Stratigraphy and Origin of the Triassic Moenkopi Formation and Related Strata in the Colorado Plateau Region

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With a section on SEDIMENTARY PETROLOGY

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Description of the stratigraphic succession, sedimentary facies, petrology, primary sedimentary structures, fossils, and depositional environments of the Moenkopi Formation and regionally correlative strata

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By J. H. Stewart, F. G. Poole, and R. F. Wilson

ABSTRACT

The Moenkopi Formation of Triassic(?) and Early and Middle(?) Triassic age is one of the typical red-bed units that characterize the upper Paleozoic and lower and middle Mesozoic rocks of the Colorado Plateaus province. It was named in 1901 for exposures in Moenkopi Wash in north-central Arizona. The formation crops out throughout most of the western two-thirds of the Colorado Plateaus province, and ranges in thickness from more than 2,000 feet in the westermost part of the province to a thin edge in the eastern part.

Many members of distinct lithologic character are recognized in the formation. None of the members extend throughout the entire depositional area of the formation, and most occur in only a relatively small part of the province.

In southwestern Utah and northwestern Arizona, and part of southern Nevada, six members are recognized in the Moenkopi Formation. These are, in ascending order, the Timpoweap Member, lower red member, Virgin Limestone Member, middle red member, Shnabkaib Member, and upper red member. The Timpoweap Member consists of red siltstone, gray limestone, and chert pebble conglomerate. The Virgin Limestone Member consists of limestone and siltstone. It thins and pinches out to the east. The Shnabkaib Member consists of red siltstone, gypsum, and limestone. It grades to the east into red siltstone. The lower, middle, and upper red members consist dominantly of red siltstone.

In most of north-central and east-central Arizona, the Moenkopi Formation is divided into three members. The lowest, the Wupatki Member, is composed mostly of pale-reddish-brown siltstone. It contains one thin widespread sandstone unit, referred to as the "lower massive sandstone," which extends to the west beyond the limits of the member. The Moqui Member overlies the Wupatki Member and is composed dominantly of pale-reddish-brown siltstone and minor amounts of white gypsum. The highest member, the Holbrook Member, is composed of interstratified and interfingering lenses of sandstone and siltstone.

In west-central New Mexico, a thin unit of red siltstone and sandstone is tentatively correlated with the Moenkopi Formation. This unit probably extends as far east as the Lucero uplift and to near Socorro.

In southeastern Utah, six members are recognized in the Moenkopi Formation. These members, in ascending order, are the Hoskinnini, lower slope-forming, Sinbad Limestone, ledge-forming, upper slope-forming, and cliff-forming. The Hoskinnini Member consists of pale-reddish-brown siltstone and very fine grained sandstone containing scattered fine, medium, and coarse sand grains. The lower slope-forming member consists of grayish-red, yellowish-gray, and light-greenish-gray siltstone and sandy siltstone. The ledge-forming member is composed of red siltstone and sandy siltstone or sandstone. The sandy siltstone or sandstone weathers to form ledges, and the member as a whole forms a ledgy interval in the formation. The Sinbad Limestone Member is composed of gray limestone and is a marine unit that thins and pinches out to the east. The upper slope-forming member consists of grayish-red and pale-reddish-brown siltstone. The cliff-forming member is composed of pale-reddish-brown and grayish-red siltstone characterized by abundant ripple laminae.

In the salt anticline region of east-central Utah and west-central Colorado, the Moenkopi Formation is exposed in and around a series of northwest-trending salt anticlines that started to form during Pennsylvanian time. Uplift of the salt anticlines during Triassic time effected the deposition of the Moenkopi Formation; local downwarped basins adjacent to the anticlines received thick sequences of sediments, and uplifted areas formed by the crests of anticlines received thin sequences. In some places the formation is absent over the crests of anticlines. In this region, the Moenkopi Formation is divided into four members which are, in ascending order, the Tenderfoot, Ali Baba, Sewemup, and Pariott Members. The Tenderfoot Member consists of pale-reddish-brown siltstone and very fine grained sandstone, and it contains thin local units of conglomerate and gypsum near the base. The Ali Baba Member consists of conglomeratic sandstone and sandstone interstratified with siltstone. The Sewemup Member consists of pale-reddish-brown and grayish-red siltstone; it contains gypsum locally. The Pariott Member is a local unit of red-brown, purplish-brown, chocolate-brown, orange, and red sandstone, mudstone, siltstone, and shale.

In northeastern Utah and northwestern Colorado, red beds in the eastern Uinta Mountains are referred to as the Moenkopi Formation, whereas laterally equivalent, but thicker, strata in the western Uinta Mountains are assigned to the Woodside, Thaynes, and Mahogany (new usage) Formations. The Moenkopi Formation as recognized in the eastern Uinta Mountains and the Woodside and Mahogany Formations in the western Uinta Mountains are composed largely of red siltstone and sandstone and contain some gypsum. The Thaynes Formation is a marine limestone unit that thins out to the east among the red beds of the Moenkopi Formation.

In central Colorado, strata at least in part physically and temporally equivalent to the Moenkopi Formation (called upper member of the State Bridge Formation) consist of red siltstone and contain minor amounts of sandstone, claystone, and gypsum.

A gradual change in facies is displayed in the Moenkopi Formation from its east margin to the west and northwest across the Colorado Plateau. Along its east margin the formation and equivalent strata contain much cross-stratified sandstone and siltstone and other current-deposited strata. In the western part of the Colorado Plateau it consists almost entirely of horizontally stratified siltstone, claystone, limestone, dolomite, and gypsum.

The Moenkopi Formation contains a varied, although not large, assemblage of fossils. Worms, brachiopods, pelecypods, gastropods, cephalopods, arthropods, and echinoderms occur in the marine limestone of the formation in the western part of the Colorado Plateau. Fish, amphibians, reptiles, and plants occur in continental strata in the eastern part of the Moenkopi depositional basin.

The Moenkopi Formation is interpreted to represent a complex of deposits formed in continental and marine environments. Cross-stratified sandstone and siltstone along the east margin of the formation are interpreted to be dominantly fluvial deposits. Limestone, dolomite, and horizontally stratified siltstone in the western exposures of the formation are considered to be shallow marine deposits. Between the areas of continental deposits on the east and marine deposits on the west is a coastal area containing deposits of both environments. Ripple-laminated siltstone, which is most abundant in these intermediate areas, may represent deposits formed on delta flood plains and perhaps in part on tidal flats and in shallow seas.

Directions of streamflow, as determined from the orientation of cross-strata in supposed fluvial strata, were to the northwest and west during deposition of the Moenkopi Formation. These flow directions, when considered in relation to the dominant fluvial deposition along the east margin of the formation, indicate source areas to the east of the east limit of the formation. Some sediment may have also been contributed to the formation from a southern source and possibly even from a western source.

INTRODUCTION

The Moenkopi Formation is the oldest part of the Triassic sequence on the Colorado Plateaus (fig. 1) and is one of the typical red-bed units that characterize the late Paleozoic and early and middle Mesozoic times of the Plateaus. The formation is present in most of the plateau area and typically weathers to form slopes and benches on wide exposure belts or to form irregular cliffs and slopes on canyon walls. It is characteristically red brown or chocolate brown. Perhaps the best known exposures of the Moenkopi are those along the Echo Cliffs in Arizona and the Vermilion Cliffs (pl. 1) in Arizona and Utah, those forming the scenic Belted Cliffs immediately west of Zion National Park, and those in Capitol Reef National Monument in Utah, where the formation is eroded into picturesque monuments.

The Moenkopi Formation has attracted much scientific attention in the past, particularly for the wide variety of sedimentary structures and evidence of depositional environments which it displays, and for the vertebrate trackways and fossils which it contains. Strata of the Moenkopi were described in the classic reports of the Powell, Wheeler, Hayden, and King surveys in the latter part of the 19th century, although the name Moenkopi, given by L. F. Ward, was not proposed until 1901. A study by E. D. McKee (1954) describes the detailed stratigraphy of the formation in Arizona and adjacent areas.

The present report represents a part of the results of an investigation designed to study the Triassic strata of the Colorado Plateau on a regional scale. The purpose of the study was to obtain information regarding areal distribution, local and regional differences in rock types, sources and character of constituents, and conditions of deposition of the strata involved. The study was undertaken as a part of the investigations of the geology of uranium deposits of the Colorado Plateau, and was conducted by the U.S. Geological Survey on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission.

METHODS OF STUDY AND SCOPE OF REPORT

Six principal aspects of the Moenkopi Formation were investigated in this study: (a) regional stratigraphy, (b) sedimentary facies, (c) sedimentary structures, (d) clay mineralogy, (e) sedimentary petrology, and (f) pebbles.

