; SHALE contains coaly horizons; SILTSTONE occurs as lenses, averaging 3 cm in thickness, in middle and top of unit; contact with above marked by overhang of unit 11.	10.7 (35.3)
9	SILTSTONE--grayish orange (10 YR 7/4) - very pale orange (10 YR 8/2) weathered and fresh; beds medium - thick, irregular, uneven with some thin, wavy, discontinuous, parallel laminae (mostly massive); small-	8.0 (26.4)

	scale, tangential, low-angle, solitary, tabular-planar(?) cross bedding; grains are silt, well sorted; composed of quartz, calcareous; trace of organic material; contact with above sharp.	
8	INTERBEDDED CARBONACEOUS SHALE AND SILTSTONE--color not recorded; SILTSTONE is like that of unit 7 below but lacks cross bedding; 1-dcm-thick CLINKER bed occurs 2 dcm above base of unit.	18.2 (60.1)
7	SILTSTONE--very pale orange (10 YR 8/2) weathered and fresh; beds thin, irregular, uneven with thin, wavy, discontinuous, convergent laminae; small-scale, tangential - concordant(?), low-angle, solitary, trough cross bedding; grains are silt, moderate sorting; composed of quartz, calcareous; contact with above sharp.	2.5 (8.3)
6	CARBONACEOUS SHALE--pale brown (5 YR 5/2) with dark yellowish orange (10 YR 6/6) iron staining weathered and fresh; some discontinuous layers of low-grade COAL; organic material in partings locally; contact with above gradational.	3.2 (10.6)

GALLUP SANDSTONE (main body)

5	SANDSTONE--grayish orange (10 YR 7/4) weathered, white (N9) fresh; beds thin - medium, irregular, uneven with thin, planar, discontinuous, parallel laminae, small- and large-scale, tangential, mostly low-angle (1 set of high-angle seen), solitary, tabular-planar cross bedding; grains silt - fine sand, moderate sorting, subangular - subrounded; composed almost entirely of quartz, silt matrix, calcareous, some iron cement; unit appears to thin out within 100 m to west and east of where measured; contact with above sharp.	8.0 (26.4)

MANCOS SHALE
D-CROSS MOUNTAIN TONGUE(?)

4	SHALE--medium gray (N5) weathered and fresh; contact with above sharp.	33.6 (110.9)

GALLUP SANDSTONE
"BED B"

3	SANDSTONE--color not recorded(?); beds medium, regular(?), uneven(?) with thin, planar continuous(?), parallel(?) laminae (lower 7 m massive); large-scale, tangential, high- and low-angle, grouped cross bedding in upper 1 m (type uncertain, both trough and planar types seem represented); grains silt - fine sand, poor - well sorted (depending on silt content), angular - subrounded; composed of quartz and minor amounts of unidentified black grains(?), clay matrix(?), calcareous; contact with above sharp.	8.0 (26.4)

MANCOS SHALE (main body)

2	SHALE--medium gray (N5) weathered and fresh; contact with above gradational, contact selected is irregular and characterized by scours yielding up to 1 m of relief.	20.3 (67.0)

GALLUP SANDSTONE
"BED A"

1	SANDSTONE--color not recorded(?); beds thin - medium, irregular, uneven with thin wavy, discontinuous convergent laminae; minor large-scale, tangential, low-angle, solitary tabular-planar cross bedding; grains silt - fine sand, bimodal, angular; composed mainly of quartz with unidentified black grains(?), silt matrix, calcareous; contact with above sharp; lower part is typical transition zone deposit with interbedded SANDSTONE and SHALE, SANDSTONE increasing in abundance and thickness upward.	7.0 (23.1)

Total section thickness = 160.3 (529.0)

Base of section is base of "Bed A" of the Gallup; placed at base of first persistent sandstone layer above which sandstone predominates in abundance. About 35 m of Mancos Shale exposed in slope below "Bed A" here. Dip could not be measured; used 2° N13°E from geologic map (USGS GQ-518).

AREA 3 SECTIONS
(Rio Arriba, Sandoval, and Valencia Counties)

The third area studied includes all remaining parts of the San Juan Basin in New Mexico (i.e., those not lying in San Juan or McKinley Counties).

This area is significant because it includes the open-pit uranium mines near Laguna, the Star Lake, Torreon Wash, and La Ventana coal areas, it has been the site of extensive uranium exploration in the Ojo Alamo Sandstone and San Jose Formation, and it contains the southwestern discharge zone for the deep ground-water flow system.

The area was divided into two parts based on the basis of Latitude 36°N: Area 3 South and Area 3 North. For Area 3 South, three sections in Sandoval County and one in Valencia County were selected for measurement. These provide information on both the major Jurassic and Cretaceous deposits of this part of Area 3. For Area 3 North, three sections are presented for Rio Arriba County, covering selected Cretaceous and Tertiary units. Table 4 gives the location and coverage of each of these sections and the source of additional sections measured for the hydrogeologic study.

Table 4. Catalog of sections measured in Area 3 (Rio Arriba, Sandoval, and Valencia Counties) by location; parentheses indicate locations based on projected land grid. Abbreviations for units same as in Table 1.

Location (sec. T, R)	Section No.	Units Covered	Page
AREA 3 SOUTH--portion south of Latitude 36°N			
36, 20N, 1W	S - 1	Kd, Km	104
20, 19N, 1W	S - 2	Kmf, Kch	106
24, 16N, 1W	S - 3	Trc, Je, Jt	109
25, 9N, 3W	V - 1	Kg	112

Additional sections for this area measured for the hydrogeologic study will appear in New Mexico Tech M.S. thesis by S.D. Craigg.