Regional stratigraphy was studied by correlating lithologic units throughout the Colorado Plateau, and in a few areas adjacent to the Plateau, for the purpose of establishing a firm background of information on distribution, lithology, facies, and thickness of units. About 50 stratigraphic sections were measured and described from outcrops, and many sections measured by other geologists were studied in detail. Stratigraphic units were correlated between sections on the basis of lithologic characteristics and by tracing of units along outcrops. The study consisted mostly of examining the many outcrops, but some logs of drill holes were also examined in an effort to corroborate correlation made on the basis of surface exposures and to determine thickness trends.

The measured sections, including those measured by us as well as by other geologists, the drill holes where stratigraphic information was obtained, and the margins of units where they can be determined on outcrops are located on plate 1. Table 1 gives the locality and the source of data for points on plates 1, 4, and 5. Each State has an independent locality numbering system. Locality numbers cited in the text are preceded, in the text only, by a letter indicating the State in which they occur (A, Arizona; C, Colorado; N, Nevada; NM, New Mexico; and U, Utah).

The sedimentary facies study consisted of measuring the abundance of specific lithologic rock types in the Moenkopi Formation and plotting the regional variation of rock types on maps. Seventy sections were used in this study that led to an understanding of the overall change in sedimentary facies within the formation and assisted both in delimiting possible source areas and in determining distribution of dominant sedimentary environments.

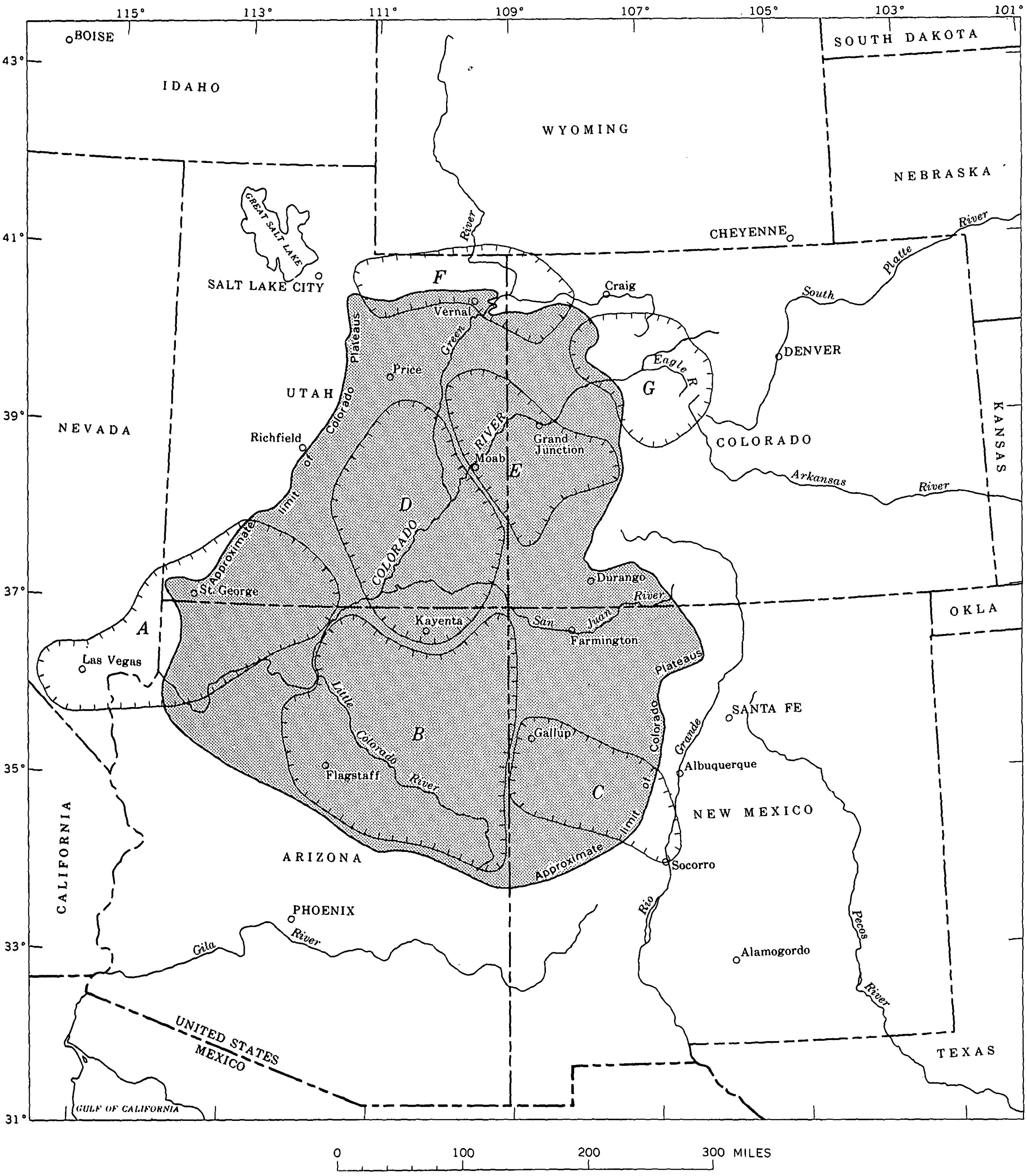

FIGURE 1.—Colorado Plateaus and areas discussed in text. *A*, southern Nevada, northwestern Arizona, and southwestern Utah; *B*, northeastern Arizona; *C*, west-central and central New Mexico; *D*, southeastern Utah; *E*, east-central Utah and west-central Colorado (salt anticline region); *F*, northeastern Utah and northwestern Colorado (Uinta Mountains region); *G*, central Colorado.

TABLE 1.—*Index to locality and source of control points shown on plates 1, 4, and 5*

[Explanation of abbreviations: AEC, U.S. Atomic Energy Commission; Am Strat, American Stratigraphic Co.; GSRM, Gila and Salt River meridian; MDM, Mount Diablo meridian; NBL, Navajo base line; NMPM, New Mexico principal meridian; SLM, Salt Lake meridian; UM, Uinta meridian; UPM, Ute principal meridian; 6th PM Sixth principal meridian. Dagger (†) preceding locality number indicates stratigraphic section included in present report. Asterisk (*) preceding the "Source of data" reference indicates the source is unpublished.]

County	Number (loc. No. on pls. 1, 4, 5)	Locality	Source of data
		ARIZONA	
Apache	†A1	Black Creek; long 109°13′35″ W., lat 35°19′40″ N	This report.
	†5	Hunters Point; long 109°07′50″ W., lat 35°34′10″ N	Do.
	6a	Lukachukai Trading Post; long 109°16′ W., lat 36°29′ N	Do.
	8	Nazlini Trading Post; long 109°25′10″ W., lat 35°52′50″ N	Stewart, Poole, and Wilson (1972).
	†9	St. Johns; long 109°21′40″ W., lat 34°25′40″ N	This report.
Coconino	†11	Shinarump Cliffs; N½ T. 40 N., R. 1 W., to sec. 7, T. 41 N., R. 1 W., GSRM.	Do.
	†12	East Sunset Mountain; secs. 13 and 24, T. 17 N., R. 13 E., and sec. 19, T. 17 N., R. 14 E., GSRM.	Do.
Navajo	†13	Owl Rock; long 110°14′10″ W., lat 36°52′10″ N	Do.
Coconino	15	Big Canyon; long 111°33′20″ W., lat 36°08′45″ N	Do.
	16	Red Point; long 111°39′ W., lat 36°42′ N	Do.
	18	Cedar Ridge; long 111°34′ W., lat 36°26′30″ N	Do.
	19	Coconino Point; long 111°30′20″ W., lat 35°53′20″ N	Do.
	21	Ott Mountain; sec. 15, T. 19 N., R. 4 E., GSRM	Do.
	23	Soap Creek; sec. 28, T. 39 N., R. 6 E., GSRM	Do.
	24	The Gap; long 111°28′30″ W., lat 36°17′50″ N	Do.
Apache	33	Fort Defiance; sec. 7, T. 1 N., R. 6 W., NBL	*M. E. Cooley and J. R. Howard.
	35	Klagetoh; long. 109°29′ W., lat 35°28′40″ N	*J. P. Akers.
	39	Oak Springs; long 109°10′30″ W., lat 35°27′ N	Do.
	41	Round Rock; long 109°26′ W., lat 36°34′ N	*C. A. Repenning.
Coconino	52	South of Navajo Bridge; long 111°37′40″ W., lat 36°43′20″ N	*M. E. Cooley and J. P. Akers.
	56	Vermilion Cliffs; sec. 15, T. 38 N., R. 5 E., GSRM	Do.
Navajo	58	Castle Butte water well; long 110°23′ W., lat 35°10′40″ N	*P. R. Stevens and C. A. Repenning.
	60	Holbrook; sec. 18, T. 17 N., R. 21 E., GSRM	*M. E. Cooley.
	67	The Sinks; about sec. 28 or 29, T. 14 N., R. 20 E., GSRM	McKee (1954, p. 83).
Apache	68	Concho; near sec. 16, T. 14 N., R. 25 E., GSRM	McKee (1954, p. 84).
Navajo	69	Woodruff Butte; about sec. 5 or 6, T. 16 N., R. 22 E., GSRM	Adapted from McKee (1954, p. 85).
Coconino	70	Winslow; about sec. 3, T. 19 N., R. 14 E., GSRM	McKee (1954, p. 86).
	73	East of Black Point	McKee (1954, p. 91–92).
	74	Black Falls; sec. 34, T. 26 N., R. 10 E., GSRM	McKee (1954, p. 92–93).
	75	West of Black Point; long 111°19′40″ W., lat 35°42′20″ N	McKee (1954, p. 94).
	77	Poverty Tank; long 111°30′ W., lat 35° 48′ 30″ N	McKee (1954, p. 96).
	79	Northwest of Cameron; long 111°36′ W., lat 35°57′ N	McKee (1954, p. 99).
	80	North of Cedar Ridge; long 111°36′ W., lat 36°32′40″ N	McKee (1954, p. 105).
	81	Shinumo Altar; long 111°42′40″ W., lat 36°25′20″ N	McKee (1954, p. 106).
	83	Lees Ferry; long 111°35′ W., lat 36°52′30″ N	McKee (1954, p. 109).
	84	Vermilion Cliffs; secs. 5 and 6, T. 39 N., R. 7 E., GSRM	McKee (1954, p. 110).
	85	Vermilion Cliffs; sec. 15, T. 38 N., R. 5 E., GSRM	McKee (1954, p. 112–114).
	86	Vermilion Cliffs; sec. 13, T. 38 N., R. 4 E., GSRM	McKee (1954, p. 114).
	87	Fredonia; sec. 14, T. 41 N., R. 2 W., GSRM	McKee (1954, p. 115–117).
	88	Johnson Canyon; sec. 5, T. 40 N., R. 2 W., GSRM	Gregory (1950a, p. 118).
Mohave	89	Black Rock Spring (Black Rock Mountain area), about T. 39 N., W½ R. 13 W. and E½ R. 14 W., GSRM.	Reeside and Bassler (1922, p. 75.)
	90	Bullrush; about sec. 26, T. 40 N., R. 4 W., GSRM	Reeside and Bassler (1922, p. 70).
Coconino	92	Cedar Mountain; long 111°45′30″ W., lat 36°4′ N	Noble (1922).
	93	Coyote Springs; secs. 13 and 14, T. 41 N., R. 3 E., GSRM	Wells (1960, p. 145).
	96	North of The Gap; long 111°31′30″ W., lat 36°21′40″ N	McKee (1954, p. 102).
Apache	97	El Paso National Gas Navajo water well 1; long 109°42′40″ W., lat 35°33′30″ N.	*J. W. Harshbarger.
Navajo	104	Holbrook Quarry; sec. 31, T. 18 N., R. 20 E., GSRM	Welles (1947, p. 243).
	105	General Petroleum Creager-State 14–6; sec. 6, T. 19 N., R. 23 E., GSRM.	*Am Strat Log 96.
Mohave	106	T. W. George Word 1; sec. 12, T. 40 N., R. 6 W., GSRM	*Am Strat Log D–960.
Coconino	109	Sinclair Oil and Gas and Phillips Petroleum Navajo 1; long 110°50′30″ W., lat 36°34′45″ N.	*Am Strat Log 489 and J. W. Harshbarger.
Apache	112	Amerada and Stanolind Navajo Black Mountain 1; long 109°51′ W., lat 36°7′30″ N.	*Am Strat Log 299.
Navajo	114	Silver Creek; sec. 18, T. 14 N., R. 22 E., GSRM	Harrell and Eckel (1939, pl. 2).
	115	Woodruff; sec. 11, T. 16 N., R. 21 E., GSRM	Do.
	116	Porters Tank; sec. 29, T. 16 N., R. 20 E., GSRM	Do.
	117	Chevelon Creek; sec. 32, T. 18 N., R. 17 E., GSRM	Do.

TABLE 1.—*Index to locality and source of control points shown on plates 1, 4, and 5*—Continued

County	Number (loc. No. on pls. 1, 4, 5)	Locality	Source of data
		ARIZONA—Continued	
Apache	A118	Northeast of Klagetoh; long 109°27′ W., lat 35°36′30″ N	Harshbarger, Repenning, and Irwin (1957, map of southeast-central part of Navajo Reservation).
	119	West of Hunters Point; long 109°13′20″ W., lat 35°31′20″ N	Do.
	120	West of Hunters Point; long 109°11′45″ W., lat 35°32′00″ N	Do.
	121	Hunters Point; long 109°08′30″ W., lat 35°34′45″ N	Do.
		COLORADO	
Archuleta	C1	Piedra River; sec. 31, T. 35 N., R. 4 W., NMPM	Stewart, Poole, and Wilson (1972).
Eagle	†2	East Brush Creek; sec. 7, T. 6 S., R. 83 W., 6th PM	This report.
	†3	Sheephorn Creek; sec. 1, T. 2 S., R. 82 W., 6th PM	Do.
Garfield	†4	South Canyon Creek; sec. 2, T. 6 S., R. 90 W., 6th PM	Do.
La Plata	5	Durango; sec. 3, T. 35 N., R. 9 W., NMPM	Stewart, Poole, and Wilson (1972).
Mesa	6	Bridgeport; sec. 19 (unsurveyed), T. 14 S., R. 98 W., 6th PM.	Do.
	7	Carson Hole; sec. 19, T. 15 S., R. 100 W., 6th PM	Do.
	†8	The Palisade; sec. 16, T. 51 N., R. 19 W., NMPM	This report.
	9	The Serpents Trail; sec. 31, T. 1 S., R. 1 W., UPM	Stewart, Poole, and Wilson (1972).
Moffat	†11	Miller Creek; secs. 28 and 33, T. 4 N., R. 101 W., 6th PM	This report.
Montezuma	14	Stoner; sec. 1, T. 38 N., R. 13 W., and sec. 4, T. 38 N., R. 12 W., NMPM.	Stewart, Poole, and Wilson (1972).
Montrose	†15	Paradox Valley; sec. 10, T. 47 N., R. 18 W., NMPM	This report.
Ouray	16	Ouray; sec. 35, T. 45 N., R. 8 W., NMPM	Stewart, Poole, and Wilson (1972).
Pitkin	17	Aspen; long 106°51′45″ W., lat 39°10′40″ N	Do.
Rio Blanco	†18	Meeker; secs. 23 and 24, T. 1 S., R. 93 W., 6th PM	This report.
San Miguel	19	Sawpit; sec. 7, T. 43 N., R. 10 W., NMPM	Stewart, Poole, and Wilson (1972).
	21	Dolores Canyon; sec. 11, T. 42 N., R. 18 S., NMPM	This report.
Ouray	22	Cow Creek; secs. 27, 28, 34, T. 45 N., R. 7 W., and sec. 3, T. 44 N., R. 7 W., NMPM.	Cross, Howe, and Irving (1907, p. 5).
	23	Ouray; long 107°39′24″ W., lat 38°01′30″ N	Cross, Howe, and Irving (1907).
Archuleta	25	Phillips Petroleum 1 Crowley; sec. 12, T. 32 N., R. 1 E., NMPM	Wood, Kelley, and MacAlpin (1948).
	26	Wirt-Franklin et al Sullenberger 1; sec. 28, T. 35 N., R. 2 W., NMPM.	Do.
Mesa	30	Bull Hill; sec. 16, T. 51 N., R. 18 W., NMPM	Cater (1955a).
	32	Larsen Canyon; sec. 36, T. 51 N., R. 19 W., NMPM	Do.
	33	Ute Creek; sec. 36, T. 15 S., R. 103 W., 6th PM	Cater (1955b).
	34	Indian Creek; sec. 5, T. 50 N., R. 17 W., NMPM	Do.
	35	Dark Canyon; secs. 28 and 33, T. 50 N., R. 17 W., NMPM	Cater (1955c).
	36	Cottonwood Canyon; secs. 11 and 13, T. 50 N., R. 19 W., NMPM	Shoemaker (1955).
	37	Sinbad Valley; sec. 15, T. 49 N., R. 19 W., NMPM	Shoemaker and Newman (1959, p. 1838–1841).
Montrose	38	Traver Creek; sec. 27, T. 49 N., R. 12 W., NMPM	*C. N. Holmes and T. E. Mullens.
	39	Continental Oil Nucla 1; sec. 18, T. 47 N., R. 14 W., NMPM	*Am Strat Log 312.
	40	Pure Oil Co. Horsefly 1; sec. 14, T. 46 N., R. 13 W., NMPM	*Am Strat Log 291.
Garfield	41	Kerr-McGee and Phillips 1; sec. 8, T. 8 S., R. 102 W., 6th PM	*Am Strat Log 74.
Mesa	42	Amerada Petroleum 1; sec. 14, T. 9 S., R. 101 W., 6th PM	*Am Strat Log 204.
Montezuma	44	Gulf Oil Corp. Fulks 1; sec. 27, T. 37 N., R. 17 W., NMPM	*Am Strat Log 697.
Eagle	46	Antelope Creek; sec. 33, T. 1 S., R. 84 W., 6th PM	Sheridan (1950).
	47	Bond; sec. 17, T. 2 S., R. 83 W., 6th PM	Do.
	48	Eiby Creek; sec. 7, T. 4 S., R. 84 W., 6th PM	Do.
	49	Garden Creek; sec. 5, T. 2 S., R. 82 W., 6th PM	Do.
	51	Posey Creek; sec. 15, T. 3 S., R. 85 W., 6th PM	Do.
	53	Red Canyon; sec. 9, T. 2 S., R. 84 W., 6th PM	Do.
	54	State Bridge; sec. 23, T. 2 S., R. 83 W., 6th PM	Do.
	55	Sylvan; sec. 22, T. 2 S., R. 85 W., 6th PM	Do.
	58	Kent; sec. 18, T. 4 S., R. 83 W., 6th PM	Do.
	61	Basalt; secs. 4 and 5, T. 8 S., R. 86 W., 6th PM	*F. G. Poole.
Montrose	67	Red Canyon; sec. 33, T. 47 S., R. 12 W., NMPM	*C. N. Holmes.
	68	Dry Creek anticline; sec. 4, T. 45 N., R. 16 W., NMPM	*L. C. Craig and L. R. Stieff.
	70	Red Canyon of Black Canyon; sec. 19, T. 51 N., R. 8 W., NMPM	*C. N. Holmes and T. E. Mullens.