AREA 3 NORTH--portion north Latitude 36°N			
14, 25N, 1E	RA - 1	Jm, Kd	114
34, 26N, 1E	RA - 2	Kpl, Kmf, Kch	117
33, 26N, 1E	RA - 3	Kl, Kf/Kk, Toa	121

Additional sections for this area measured for the hydrogeologic study will appear in New Mexico Tech M.S. thesis by S.K. Anderholm.

SECTION S-1, SAN MIGUELITO CANYON (San Pablo 7½ Quad.). East-facing slope of north-south trending hogback, 7.5 air miles southeast of Cuba, north and west of Forest Service road, 2.5 air miles east of old NM 44, just across boundary in Santa Fe National Forest; SW¼, NW¼, sec. 36, T20N, R1W, Sandoval County; section measured by Stephen D. Craigg, July 1978.

Unit	Lithology	Thickness: m(ft)
MANCOS SHALE		
6	COVERED INTERVAL--soil olive gray (5 Y 3/2) weathered and fresh; dug 3 foot trench and did not find bedrock, but is probably shale.	3.4 (11)
DAKOTA SANDSTONE		
5	SANDSTONE--dusky yellow (5 Y 6/4) - yellowish gray (5 Y 7/2) weathered, dark greenish yellow (10 Y 6/6) - yellowish gray (5 Y 7/2) fresh; beds thick, regular, uneven, with medium, planar laminae; grains fine - medium, well sorted, subrounded; composed mainly of clear quartz and feldspar with clay matrix and siliceous cement; abundant trace fossils along bedding; trace of carbonaceous material; weathers with a knobby/pitted, iron-stained surface; contact with above sharp, conformable.	7.5 (24.6)
4	COVERED INTERVAL--soil grayish olive green (5 GY 3/2) weathered and fresh; contact with above sharp, conformable; dug 3 foot trench and did not hit bedrock, but is probably shale.	25.0 (82)
3	SANDSTONE--dusky yellow (5 Y 6/4) - yellowish gray (5 Y 7/2) weathered, dark greenish yellow (10 Y 6/6) - yellowish gray (5 Y 7/2) fresh; beds thick, regular, uneven, with medium, planar laminae; grains fine - medium, well sorted, subrounded; composed mainly of clean quartz and feldspar with clay matrix and siliceous cement; abundant trace fossils along bedding; trace of carbonaceous material; weatheres with a knobby/pitted, iron-stained surface; contact with above sharp, conformable.	7.0 (23)

2	COVERED INTERVAL--soil grayish yellow green (5 GY 3/2) weathered and fresh; contact with above sharp, conformable, dug 3 foot trench and did not find bedrock, but is probably shale.	13.6 (44.6)
1	CONGLOMERATIC SANDSTONE--pinkish gray (5 YR 8/1) weathered, yellowish gray (5 GY 7/2) fresh; beds thick, irregular, uneven, with thick, wavy laminae; grains medium sand to pebbles, poorly sorted, angular to subrounded; composed mainly of quartz and feldspar with clay matrix and siliceous cement; contact with above sharp, conformable	3.6 (11.8)
	Total Section Thickness =	60.1 (197)

Measurement was begun at the base of the lowest exposed sandstone in the bottom of an arroyo which cuts across the section in an east-west direction. The strata strike N 3° E and dip 80° W.

SECTION S-2, ARROYO DE LOS PIÑOS (La Ventana 7½' Quad.). Southeast-facing slope just north of dirt road connecting NM 44 and old NM 44 along north bank of Arroyo de los Piños; about ½ road mile east of NM 44, 2.5 air miles north of La Ventana rest stop on NM 44; SE¼, NE¼, SW¼, sec. 20, T19N, R1W, Sandoval County; section measured by Stephen D. Craigg, July 1978.

Unit	Lithology	Thickness: m(ft)
	CLIFF HOUSE SANDSTONE LA VENTANA TONGUE	
6	SANDSTONE--yellowish gray (5 Y 7/2) - dusky yellow (5 Y 6/4) weathered, grayish yellow green (5 GY 7/2) fresh; beds thick - very thick, regular, uneven, with thin - medium, planar laminae; symmetrical, continuous, straight ripple marks on surfaces in upper part of unit, crest height 3-6 mm, wavelength 6-8 cm; striking N 60° W, current in northeast/ southwest direction; grains fine - medium, moderately well sorted, subrounded; composed mainly of clear quartz and feldspar with clay matrix and calcite cement; few Ophiomorpha; contains numerous selenite stringers 0.5-2 cm thick and parallel to bedding, and scattered, elongate, iron-stained carbonate concretions; top of unit covered with a few cm of eolian sand.	13.5 (44.3)
	MENEFEE FORMATION	
5	CARBONACEOUS SHALE--dark gray (N3) weathered and fresh; beds very thick, regular, even, with thin, planar laminae; contains numerous plant-stem fragments; upper part of unit covered by talus; contact with above sharp, disconformable.	3.0 (9.8)
4	SANDSTONE--very pale orange (10 YR 8/2) weathered and fresh; beds thick - very thick, irregular, uneven, with thick, planar - curved laminae; large-scale, tangential, low-angle, grouped, trough cross bedding occurs throughout unit; grains fine - medium, moderately well sorted, subangular - subrounded; composed mostly of clear quartz and feldspar with clay matrix; locally contains carbonaceous,	6.8 (22.3)

silty shales about 10 - 20 cm thick; contains elongate, lens-like iron nodules near base of unit about 20 cm thick by 3-4 m long which follow bedding surfaces; contact with above sharp, conformable.