TABLE 1.—*Index to locality and source of control points shown on plates 1, 4, and 5*—Continued

County	Number (loc. No. on pls. 1, 4, 5)	Locality	Source of data
		COLORADO—Continued	
Gunnison	C71	Sapinero; sec. 23, T. 49 N., R. 4 W., NMPM	*C. N. Holmes.
Pitkin	73	Potato Bill Creek; 34, T. 8 S., R. 88 W., 6th PM	Poole (1954).
	74	North Thompson Creek; sec. 31, T. 8 S., R. 88 W., and sec 36, T. 8 S., R. 89 W., 6th PM.	Do.
Gunnison	75	Almont; sec. 28, T. 51 N., R. 1 E., NMPM	*L. C. Craig, in Langenheim (1957).
San Miguel	88	Reynolds Mining Co. Egnar 1; sec. 14, T. 43 N., R. 19 W., NMPM.	*Am Strat Log 776.
La Plata	93	Stanolind Oil and Gas Ute Indian B 6; sec. 17, T. 33 N., R. 7 W., NMPM.	*Am Strat Log 848.
Montezuma	94	Continental Oil Co. Government 3; sec. 15, T. 33 N., R. 20 W., NMPM.	*Am Strat Log 882.
	95	Continental Oil Co. Government 2 Ute Mountain; sec. 18, T. 32 N., R. 18 W., NMPM.	*Am Strat Log 854.
Montrose	96	R. E. Weir Fee 1; sec. 27, T. 50 N., R. 10 W., NMPM	*Am Strat Log 18.
Mesa	97	California Co. Divide Creek 1; sec. 36, T. 8 S., R. 91 W., 6th PM	*F. G. Poole.
Rio Blanco	98	Superior Oil Co. Douglas Creek 1; sec. 5, T. 3 S., R. 101 W., 6th PM.	*Am Strat Log 588.
San Miguel	100	Penrose and Tatum Marie Scott 1; sec. 13, T. 45 N., R. 12 W., NMPM.	*Am Strat Log 495.
Garfield	101	Forest Oil Corp. Government 1; sec. 2, T. 7 S., R. 104 W., 6th PM.	*Am Strat Log 571.
	102	Greenbriar Federal Government 1: sec. 24, T. 5 S., R. 102 W., 6th PM.	*Am Strat Log 396.
Rio Blanco	103	Superior Oil Co. Fee 1, South Douglas Creek; sec. 12, T. 4 S., R. 102 W., 6th PM.	*Am Strat Log 772.
	104	Phillips Petroleum Douglas 1–B; sec. 18, T. 1 S., R. 101 W., 6th PM.	*Am Strat Log 800.
	105	California Co. Raven 2–A; sec. 31, T. 2 N., R. 102 W., 6th PM	*Am Strat Log 647.
Moffat	106	Hells Canyon; secs. 1 and 12, T. 5 N., R. 103 W., 6th PM	Thomas, McCann, and Raman (1945).
Grand	107	British American Lazy U 1; sec. 3, T. 2 N., R. 77 W., 6th PM	*Am Strat Log 576.
Moffat	108	Continental Oil Co. Lewin 1; sec. 17, T. 3 N., R. 91 W., 6th PM	*Am Strat Log 329.
Grand	109	De Barand Cattle Co. State 1; sec. 27, T. 4 N., R. 81 W., 6th PM	*Am Strat Log 460.
Routt	110	Union Oil Co. Crawford 1; sec. 32, T. 4 N., R. 89 W., 6th PM	*Chemical Laboratories File 47, Casper, Wyo.
Moffat	111	Stanolind Oil and Gas Madison unit 1; sec. 22, T. 4 N., R. 92 W	*Am Strat Log 211.
	112	Tom Palmer Government 1; sec. 34, T. 4 N., R. 99 W., 6th PM	*Am Strat Log 580.
	113	Zephyr Drilling Corp. Government 2; sec. 36, T. 4 N., R. 104 W., 6th PM.	*Am Strat Log 639.
	114	Carter Oil Gossard 1: sec. 29, T. 5 N., R 93 W., 6th PM	*Am Strat Log 590.
Jackson	115	Hiawatha Oil and Gas Co. Government 1–25; sec. 25, T, 7 N R. 81 W., 6th PM.	*Am Strat Log 493.
Rio Blanco	117	General Petroleum Corp. Well 1; sec. 24, T. 2 S., R. 103 W 6th PM.	*Chemical Laboratories File 70, Casper, Wyo.
Garfield	118	General Petroleum Corp. Schulte 1; sec. 15, T. 6 S., R. 103 W 6th PM.	*Am Strat Log 566.
Park	119	Shell Oil Co. State 4343 1; sec. 36, T. 11 S., R. 75 W., 6th PM	*Am Strat Log 873.
	120	McDonnald Oil Co. State 1; sec. 20, T. 12 S., R. 74 W., 6th PM	*Am Strat Log 194.
Moffat	121	Cross Mountain; sec. 29, T. 7 N., R. 98 W., 6th PM	Thomas, McCann, and Raman (1945).
	122	Vermilion Creek; sec. 2, T. 9 N., R. 101 W., 6th PM	Do.
Garfield	123	Elk Creek; sec. 15, T. 5 S., R. 91 W., 6th PM	*C. N. Holmes and T. E. Mullens.
Routt	124	O. D. Robinson R. Kagie 1; sec. 29, T. 4 N., R. 87 W., 6th PM	*Am. Strat Log 587.
Gunnison	130	Triano Creek; sec. 18, T. 49 N., R. 5 E., NMPM	Dings and Robinson (1957, pl. 1).
	131	Hot Springs Creek; sec. 2, T. 49 N., R. 4 E., NMPM	Do.
Grand	138	Rabbit Ears Pass; sec. 19, T. 5 N., R. 82 W., 6th PM	Rocky Mtn. Assoc. Geologists (1957).
	139	Gore Pass; sec. 11, T. 2 N., R. 82 W., 6th PM	Do.
	140	Parshall; sec. 15, T. 1 N., R. 79 W., 6th PM	Do.
Summit	141	Gore Range; sec. 14, T. 2 S., R. 81 W., 6th PM	Do.
Grand	142	Blue River; sec. 26, T. 1 S., R. 81 W., 6th PM	Do.
	143	Gore Range; sec. 4, T. 1 S., R. 81 W., 6th PM	Do.
	144	Canyon Creek; sec. 31, T. 1 N., R. 81 W., 6th PM	Do.
	145	Colorado River Canyon; sec. 21, T. 1 S., R. 82 W., 6th PM	Do.
Eagle	146	Sheephorn Creek; sec. 3, T. 2 S., R. 82 W., 6th PM	Do.
Routt	147	Solomon Creek; sec. 6, T. 10 N., R. 84 W., 6th PM	Hunter (1955, pl. 4).
	148	Tow Creek, Texas Co. 1 Colvert; sec. 7, T. 6 N., R. 86 W., 6th PM.	Intermountain Assoc. Petroleum Geologists (1955, pl. 8).

TABLE 1.—*Index to locality and source of control points shown on plates 1, 4, and 5*—Continued

County	Number (loc. No. on pls. 1, 4, 5)	Locality	Source of data
		COLORADO—Continued	
Summit	C149	Dillon; sec. 17, T. 5 S., R. 77 W., 6th PM	Lovering and Goddard, (1950, pl. 2).
	150	Illinois Gulch; sec. 10, T. 7 S., R. 77 W., 6th PM	Do.
	151	Mount Guyot; sec. 7, T. 7 S., R. 76 W., 6th PM	Do.
Park	152	Little Baldy Mountain; sec. 25, T. 8 S., R. 77 W., 6th PM	Stark and others (1949, pl. 1).
	153	Hartsel; sec. 4, T. 12 S., R. 75 W., 6th PM	Do.
	154	Chase Gulch; sec. 31, T. 11 S., R. 74 W., 6th PM	Do.
		NEVADA	
Clark	†N1	Horse Spring valley; secs, 13 and 14 (unsurveyed), T. 18 S., R. 70 E., MDM.	This report.
	4	Sandstone Spring Valley; about sec. 12, T. 20 S., R. 66 E., MDM	Longwell (1928, p. 49–50).
	5	Logan Wash; about sec. 12, T. 16 S., R. 66 E., MDM	Longwell (1928, p. 46–48).
	7	Spring Mountains; T. 22 S., R. 58 E., MDM	Hewett (1931, p. 32–33).
		NEW MEXICO	
McKinley	† NM1	Chavez-Prewitt; sec. 36, T. 13 N., R. 12 W., NMPM	This report.
	3	Fort Wingate; long 108°33′35″ W., lat 35°27′40″ N	Stewart, Poole, and Wilson (1972).
Rio Arriba	6	Abiquiu; sec. 15 (unsurveyed), T. 23 N., R. 5 E., NMPM	Do.
	7	Coyote; sec. 21, T. 23 N., R. 3 E., NMPM	Do.
	8	Gallina; sec. 3, T. 23 N., R. 1 E., NMPM	Do.
Sandoval	12	Arroyo de los Pinos; secs. 13 and 14, T. 19 N., R. 1 W., NMPM	Do.
	13	San Ysidro; sec. 36, T. 16 N., R. 1 E., NMPM	Do.
	14	Senorito Canyon; sec. 1, T. 20 N., R. 1 W., NMPM	Do.
Socorro	† 16	Riley; sec. 24, T. 2 N., R. 4 W., NMPM	This report.
	† 17	Sevilleta Grant; sec. 10 (unsurveyed), T. 1 S., R. 2 E., NMPM	Do.
Valencia	† 20	Mesa Gallina; sec. 10, T. 5 N., R. 4 W., NMPM	Do.
Rio Arriba	22	Rio Canones; long 106°31′ W.(?), lat 36°49′ N. (?)	Dane (1948).
	23	Richmond Oil Co. Tierra Amarilla Grant; sec 30 (unsurveyed), T. 10 N., R. 2 E., NMPM.	Do.
	24	Willow Creek Oil Syndicate and E. T. Williams, Tierra Amarilla Grant; sec. 22 (unsurveyed), T. 30 N., R. 2 E., NMPM	Do.
	27	Chavez Creek; long 106°28′W., lat 36°46′ N	Muehlberger (1957).
McKinley	32	Cheechilgeetho Day School water well; about sec. 20, T. 12 N., R. 18 W., NMPM.	*J. W. Harshbarger.
	33	Iyanbito Day School water well; about long 108°29′ W., lat 35°31′ N.	*C. A. Repenning and P. R. Stevens.
	34	Thoreau School water well; about long 108°12′ W., lat 35°24′N	*J. T. Callahan, J. W. Harshbarger, C. A. Reppening, and P. R. Stevens.
	35	Zuni water well 1; about sec. 33, T. 10 N., R. 19 W., NMPM	*P. R. Stevens.
	36	Rehoboth Mission water well; about long 108°39′ W., lat 35°31′ N.	*J. T. Callahan and P. R. Stevens.
	37	Superior Oil Co. San Mateo Government 1–14; sec. 14, T. 14 N., R. 8 W., NMPM.	*Am Strat Log 617.
	38	Great Western Drilling Co. Hospah-Santa Fe; sec. 1, T. 17 N., R. 9 W., NMPM.	*Am Strat Log 753.
Sandoval	39	Reynolds Mining Co. Torreon 1; sec. 22, T. 18 N., R. 4 W., NMPM.	*Am Strat Log 797.
San Juan	41	Continental Oil Co. Rattlesnake 100; sec. 2, T. 29 N., R. 19 W., NMPM.	Strobell (1956).
Rio Arriba	42	Gallina Canyon; sec. 12, T. 25 N., R. 1 E., and sec. 8, T. 25 N., R. 2 E.	Lookingbill (1953).
San Juan	45	Gulf Oil Co. Navajo Federal 1; sec. 28, T. 25 N., R. 16 W., NMPM.	*Am Strat Log 707.
	46	Stanolind Hogback U S G 13; sec. 19, T. 29 N., R. 16 W., NMPM.	*Am Strat Log 448.
	47	Phillips Petroleum Navajo 1; sec. 5, T. 30 N., R. 17 W., NMPM.	*Am Strat Log 471.
Valencia	48	Ojo Caliente Pueblo; secs. 20–21, T. 8 N., R. 20 W., NMPM	Dane and Backman (1957).
Sandoval	49	Senorito Canyon; sec. 6, T. 20 N., R. 1 E., NMPM	Wood, Northrop, and Cowan (1946)
	50	Blue Bird Mesa; secs. 2 and 3, T. 20 N., R. 1 E., NMPM	Do.
Rio Arriba	53	Magnolia Petroleum Jicarilla "A" 1; sec. 18, T. 23 N., R. 2 W., NMPM.	*Am Strat Log 761.

TABLE 1.—*Index to locality and source of control points shown on plates 1, 4, and 5*—Continued