3 SANDSTONE AND SILTY CARBONACEOUS SHALE 33.4 (109.5)

b SANDSTONE--grayish orange pink (5 YR 7/2) - pale greenish yellow (10 Y 8/2) weathered, very pale orange (10 YR 8/2) - light olive brown (5 Y 5/6) fresh; beds thick, irregular - regular, uneven, with medium-thick, planar laminae; large-scale, tangential, low-angle, grouped, trough cross bedding is present throughout sandstone units; grains fine-medium, moderately well-sorted, subangular - subrounded; composed mostly of clear quartz and feldspar with clay matrix with or without calcite cement; sandstones contain local 5-10 mm coaly layers; localized iron nodules occur throughout units; contacts with overlying shale units (a) sharp, conformable.

a SILTY CARBONACEOUS SHALE--dark gray (N3) weathered and fresh; beds thick, irregular, uneven, with thin - medium, planar laminae; contacts with overlying sandstone units (b) sharp, disconformable.

Contact of unit 3 with unit 4 above is sharp, disconformable.

2 SANDSTONE--moderate yellowish brown (10 YR 5/4) weathered, light greenish gray (5 GY 8/1) fresh; beds thick, irregular, uneven, with medium-thick, planar laminae; large-scale, tangential, low-angle, solitary - grouped, trough cross bedding occurs throughout unit; grains medium-coarse, moderately well-sorted, subangular - subrounded; composed mostly of clear quartz and feldspar with clay matrix and calcite cement; contact with above sharp, conformable. 6.4 (21)

1 SANDSTONE--grayish orange pink (5 YR 7/2) weathered, very pale orange (10 YR 8/2) fresh; beds thick, irregular, uneven, with medium, planar laminae; large-scale, 2.4 (8)

tangential, high-angle, solitary, trough and wedge-planar cross bedding present throughout unit; grains fine - medium, moderately well sorted, subrounded; composed mostly of clear quartz and feldspar with clay matrix and calcite cement; contains numerous elongate iron nodules about 20 cm thick by 2 m long which are parallel to bedding of the unit; contact with above sharp, disconformable.

Total Section Thickness = 65.5 (215)

Measurement was begun at base of exposed Menefee Formation.

SECTION S-3, CUCHILLO ARROYO (Ojito Spring 7½' Quad.). East-facing slope on west side NM 44, 9.6 highway miles north of San Ysidro, on Zia Indian Reservation; NW¼, NE¼, sec. 24, T16N, R1W. Sandoval County; section measured by Stephen D. Craigg, July 1978.

Unit	Lithology	Thickness: m(ft)
	TODILTO LIMESTONE	
8	GYPSUM--very light gray (N8) weathered, white (N9) fresh; beds very thick, regular, even, massive with "chicken-wire" structure; top of unit deeply fractured and eroded.	6.0 (19.7)
7	GYPSIFEROUS LIMESTONE--olive gray (5 Y 4/1) weathered and fresh; beds very thin - thin, regular, even, with very thin, wavy laminae; locally contains 5-mm-thick selenite stringers parallel to bedding; contact with above sharp, conformable.	3.0 (9.8)
6	LIMESTONE--light olive gray (5 Y 6/1) weathered, olive gray (5 Y 4/1) fresh; beds thin - medium, regular, uneven, with thin - medium, planar laminae; sparry - crystalline; contact with above sharp, conformable.	1.7 (5.6)
	ENTRADA SANDSTONE	
5	SANDSTONE--light brown (5 YR 6/4) weathered and fresh; beds thick - very thick, regular, uneven, with thin - medium, planar laminae; large-scale, discordant, high-angle, grouped, tabular - wedge planar cross bedding throughout unit; grains medium - coarse, moderately well sorted, subrounded - well rounded; composed mostly of quartz and feldspar with clay matrix and calcite cement; contains numerous iron stained gypsiferous/calcareous concretions near top of unit; with above sharp, conformable.	18.5 (60.7)
4	SANDSTONE--moderate reddish brown (10 R 4/6) weathered and fresh; beds very thick, regular, even, with thin, planar laminae; conspicuous adhesion ripples; grains fine, well sorted, subrounded; composed mostly of quartz with clay matrix and calcite	7.5 (24.6)

cement; contains numerous "rock-babies" up to 1 m in diameter; locally color-banded (bands = 2 mm) with light grays; contact with above sharp, conformable.

3 SILTY SANDSTONE--grayish pink (5 R 8/2) - moderate reddish brown (10 R 4/6) weathered and fresh; beds medium, regular uneven, with medium, planar laminae; conspicuous adhesion ripples; grains fine, well-sorted, subrounded; composed mostly of quartz with clay matrix and calcite cement; contains numerous "rock-babies" about 8 mm in diameter; contact with above sharp, conformable. 5.6 (18.4)

2 SANDSTONE--moderate reddish brown (10 R 4/6) weathered and fresh; beds very thick, regular, uneven, with thin, planar laminae; large-scale, discordant, high-angle, grouped, tabular - wedge planar cross beds present throughout unit; grains fine, well-sorted, subrounded; composed mostly of quartz with clay matrix and calcite cement; contact with above sharp, conformable. 3.4 (11.2)