County	Number (loc. No. on pls. 1, 4, 5)	Locality	Source of data
NEW MEXICO—Continued			
San Juan	NM54	Pan American Petroleum Co. O. J. Hoover A 1; sec. 23, T. 30 N., R. 16 W., NMPM.	*Am Strat Log 893.
Rio Arriba	55	Derby Drilling Co. Apache 1; sec. 33, T. 28 N., R. 1 E., NMPM	*Am Strat Log 70.
	56	Southwest Exploration Co., Pennsylvania Bldg. Co., 1; sec. 22, T. 28 N., R. 2 E., NMPM.	*Am Strat Log 48.
Sandoval	57	El Paso Natural Gas Elliott State 1; sec. 36, T. 19 N., R. 2 W., NMPM	*Am Strat Log 547.
	58	Magnolia Petroleum Co. Hutchinson-Federal 1; sec. 14, T. 19 N., R. 3 W., NMPM.	*Am Strat Log 551.
Rio Arriba	59	Continental Oil Co. Unit 1; sec. 6, T. 28 N., R. 2 W., NMPM	*Am Strat Log 441.
San Juan	60	Southern Union Barker 17; sec. 27, T. 32 N., R. 14 W., NMPM	*Am Strat Log 26.
McKinley	61	Pure Oil Co. Navajo Tribe Tract 9 No. 1; sec. 29, T. 19 N., R. 17 W., NMPM.	*Am Strat Log 609.
Sandoval	66	Humble Oil Santa Fe Pacific 1; sec. 20, T. 14 N., R. 1 W., NMPM	*Am Strat Log 605.
UTAH			
Emery	† U2	Block Mountain; long 110°42′25″ W., lat 38°47′15″ N., and long 110°44′10″ W., lat 38°48′00″ N.	This report.
	† 6	Muddy River; long 110°58′00″ W., lat 38°34′30″ N	Do.
	† 7	Straight Wash; sec. 29, T. 23 S., R. 13 E., SLM	Do.
	† 8	Temple Mountain; long 110°40′30″ W., lat 38°41′40″ N	Do.
Garfield	† 9	Buckacre Point; long 110°24′ W., lat 38°06′N	Do.
	† 10	Horse Canyon; long 111°11′55″ W. to 111°12′40″ W., lat 37°56′25″ N. to 37°57′05″ N.	Do.
	† 11	Muley Twist; long 111°01′55″ W., lat 37°50′30″ N	Do.
	† 13	Range Canyon; long 110°05′20″ W., lat 38°07′50″ N	Do.
	† 14	Silver Falls Creek; long 111°05′ W., lat 37°44′ N	Do.
Grand	† 18	Richardson Amphitheater; sec. 25, T. 23 S., R. 23 E., SLM	Do.
	† 20	Moab Canyon; sec. 19, T. 25 S., R. 21 E., SLM	Do.
	21	Westwater Canyon; sec. 22, T. 20 S., R. 25 E., SLM	Stewart, Poole, and Wilson (1972).
Iron	† 22	Kanarraville; sec. 10, T. 38 S., R. 12 W., SLM	This report.
San Juan	† 25	Bears Ears; sec. 3 (unsurveyed), T. 37 S., R. 18 E., and sec. 34, T. 36 S., R. 18 E., SLM.	Do.
	† 26	Bridger Jack Mesa; sec. 25 (unsurveyed), T. 32 S., R. 20 E., SLM.	Do.
	† 27	Comb Wash; long 109°39′ W., lat 37°19′ N	Do.
	† 28	Cottonwood Creek; secs. 33 and 34 (unsurveyed), T. 34 S., R. 20 E., SLM.	Do.
	† 29	Hite; long 110°25′40″ W., lat 37°47′05″ N	Do.
	† 30	Jacobs Chair; long 110°14′25″ W. to 110°13′00″ W., lat 37°42′35″ N. to 37°43′15″ N.	Do.
	† 32	Lockhart Canyon; secs 23 and 24, T. 28 S., R. 20 E., SLM	Do.
	† 33	Milk Ranch Point; sec. 35 (unsurveyed), T. 36 S., R. 20 E., SLM	Do.
	† 34	Monitor Butte; long 110°26′ W., lat 37°13′ N	Do.
	† 35	North Sixshooter Peak; secs. 30 and 31, T. 30 S., R. 21 E	Do.
	† 36	Poncho House; long 109°45″ W., lat 37°07′ N., and long 109°45″ W., lat 37°07′ N.	Do.
	† 37	The Rincon; long 110°47′ W., lat 37°19′30″ N	Do.
	† 38	Steer Mesa; long 110°00′ W., lat 38°25′ N	Do.
Uintah	† 40	Cliff Creek; secs. 15, 16, and 22, T. 5 S., R. 24 E., SLM	Do.
	† 41	Vernal; sec. 32, T. 2 S., R. 22 E., and sec. 5, T. 3 S., R. 22 E., SLM.	Do.
Wayne	† 42	Capitol Wash; sec. 12, T. 30 S., R. 6 E., SLM	Do.
	† 43	Chimney Rock; secs. 5 and 7, T. 29 S., R. 6 E., SLM	Do.
Washington	†47a	St. George A; long 113°40′00″ W. and lat 37°01′45″ N., long 113°41′30″ W. and lat 37°03′15″ N., long 113°40′20″ to 113°38′55″ W., lat 37°03′25″ to 37°04′15″ N.	Do.
	†47b	St George B; long 113°42′10″ W., lat 37°02′40″ N	Do.
Emery	48	Mexican Bend; sec. 6, T. 21 S., R. 13 E., SLM	Do.
San Juan	49	Clay Hills Pass; sec. 12, T. 39 S., R. 14 E., and sec. 7, T. 39 S., R. 15 E., SLM.	Do.
	50	Shafer Canyon; sec. 13, T. 27 S., R. 19 E., SLM	Do.
Washington	52	Deadman Hollow; sec. 8, T. 39 S., R. 12 W., SLM	Gregory and Williams (1947, p. 236–237).
	53	Taylor Creek; secs. 28 and 29, T. 38 S., R. 12 W., SLM	Gregory and Williams (1947, p. 234–235).

TABLE 1.—*Index to locality and source of control points shown on plates 1, 4, and 5*—Continued

County	Number (loc. No. on pls. 1, 4, 5)	Locality	Source of data
		UTAH—Continued	
Iron	U54	Coal Creek Canyon; secs. 12 and 13, T. 36 S., R. 11 W., SLM	Thomas and Taylor (1946, p. 20–21).
Washington	55	Belted Cliffs; secs. 19, 17, 18, T. 41 S., R. 12 W., SLM	Gregory (1950a, p. 115–118).
	56	Little Creek Mountain; secs. 10, 11, 12, T. 43 S., R. 13 W., SLM	Gregory (1950a, p. 113–115).
	57	Beaver Dam Mountains; about long 113°51′ W., lat 37°15′ N	Reber (1951).
	58	Harrisburg Dome; about sec. 17, T. 42 S., R. 14 W., SLM	Reeside and Bassler (1922, p. 73–74).
	59	Smiths Mesa; about sec. 10 or 11, T. 41 S., R. 12 W., SLM	Reeside and Bassler (1922, p. 73).
	60	Washington Dome; about sec. 19 or 20, T. 42 S., R. 14 W., SLM	Reeside and Bassler (1922, p. 74).
	61	St. George area; NW¼ T. 43 S., R. 16 W., to SW¼ W. 42 S., R. 17 W., SLM.	Poborski (1954, p. 996–1005).
Kane	62	Kaibab Gulch; sec. 30(?), T. 42 S., R. 2 W., SLM	Noble (1928); Gregory (1948).
	63	Quarry Ridge; sec. 29, T. 43 S., R. 3 W., SLM	Gregory (1948, p. 227).
Wayne	64	Miners Mountain; sec. 31, T. 30 S., R. 7 E., SLM	* J. H. Stewart and G. A. Williams.
	71	North Trail; long 110°07′30″ W., lat 38°13′30″ N	Baker (1946, pl. 7, p. 47, 59, 62, 65).
Garfield	77	South Block; about long 110°16′ W., lat 37°58′ N	Baker (1946, p. 56–57).
	78	Clearwater Canyon; about long 110°10″ W., lat 38°03′ N	Baker (1946, p. 57).
	79	Teapot Rock; about long 110°07′ W., lat 38°04′30″ N	Do.
Wayne	81	Elaterite Basin; about long 110°04′30″ W., lat 38°11′30″ N	Baker (1946, pl. 7).
San Juan	91	Hoskinnini Mesa; sec. 17, T. 43 S., R. 14 E., SLM	Baker (1936, p. 39, 43).
	92	Oljeto Mesa; sec. 35, T. 43 S., R. 15 E., SLM	Baker (1936, p. 39, 42).
	93	Nokai Canyon; sec. 11, T. 43 S., R. 12 E., SLM	Do.
	94	Copper Canyon; sec. 9, T. 42 S., R. 13 E., SLM	Baker (1936, p. 39, 41).
Emery	107	Muddy River; sec. 34, T. 24 S., R. 8 E., SLM	Gilluly and Reeside (1928, p. 84); Gilluly (1929, p. 88, 89, 92).
	109	Red Canyon; about secs. 32, 29, 20, T. 20 S., R. 12 E., SLM	Gilluly (1929, p. 86, 87, 89, 92).
San Juan	126	Hatch Point; sec. 27, T. 29 S., R. 20 E., SLM	Baker (1933, p. 35).
Grand	128	Fisher Valley; sec. 13, T. 24 S., R. 24 E., SLM	Dane (1935, p. 49).
	130	Utah Southern State 1; sec. 26, T. 21 S., R. 23 E., SLM	Dane (1935, p. 51).
	131	Beaver Creek; sec. 6(?), T. 24 S., R. 26 E., SLM	Dane (1935, p. 49, 59–60).
	132	Richardson; sec. 4(?), T.. 24. S., R. 23 E., SLM	Dane (1935, p. 44–45, 57).
	133	North of Dry Gulch; sec. 33, T. 21 S., R. 25 E., SLM	Dane (1935, p. 60–61).
	141	Cane Creek anticline; sec. 22, T. 26 S., R. 20 E., SLM	McKnight (1940, p. 57).
Garfield	149	North Wash; about long 110°25′ W., lat 37°54′ N	Hunt (1953, p. 51).
Wayne	161	Pleasant Creek; sec. 30, T. 30 S., R. 7 E., SLM	*J. F. Smith, Jr.
Grand	162	Pariott Mesa; sec. 5, T. 25 N., R. 23 E., SLM	Shoemaker and Newman (1959, p. 1841–1843).
Duchesne	163	Duchesne River; T. 1 N., R. 8 W., UM	Thomas and Krueger (1946, p. 1284).
	164	Lake Fork River; sec. 1, T. 1 N., R. 5 W., to sec. 26, T. 2 N., R. 5 W., UM.	Thomas and Krueger (1946, p. 1285).
Uintah	165	Split Mountain; between T. 5 S., R. 23 E., and T. 5 S., R. 24 E., SLM.	Thomas and Krueger (1946, p. 1290).
	167	Whiterocks Canyon; secs. 18 and 19, T. 2 N., R. 1 E., UM	Thomas and Krueger (1946, p. 1287, 1288).
Dagget	168	Manila; sec. 3, T. 2 N., R. 19 E., and sec. 3, T. 2 N., R. 20 E., SLM	Thomas and Krueger (1946, p. 1292).
Grand	169	Salt Valley anticline; sec. 30, T. 23 S., R. 21 E., SLM	Shoemaker and Newman (1959, p. 1849).
San Juan	170	Idle Day claim; secs. 12 and 13, T. 30 S., R. 24 E., SLM	*G. W. Weir and W. H. Starrett.
	171	Little Valley; secs. 21, 29, and 31, T. 30 S., R. 25 E., SLM	Do.
Grand	172	Granite-Ryan Creek; sec. 4, T. 23 S., R. 25 E., SLM	*C. N. Holmes and T. E. Mullens.
San Juan	173	Clay Gulch; secs. 7 and 8, T. 40 S., R. 14 E., SLM	*T. E. Mullens and J. H. Stewart.
	175	Lavender Canyon; sec. 31, T. 31 S., R. 21 E., SLM	*E. N. Hinrichs and W. J. Krummel.
Uintah	176	Phillips Petroleum Watson "B" 1; sec. 34, T. 9 S., R. 25 E., SLM	*Am Strat Log 812.
San Juan	178	Byrd-Frost Inc. Randall 1; sec. 23, T. 33 S. R. 24 E., SLM	*Am Strat Log 390.
Garfield	180	Lion Oil Co. (Monsanto) Bryce 1; sec. 10, T. 36 S., R. 4 W., SLM	*Am Strat Log 894.
Wayne	182	Stanolind Cainville 1; sec. 29, T. 28 S., R. 8 E., SLM	*Am Strat Log 786.
Emery	183	Carter Oil Co. Government Wheatley 1; sec. 27, T. 16 S., R. 12 E., SLM.	*Am Strat Log 886.
San Juan	184	Shell Oil Co. Bluff 3; sec. 4, T. 40 S., R. 23 E., SLM	*Am Strat Log 877.
Emery	185	Tidewater Oil 6–25; sec. 25, T. 26 S., R. 13 E., SLM	*Am Strat Log 176.
San Juan	186	Reynolds Mining Co. Hatch 1; sec. 4, T. 39 S., R. 24 E., SLM	*Am Strat Log 787.
Uintah	187	Carter Oil Co. Minton State 1; sec. 32, T. 14 S., R. 20 E., SLM	*Am Strat Log 790.
Wayne	188	Carter Oil Co. Nequoia 1; sec. 5, T. 27 S., R. 14 E., SLM	*Am Strat Log 775.