CHINLE FORMATION
UPPER MEMBER

1 CONGLOMERATIC SANDSTONE AND SANDSTONE 3.0 (9.8)

b CONGLOMERATE SANDSTONE--pale reddish brown (10 R 5/4) weathered, pale red (10 R 6/2) fresh; beds medium - thick, irregular, uneven, with - medium - thick, planar laminae; grains medium sand - pebbles, poorly sorted, subrounded; composed mostly of clear quartz and mudrock fragments with clay matrix and calcite cement; conglomeratic sandstones occur at base and mid thickness of unit; contact with overlying sandstone units (a) sharp, conformable.

a SANDSTONE--pale reddish brown (10 R 5/4) weathered, pale red (10 R 6/2) fresh; beds medium - very thick, irregular, uneven, with medium - thick, planar laminae; parting lineations common on upper surfaces of sandstone beds, striking about N 40° W; large-scale, concordant - tangential,

high-angle, grouped, wedge-planar cross bedding present throughout sandstone beds; grains medium - coarse, moderately sorted, subrounded; composed mostly of clear quartz and feldspar with clay matrix and calcite cement; contact with overlying conglomeratic sandstone units (b) sharp, disconformable.

Total Section Thickness = 48.7 (159.7)

Measurement was begun in uppermost part of Chinle Formation, on a steep slope, near the point at which a north-south barbed-wire fence crosses the hillside.

SECTION V-1, CAÑONCITO ROADCUT (South Garcia 7½' Quad.). South-facing roadcut on north side of I-40, about 1 mile west of Cañoncito exit, on Laguna Indian Reservation; NE¼, NW¼, sec. 25, T9N, R3W, Valencia County; section measured by Stephen D. Craigg, August 1978.

Unit	Lithology	Thickness: m(ft)
GALLUP SANDSTONE		
3	SANDSTONE--moderate olive brown (5 Y 4/4) - yellowish gray (5 Y 7/2) - pale brown (5 Y 5/2) weathered, yellowish gray (5 Y 8/1) - grayish yellow (5 Y 8/4) fresh; beds medium, regular, uneven, with medium - thick,curved laminae; large-scale, tangential - concordant, low-angle, solitary, trough cross bedding throughout unit; grains fine - medium, moderately - well sorted, subrounded; composed mainly of clear quartz and feldspar with clay matrix with calcite cement; weathers with a beehive-like surface; top of unit covered locally with eolian sand a few cm thick.	1.6 (5.3)
2	SANDSTONE--moderate olive brown (5 Y 4/4) - yellowish gray (5 Y 7/2) - pale brown (5 YR 5/2) weathered, yellowish gray (5 Y 8/1) - grayish yellow (5 Y 8/4) fresh; beds medium - thick, regular, uneven, with medium - thick,planar laminae; grains fine - medium, moderately well sorted, subrounded; composed mainly of clear quartz and feldspar with clay matrix and calcite cement; commonly bioturbated; weathers with a behive-like surface; contains selenite stringers a few mm thick oriented parallel to bedding of unit; contact with above gradational, conformable.	22.8 (74.8)
1	SANDSTONE AND SHALE	1.6 (5.3)
b	SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds thin - thick, regular, uneven, with medium,planar laminae; grains fine - medium, moderately well sorted, subrounded; composed mainly of quartz and feldspar with clay matrix and calcareous cement; intensely bioturbated; contact with above sharp, conformable.	

a SHALE--light brown (5 YR 5/6) weathered, pale brown (5 YR 5/2) fresh; beds thick, regular, even, with medium, planar laminae; contact with above sharp, conformable.

Total Section Thickness = 26.0 (85.3)

Measurement was begun at the base of the roadcut, at the highway surface.

SECTION RA-1, RIO GALLINA (Llaves 15' Quad.). East-facing slopes approximately 100 m (330 ft) northeast of small ridge near river valley; 3/4 mile northeast of the end of the road which stops near the river, 2 air miles southwest of Dead Man Peak Lookout tower, 4¼ air miles northeast of Llaves; E½, sec. 14, T25N, R1E, Rio Arriba County; section measured by Scott Anderholm and Steve Craigg, May 1979.

Unit	Lithology	Thickness: m(ft)
DAKOTA SANDSTONE		
13	SANDSTONE--grayish orange (10 YR 7/4) weathered, very pale orange (10 YR 8/2) fresh; beds medium - thick, irregular, uneven, with thin, planar, continuous, parallel laminae - massive; grains very fine - fine, moderately well sorted, subrounded; composed mainly of quartz; contains carbonaceous material and is iron stained; top of unit eroded.	1.8 (5.9)
12	SILTY SANDSTONE--light olive gray (5 Y 6/1) weathered and fresh; beds medium, irregular, uneven, massive; grains silt - fine, moderately sorted, subrounded; composed mainly of quartz; iron staining and carbonaceous material present; contact with above sharp.	4.7 (15.4)
11	SANDSTONE--grayish orange (10 YR 7/4) weathered, very light gray (N8) fresh; beds medium - thick, irregular, uneven, with thin - thick, curved - planar, continuous, parallel laminae; symmetrical, straight crested, ripple marks near middle of unit having a crest height of 2 - 4 cm and a wave length of 15 - 20 cm; large-scale, tangential, low angle (8 - 10°), solitary, trough - wedge cross bedding near top of unit; grains silt - medium, well sorted subrounded - rounded; composed mainly of quartz; carbonaceous material in some layers, bioturbated; fine upward; contact with above sharp.	10.0 (32.8)
10	SILTSTONE--dark gray (N3) weathered and fresh; contains carbonaceous material; contact with above sharp.	4.1 (13.5)
9	SANDSTONE--very pale orange (10 YR 8/2) weathered and fresh; beds medium - thick, irregular, uneven with thick, planar, continuous, parallel laminae; grains medium -	3.1 (10.2)

	fine, well sorted, subrounded; composed mainly of quartz with clay matrix; bioturbated, contains trace fossils and carbonaceous material; contact with above sharp.	
8	SANDSTONE--light gray (N7) weathered, yellowish gray (5 Y 8/1) fresh; beds thick, irregular, uneven, massive; grains fine - very fine, moderately - poorly sorted, subrounded; composed mainly of quartz with clay matrix; contains carbonaceous plant fragments; contact with above sharp.	0.7 (2.3)
7	SANDSTONE--light gray (N7) weathered, yellowish gray (5 Y 8/1) fresh; beds very thick, irregular, even, with medium, planar, curved, parallel laminae; grains fine, well sorted, subrounded; composed mainly of quartz with clay matrix; contact with above sharp.	1.7 (5.6)
6	SANDY-SILTY SANDSTONE--yellowish gray (5 Y 7/2) and light gray (N7) weathered and fresh; beds thick - thin, regular, even, massive; grains medium - clay, rounded; contact with above sharp.	1.4 (4.6)
5	SANDSTONE AND CONGLOMERATE--grayish orange (10 YR 7/4) weathered, moderate orange pink (5 YR 8/4) and dark dark greenish yellow (10 Y 6/6) fresh; beds very thick - medium, irregular, uneven, with very thick - medium, planar - curved, continuous - discontinuous, parallel laminae - massive; large-scale, tangential, low-angle, grouped, trough cross bedding, most common in the conglomerate layers; grains coarse - medium, moderately well - poorly sorted, subrounded - rounded; composed mainly of quartz and feldspar with clay matrix; four conglomerate layer approximately 1 - 1.5 m (3.3 - 5 ft) thick; contact with above sharp.	15.8 (51.8)
4	SANDSTONE--yellowish gray (5 Y 7/2) weathered, light olive brown (5 Y 5/6) fresh; beds medium, irregular, uneven, with thick, planar, continuous, parallel laminae; grains coarse - medium, well sorted, subrounded; composed mainly of quartz and feldspar with clay matrix and poorly cemented; contact with above sharp.	6.8 (22.3)

3	SANDSTONE AND CONGLOMERATE--pale yellowish brown (10 YR 6/2) weathered, light brown (5 YR 6/4) fresh; beds very thick - medium, irregular, uneven with very thick - medium planar - curved, continuous - discontinuous, parallel laminae; large-scale, tangential, low-angle, solitary - grouped, trough cross bedding; grains coarse - medium, moderately well - poorly sorted, subrounded - rounded; composed mainly of quartz and feldspar with clay matrix; contact with above sharp.	6.1 (20.0
2	CONGLOMERATE--pale yellowish brown (10 YR 6/2) weathered, light brown (5 YR 6/4) fresh; beds thick, irregular, uneven, with thick, planar, continuous, parallel laminae; grains coarse - medium, poorly sorted, subrounded; composed mainly of quartz; contains abundant green clay galls up to 5 cm in diameter; contact with below sharp.	1.0 (3.3)

MORRISON FORMATION
BRUSHY BASIN MEMBER

1	SILTSTONE AND CLAYSTONE--greenish gray (5 G 6/1) weathered, dark greenish gray (5 GY 4/1) and greenish gray (5 G 6/1) fresh; beds thick, irregular, uneven, with thick, planar, continuous, parallel laminae - massive; grains very fine - clay; outcrop partially covered; contact with above sharp.	23.5 (77.1)

Total section thickness = 80.7 (264.8)

Measurement began near large talus black on south side of wash which is approximately 100 yards north east of a small ridge formed by a sand in the Brushy Basin Member of the Morrison Formation.

SECTION RA-2, ALKALI SPRING (Llaves 15' Quad.). East-facing slopes approximately 1/2 mile north of road and 1/4 mile northwest of Alkali Spring, 4 3/4 air miles northeast of Llaves; Strike and Dip N25°E 32°W; SE¼, sec. 34, T26N, R1E, Rio Arriba County; section measured by Scott Anderholm and Steve Craigg, May 1979.

Unit	Lithology	Thickness: m(ft)
	CLIFFHOUSE SANDSTONE	
20	SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds thick - very thick, regular - irregular, uneven, with curved, continuous thick laminae - massive laminae; large-scale, tangential, high-angle, solitary, tabular cross bedding; grains fine - medium, moderately well sorted, subrounded - subangular; composed mainly of quartz and some feldspar with clay matrix; contains trace fossils; top of unit eroded.	8.0 (26.2)
	MENEFEE FORMATION	
19	CLAYSTONE--like claystone in unit 8 below.	4.7 (15.4)
	CLIFFHOUSE SANDSTONE TONGUE	
18	SANDSTONE--yellowish gray (5 Y 8/1) weathered, very pale orange (10 YR 8/2) fresh; beds medium - thick, irregular, uneven with thick, curved, continuous parallel laminae - massive; large-scale, tangential, low-angle, solitary, tabular cross bedding; grains very fine - fine, moderately sorted subrounded; composed mainly of quartz; contains marine trace fossils; contact with above sharp.	3.5 (11.5)
	MENEFEE FORMATION	
17	COAL--black weathered and fresh; contains some silt; contact with above sharp.	0.3 (1.0)
16	CLAYSTONE--like claystone in unit 8 below.	10.6 (34.8)