TABLE 1.—*Index to locality and source of control points shown on plates 1, 4, and 5*—Continued

County	Number (loc. No. on pls. 1, 4, 5)	Locality	Source of data
		UTAH—Continued	
San Juan	U189	Gulf Oil Corp. Coal Bed Canyon 1; sec. 15, T. 35 S., R. 25 E., SLM.	*Am Strat Log 779.
Emery	191	Standard Oil of California 1; sec. 32, T. 25 S., R. 15 E., SLM	*Am Strat Log 886.
San Juan	193	Superior Oil Co. Navajo "A" 1; sec. 14, T. 40 S., R. 24 E., SLM	*Am Strat Log 805.
	194	Richfield Oil Co. Federal 1; sec. 31, T. 37 S., R. 26 E., SLM	*Am Strat Log 876.
	195	Hathaway Bros. Glasco-Federal 1B; sec. 5, T. 39 S., R. 25 E., SLM.	*Am Strat Log 432.
	197	Shell Oil Co. Desert Creek 2; sec. 35, T. 41 S., R. 23 E., SLM	*Am Strat Log 679.
	198	Shell Oil Co. North Boundary Butte 1; sec. 33, T. 42 S., R. 22 E., SLM.	*Am Strat Log 714.
	199	Carter Oil Co. White Mesa 1; sec. 1, T. 42 S., R. 24 E., SLM	*Am Strat Log 649.
Emery	201	Delhi Oil Corp. W. N. Russell 1; sec. 34, T. 25 S., R. 12 E., SLM	*Am Strat Log 554.
Grand	203	Frontier-Stanolind Crittenden1; sec. 12, T. 17 S., R. 25 E., SLM	*Am Strat Log 91.
	204	Equity Oil Co. Government 1; sec. 20, T. 21 S., R. 23 E., SLM	*Am Strat Log 635.
	205	Continental-Union-Mountain Fuel 1; sec. 23, T. 20 S., R. 21 E., SLM.	*Am Strat Log 19.
Piute	206	Deer Trail Mountain; sec. 10. T. 28 S., R. 4 W., SLM	Kerr and others (1957, p. 64).
San Juan	208	Red Canyon; long 110°14′ W., lat 37°30′30″ N	This report.
Garfield	209	California Co. Muley Creek 1; sec. 18, T. 36 S., R. 10 E., SLM	*Am Strat Log 420.
San Juan	210	Skelly Oil Co. Nokai 1-A; sec. 27, T. 40 S., R. 12 E., SLM	*Am Strat Log 572.
	211	Poison Canyon; long 109°48′30″ W., lat 37°51′ N. (approximate).	*R. Q. Lewis.
	212	Hammond Canyon; secs. 25 and 36, T. 35 S., R. 19 E. (approximate), SLM.	Do.
Wayne	225	Carter Oil Co. Nequoia Arch 2; sec. 35, T. 27 S., R. 15 E., SLM	*Am Strat Log 878.
Kane	226	Midwest Exploration C. G. Parry 31X Butler Valley; sec. 14, T. 39 S., R. 1 W., SLM.	*Am Strat Log 161.
Emery	230	Phillips Petroleum Huntington 1; sec. 15, T. 17 S., R. 8 E., SLM.	*Am Strat Log 593.
Grand	231	Pacific Western and Equity Thompson 1; sec. 33, T. 21 S., R. 21 E., SLM.	*Am Strat Log 231.
Emery	232	Hancock-Utah Development Cedar Mountain 1; sec. 9, T. 19 S., R. 12 E., SLM.	*Am Strat Log 702.
Grand	233	Tidewater Big Flat 74-11; sec. 11, T. 26 S., R. 19 E., SLM	*Am Strat Log 202.
San Juan	234	Ohio Oil Co. Navajo 1; sec. 10, T. 43 S., R. 21 E., SLM	*Am Strat Log 646.
Summit	236	Weber River; T. 1 S., R. 6 E., SLM	Thomas and Krueger (1946, p. 1282).
San Juan	245	Gulf Oil Corp. Desert Creek-Federal 1; sec. 1, T. 41 S., R. 22 E., SLM.	*Am Strat Log 858.
	246	Carter Oil Co. Navajo-Gothic 2; sec. 36, T. 40 S., R. 21 E., SLM	*Am Strat Log 861.
Kane	247	Byrd Oil Corp. Government 1; sec. 5, T. 40 S., R. 5 E., SLM	*Am Strat Log 594.
San Juan	248	Clay Hills Crossing; sec. 20, T. 40 S., R. 14 E., SLM	*T. E. Mullens.
	249	Hurrah Pass; sec. 5, T. 27 S., R. 21 E., SLM	*W. H. Krummel and J. Connor.
Garfield	250	California Co. Johns Valley 1; sec. 22, T. 35 S., R. 2 W., SLM	*Am Strat Log 191.
	251	California Co. Upper Valley 1; sec. 12, T. 36 S., R. 1 E., SLM	*Am Strat Log 68.
San Juan	252	Shell Oil Co. Hovenweep 1; sec. 5, T. 40 S., R. 26 E., SLM	*Am Strat Log 785.
	254	Sweet Springs Draw; long 109°40′ W., lat 37°22′18″ N	Sears (1956, pl. 17).
	255	Monitor Butte; long 110°26′ W., lat 37°11′40″ N	Harshbarger and others (1961, map of northwest-central part of Navajo Reservation).
	256	Piute Farms; between secs. 34 and 35, T. 40 S., R. 13 E., SLM	Mullens (1959).
	257	Shafer Canyon; sec. 7, T. 27 S., R. 20 E., SLM	McKnight (1940, pl. 1).
Uintah	273	Phillips Petroleum Two Waters 1; sec. 22, T. 14 S., R. 25 E., SLM.	*Am Strat Log 708.
Wayne	274	Range Canyon; long 110°03′45″ W., lat 38°09′20″ N	Baker (1946, pl. 1).
	275	East Fork; long 110°02′20″ W., lat 38°11′30″ N	Do.
Emery	276	Utah Oil and Refining Co. Wm. Fitzhugh 1; sec. 12, T. 19 S., R. 13 E., SLM.	*Am Strat Log 130.
Grand	277	Amerada Petroleum Co. 1; sec. 2, T. 22 S., R. 16 E., SLM	*Am Strat Log 147.
San Juan	278	White Canyon; long 110°17′10″ W., lat 37°45′10″ N	*A. F. Trites, Jr., and others, geologic map.
	279	Standing Rock Basin; sec. 33, T. 28 S., R. 19 E., and sec. 4, T. 29 S., R. 19 E., SLM.	*E. N. Hinrichs and D. E. Melick.
	280	Harts Draw; sec. 3, T. 29½ S., R. 21 E., and sec. 10, T. 30 S., SLM.	*E. N. Hinrichs
Carbon	281	Skelly Oil Co. Richard Bryner 2; sec. 25, T. 14 S., R. 7 E., SLM	*Am Strat Log D-913.
San Juan	282	Woodward Hawkins 1; sec. 13, T. 38 S., R. 21 E., SLM	*Am Strat Log 718.
Garfield	290	The Horn; long 110°26′10″ W., lat 37°46′10″ N	*M. E. Cooley, C. K. Lee, and Frank Wright.
San Juan	291	Copper Point; long 110°20′55″ W., lat 37°48′15″ N	*M. E. Cooley.
Grand	295	Moab; sec. 28, T. 25 S., R. 21 E., SLM	Stewart (1959, p. 1857).