15	SANDSTONE--yellowish gray (5 Y 8/1) weathered and fresh; beds medium, irregular, uneven, with thin - thick, planar, continuous, parallel, laminae; grains very fine; moderately well sorted, subrounded; composed mainly of quartz; contact with above sharp.	0.5	(1.6)
14	CLAYSTONE--like claystone in unit 8 below	6.2	(20.3)
13	IRON CONCRETION--blackish red (5 R 2/2) weathered, brownish gray (5 YR 4/1) fresh; contact with above sharp.	0.2	(0.6)
12	COAL--black; contains much silt; contact with above sharp.	0.4	(1.3)
	CLAYSTONE AND SOME SILTSTONE--like unit 8 below.	3.2	(10.5)
11	SANDSTONE--very pale orange (10 YR 8/2) weathered and fresh; beds thick, irregular, uneven, with thick, curved, continuous, parallel laminae; large-scale, tangential, low angle, grouped and solitary trough cross bedding; grains very fine - fine well sorted, subrounded; composed mainly of quartz, contact with above sharp.	3.5	(11.5)
10	CLAYSTONE AND SILTSTONE--like unit 8 below.	5.0	(16.4)
9	SANDSTONE--yellowish gray (5 Y 7/2) and light gray (N7) weathered, grayish yellow (5 Y 8/4) and yellowish gray (5 Y 8/1) fresh; beds thick, irregular, uneven, with medium, curved, discontinuous, parallel laminae; large scale, tangential, low angle, grouped, trough cross bedding; grains very fine - medium moderately well sorted subround; composed mainly of quartz; iron staining and iron concretions present; contact with above sharp.	6.2	(20.3)
8	CLAYSTONE AND SOME SILTSTONE	5.6	(18.4)
8b	CLAYSTONE--olive gray (5 Y 4/1) weathered and fresh; beds thick, irregular, uneven, with thin - medium, planar, discontinuous, parallel laminae; contains carbonaceous material; contact with above sharp.		
8a	SILTSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds thick, irregular, uneven, with thin - medium planar, discon-		

tinuous, parallel laminae, grains very fine - clay, moderately sorted; interbedded with claystone above.

7	SANDSTONE--very light gray (N8) weathered and fresh; beds medium, irregular, uneven, with thick, curved, discontinuous, parallel laminae; large-scale, tangential, low angle, grouped, trough cross bedding; grains fine, well sorted, subrounded; composed mainly of quartz; sandstone pinches out laterally; contact with above sharp.	1.5	(5.0)
6	SILTY CLAYSTONE--same as unit 4 below.	2.9	(9.5)
5	COAL--black (N1); contact with above sharp.	0.3	(1.0)
4	SILTY CLAYSTONE--dusky yellowish brown (10 YR 2/2) and blackish red (5 R 2/2) weathered and fresh; beds medium irregular, uneven, with thin, planar, discontinuous, parallel laminae; contains carbonaceous material; contact with above sharp.	2.0	(6.6)
3	SILTY COAL--black (N1) weathered and fresh; beds medium, irregular, uneven, with thin planar, discontinuous, parallel laminae; contact with above sharp.	0.8	(2.6)
2	SILTY CLAYSTONE, SOME SANDSTONE AND COAL	5.7	(18.7)
2c	SILTY CLAYSTONE--blackish red (5 R 2/2) weathered and fresh; contains carbonaceous material; as below.		
2b	SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds thin - medium, irregular, uneven, with thin, planar, continuous, parallel laminae; grains very fine - silt, moderately sorted, subrounded; interbedded with silty claystone.		
2a	COAL--black (N1) weathered and fresh; poor coal.		
	Contact with above sharp.		

POINT LOOKOUT SANDSTONE

1	SANDSTONE--yellowish gray (5 Y 7/2) weathered, pale olive (10 Y 6/2) fresh; beds	1.5	(4.9)

thick - very thick, regular, uneven, with thick, wavy, continuous, non parallel laminae; grains fine - medium, well sorted subrounded; composed mainly of quartz and some feldspar, with clay matrix; slightly calcareous; iron stained with some concretions; contact with above sharp.

Total section thickness = 72.6 (238.2)

Measurement began near large pine tree approximately 1/2 mile north of road on hogback where the Cliff House Sandstone seems to be well developed.

SECTION RA-3, CHUPADERA SPRING (Llaves 15' Quad.). Started section near large pine tree on south side of landslide deposit approximately 200 yards north of large cut in Ojo Alamo Cliffs; about 3 3/4 miles north of Llaves, approximately 1/2 west of NM 112 and about 1¼ mile west of Alkali Spring; rocks dip N26°W 14°W; NE¼, SE¼, sec. 33, T26N, R1E; section measured by Scott Anderholm and Steve Craigg, May 1979.

Unit	Lithology	Thickness: m(ft)
OJO ALAMO		
11	SANDSTONE--dark yellowish orange (10 YR 6/6) weathered, dark yellowish brown (10 YR 4/2) fresh; beds very thick, irregular, even with thick planar, continuous, parallel laminae; grains fine - coarse, moderately well sorted, subrounded - subangular; composed mainly of quartz; iron nodules 3 - 5 cm in diameter; top of unit eroded.	3.3 (10.8)
10	SILTY SANDSTONE--dark yellowish orange (10 YR 6/6) weathered, dark yellowish brown (10 YR 4/2) fresh; beds thin, regular, uneven, with thin planar, continuous, parallel, laminae; grains silt - medium, moderately sorted subrounded; composed mainly of quartz; contact with above sharp.	0.2 (0.6)
9	SANDSTONE--dark yellowish orange (10 YR 6/6) weathered dark yellowish brown (10 YR 4/2) fresh; beds very thick, irregular, even, with thick planar, continuous, parallel laminae; grains fine - coarse, moderately well sorted, subrounded - subangular; composed mainly of quartz with orange clay matrix and calcite cement; iron nodules up to 8 cm in diameter; contact with above sharp.	18.6 (61.0)
8	SILTY CLAYSTONE - SILTY SANDSTONE--dark yellowish orange (10 YR 6/6) weathered, dark yellowish brown (10 YR 4/2) fresh; beds thick, irregular, even, with thin, planar, continuous, parallel laminae; grains clay - fine; claystone near top; contact with above sharp.	3.0 (9.8)
7	SANDSTONE--light olive gray (5 Y 6/1) weathered, yellowish gray (5 Y 8/1) fresh; beds very thick, irregular, even, massive; grains medium - coarse, well sorted, subrounded - subangular; composed mainly of	14.4 (47.2)

quartz and some white feldspar with white clay matrix and calcite cement; contains some carbonized wood fragments; contact with above sharp.

6	SILTY SHALE--yellowish gray (5 Y 7/2) weathered, light olive gray (5 Y 5/2) fresh; beds medium, irregular, uneven, with thin, planar, continuous, parallel laminae; contains carbonaceous material; contact with above sharp.	1.0	(3.3)
5	SANDSTONE--very pale orange (10 YR 8/2) weathered, yellowish gray (5 Y 8/1) fresh; beds very thick, irregular, uneven, massive; grains fine - medium, moderately well sorted, subrounded - subangular; composed mainly of quartz with white clay matrix; contact with above sharp.	11.1	(36.4)
4	SANDSTONE--moderate yellowish brown (10 YR 5/4) weathered, pinkish gray (5 YR 8/1) fresh; beds thin - medium, regular, uneven, with medium - thin, planar, continuous, parallel laminae; grains fine - coarse, poorly sorted, subrounded - subangular; composed mainly of quartz and feldspar with clay matrix and silica cement; pinches out laterally; contact with above sharp.	0.7	(2.3)
3	SANDSTONE--pale greenish yellow (10 Y 8/2) weathered, dark yellowish orange (10 YR 6/6) and grayish yellow (5 Y 8/4) fresh; beds very thick, irregular, uneven, with thin, curved, continuous, parallel laminae; large - very large, tangential - discordant, high - low angle, solitary trough bedding; grains fine - medium poorly sorted near bottom of unit, well sorted near top of unit, subrounded - subangular; composed mainly of quartz and feldspar with clay matrix; iron stained concretions; olive clay galls; contact with above sharp.	7.8	(25.6)

FRUITLAND FORMATION/KIRTLAND SHALE(?)

2	SILTY AND SANDY CLAYSTONE--pale yellowish brown (10 YR 6/2), light brown (5 YR 5/6) and pale brown (5 YR 5/2) weathered and fresh; beds medium - thick, irregular, uneven; grain clay - fine, poorly sorted	5.9	(19.4)

subrounded; composed mainly of clay with some quartz grains and carbonaceous material; contact with above erosional.

LEWIS SHALE

1	SHALE--moderate brown (5 YR 3/4) weathered and fresh; beds very thick, irregular, uneven, with thin, curved, discontinuous, parallel laminae; contact with above gradational.	1.3 (4.3)
	Total section thickness =	67.3 (220.8)

Measurement began near large pine tree approximately 20 yards south of large landslide deposit.

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APPENDIX

Terminology Used in Measured Section Descriptions

BEDDING SIZE (McKee and Weir, 1953 as modified by Ingram, 1954; Campbell, 1967):

Very thick beds	>100.0 cm (1 m)
Thick beds	30.0 - 100.0 cm
Medium beds	10.0 - 30.0 cm
Thin beds	1.0 - 10.0 cm
Very thin beds	<1.0 cm

BEDDING UNIFORMITY (Dunbar and Rodgers, 1963):

Regular	-	beds do not vary in thickness laterally
Irregular	-	beds do vary in thickness laterally
Even	-	all beds in vertical succession similar in size
Uneven	-	vertically adjacent beds not similar in size

INTERNAL STRUCTURE OF BEDS (McKee & Weir, 1953; Campbell, 1967):

Very thick laminae	>30.0 mm
Thick laminae	10.0 - 30.0 mm
Medium laminae	3.0 - 10.0 mm
Thin laminae	1.0 - 3.0 mm
Very thin laminae	<1.0 mm
Massive	No laminae distinguishable

BEDDING/LAMINAR SURFACE SHAPES (Modified from Campbell, 1967):

Planar	Surfaces are further described
Wavy	as to continuous/discontinuous
Curved	and parallel/convergent.

RIPPLE MARKS (Pettijohn, Potter, Siever, 1973; Allen, 1969):

1. Plan View
   - Continuous Pattern
     - Straight - (rectilinear) parallel crests, normal to current
     - Catenary - parallel crests but not straight, nor everywhere normal to current, may grade into sinuous or lunate forms.
     - Sinuous - nonparallel crests, not everywhere normal to current
   - Discontinuous Pattern
     - Lunate - crescentic, extremities point up current
     - Lingoid - crescentic, extremities point down current
2. Cross-Section View
   - Symmetrial/Asymmetrical
   - Climbing/"Normal"

CROSS-STRATIFICATION (Allen, 1963, or Jacob, 1973):

1. Magnitude (Jacob, 1973):
   - Small scale <0.05 m
   - Large scale 0.05 - 5.0 m
   - Very large scale >5.0 m

2. Relation with lower bounding surface (Jacob, 1973):
   - Concordant
   - Tangential
   - Discordant

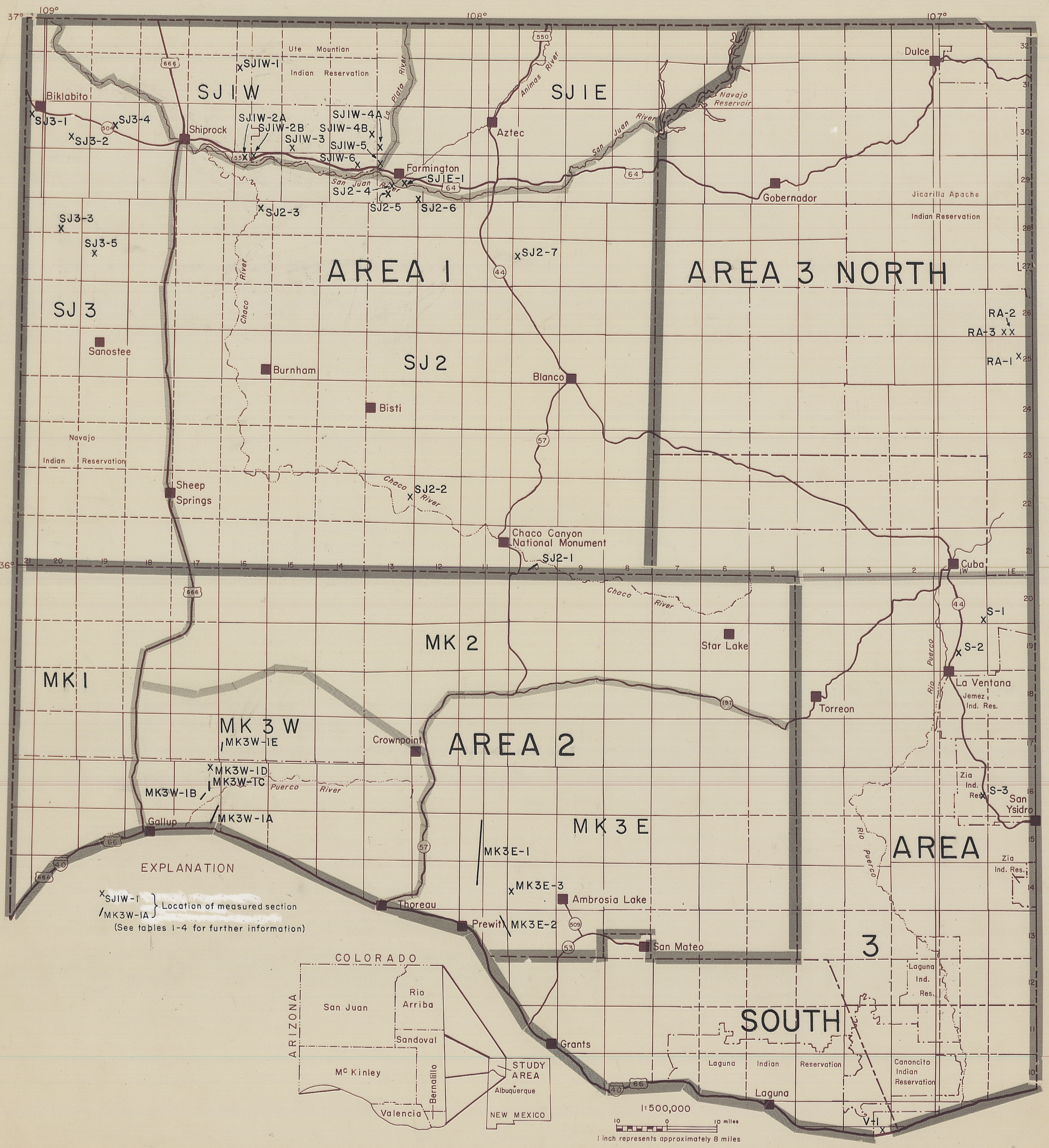
3. Dip (Jacob, 1973):
   - Low angle 2.0 - 15.0°
   - High angle >15.0°

4. Grouping (Allen, 1963):
   - Solitary
   - Grouped

5. General shape (modified from McKee & Weir, 1953):
   - Planar
     - Tabular - sets bounded by parallel planar surfaces
     - Wedge - sets bounded by converging planar surfaces
   - Nonplanar
     - Trough - sets bounded by curved surfaces

GRAIN SIZE (Wentworth, 1922):

Gravel	Boulders	>256.0 mm
	Cobbles	64.0 - 256.0 mm
	Pebbles	4.0 - 64.0 mm
	Granules	2.0 - 4.0 mm
Sand	Very coarse sand	1.0 - 2.0 mm
	Coarse sand	0.5 - 1.0 mm
	Medium sand	0.25 - 0.5 mm
	Fine sand	0.125 - 0.25 mm
	Very fine sand	0.0625- 0.125 mm
Fines	Silt	0.0039- 0.0625 mm
	Clay	<0.0039 mm



LOCATION MAP SHOWING STRATIGRAPHIC SECTIONS MEASURED, SAN JUAN BASIN, NEW MEXICO