The orientation of cross-strata was studied at 30 localities, and of ripple marks at a few localities. These data led to interpretations of regional drainage patterns and of possible source areas.

Clay-mineralogy studies (Schultz, 1963) consisted of identification, by X-ray diffraction methods, of clay minerals from many samples from localities throughout the Colorado Plateau. The study showed consistent patterns in areal distribution of clay minerals within the formation and facilitated interpretations of the origin and source of the Moenkopi Formation, particularly where strata were rich in clay.

Sedimentary petrology studies determined regional differences in composition and texture of the strata, particularly the sandstone and coarse siltstone units. They involved statistical analysis of grain-size distribution and compositional studies of detrital and allogenic constituents. This study also led to interpretations of the origin and source areas of the formation.

Pebbles in a few conglomeratic units of the Moenkopi were studied to determine the composition, average and maximum size, color, roundness, and sphericity of gravels. This pebble study contributed to the determination of possible source rocks.

This report describes in full the results of regional stratigraphic and lithofacies studies, and summarizes the results of the sedimentary structure, sedimentary petrology, and pebble studies. In addition, the paleontology of the formation is summarized. The depositional history and environments of deposition of the formation and the location and terrain of the source areas are discussed, making use of all the types of information available.

FIELD AND OFFICE WORK

Fieldwork on this project started in the summer of 1951 and continued, except during winter months, through 1956. Some field checking was done during 1957. Office research and compilation was handled as the project continued, and much of this report was prepared during 1957–58.

The following geologists worked on the project: L. C. Craig (1951–52), T. E. Mullens (1951–52), P. J. Katich (1951), G. A. Williams (1951–55), H. F. Albee (1952–55), J. H. Stewart (1952–58), O. B. Raup (1953–55), F. G. Poole (1954–58), W. Thordarson (1955–56), and R. F. Wilson (1955–58). The project was originally headed by Craig, who continued as advisor throughout the study. Williams was in charge of the project during 1953–54, and Stewart was in charge from 1955 until completion of the project. Physical stratigraphy was studied mainly by Stewart, Poole, and Wilson; lithofacies by Wilson; sedimentary structures by Poole, Raup, and Williams; and pebbles by Thordarson and Albee. Two allied studies were carried on in coordination with the principal investigations—sedimentary petrology studies by R. A. Cadigan (1951–61) and clay studies by L. G. Schultz (1954–57).

The project has benefited from many consultations with geologists of the U.S. Geological Survey and U.S. Atomic Energy Commission, as well as the geologists associated with universities and with the mining and oil industries. The help of these geologists is gratefully acknowledged. Of particular benefit were discussions with J. W. Harshbarger, M. E. Cooley, and C. A. Repenning, all of the U.S. Geological Survey, who mapped and studied the stratigraphy of the Navajo Indian Reservation in Arizona. Thanks are also given to many field assistants.

CHARACTER OF PROVINCE

The Colorado Plateau (fig. 1) is a relatively elevated structural platform comprising an area of 150,000 square miles in Utah, Colorado, Arizona, and New Mexico. It is bounded on the south and west by the Basin and Range province fault-block mountains of New Mexico, Arizona, Utah, and Nevada, on the northwest and north by the Wasatch Range (pl. 1) and the Uinta Mountains respectively, both in the central part of the Rocky Mountain System, and on the east by the Southern Rocky Mountains province. The structure within the Colorado Plateau is relatively simple; the mantle of sedimentary rocks is flat lying or gently dipping in most areas. Monoclines, faulted monoclines, and normal faults fold and break the strata along generally north- or northwest-trending belts. Broad uplifts, including the Zuni, Defiance, Monument, Circle Cliffs, and Uncompahgre Plateau uplifts and the San Rafael Swell (pl. 1), have locally raised the strata; even larger basins, including the San Juan, Black Mesa, Uinta, and Piceance basins, have depressed the strata. Belts of northwest-trending salt structures, characterized by thickened masses of salt that have intruded and disrupted the overlying rocks, occur in east-central Utah and west-central Colorado. Laccolithic mountains of Cretaceous(?) and Tertiary age puncture the sedimentary layers in isolated areas; they include the Carrizo, Ute, La Plata, Rico, Abajo, Henry, and La Sal Mountains (pl. 1) groups. Volcanic rocks of Tertiary and Quaternary age occur locally within the Colorado Plateau and are abundant along its margins.

Most of the sedimentary strata that mantle the Colorado Plateau are in relatively thin formations of wide extent. The Plateau throughout much of Paleozoic and early Mesozoic time was a broad stable shelf (craton) lying to the east of the Cordilleran geosyncline of western Utah, Nevada, and California, and many of the formations thicken in the western part of the Plateau toward the geosynclinal area. Locally thickened masses of strata were deposited in intracratonic basins on the shelf in the Plateau region.

Because of the semiarid climate of much of the Plateau, rock exposures are excellent, and therefore ideal conditions exist for the study of stratigraphy.

HISTORY OF NOMENCLATURE AND PREVIOUS WORK

The earliest geologic exploration of the Colorado Plateau was by Jules Marcou in 1853. He traversed western New Mexico and northern Arizona and divided the strata into several broad units (Marcou, 1856, 1858), among which was his "Trias" corresponding approximately with units now called Moenkopi and Chinle Formations.

Newberry (1861), another geologist to do early work on the Colorado Plateau, gave the name "Red Sandstones" (also called saliferous sandstone, salt group, and various other names) to the strata in western New Mexico and nothern Arizona now included in the Moenkopi Formation and the basal part of the Chinle Formation.

During the 1860's, 1870's, and 1880's, the Colorado Plateau and adjacent regions were the site of four great geological surveys (the Wheeler, Hayden, King, and Powell surveys). Perhaps the most impressive stratigraphic work of these surveys was that of Powell (1876), who recognized four major groups of strata of "Jura and Trias" age, as he called them. The groups were in ascending order: Shinarump Group, Vermilion Cliff Group, White Cliff Group, and Flaming Gorge Group. His Shinarump Group included three parts, the lower of which he called "lower Shinarump" and which corresponds closely with what is called Moenkopi Formation in later work. Powell correlated these groups between the Uinta Mountains on the north and northwestern Arizona on the south, and the correctness of his major correlations has been confirmed by later work.

The Moenkopi Formation was named by Ward (1901, 1905) during his study of the valley of the Little Colorado River (pl. 1) in Arizona. His original spelling was "Moencopie," which has since been changed to Moenkopi. A brief outline follows of the development of the nomenclature of the Moenkopi and related formations, by regions.

SOUTHERN NEVADA, SOUTHWESTERN UTAH, AND NORTHWESTERN ARIZONA

The term Moencopie (=Moenkopi) was first extended into southwestern Utah by Huntington and Goldthwait (1904, p. 203–208). In northwestern Arizona, the term was first used by Shimer (1919), and in southern Nevada by Longwell (1921), Glock (1929), and Hewett (1931).

Six units were recognized by Reeside and Bassler (1922) in the Moenkopi Formation in southwestern Utah and northwestern Arizona. These units are, in ascending order: Rock Canyon Conglomeratic Member, lower red beds, Virgin Limestone Member, middle red beds, Shnabkaib Shale Member, and upper red beds. The Rock Canyon Conglomeratic Member was shown by Gregory (1950a) to be equivalent in part to strata underlying the Moenkopi Formation, and he proposed that the term be abandoned and that the term Timpoweap Member be used for part of the strata formerly included in the Rock Canyon Conglomeratic Member. Some other modifications in the terminology were proposed by Gregory (1950a), but these changes are minor. Gregory's nomenclature was used by McKee (1954), and it is used in this report (fig. 2, col. A).

NORTHEASTERN ARIZONA

The early description and recognition of the Moenkopi Formation in northeastern Arizona is largely the work of Ward (1901, 1905), who named the formation, and of Gregory (1914, 1916, 1917), who extended the use of the name to places outside the type locality.

The formation was originally subdivided into members in northeastern Arizona by Hager (1922, p. 73), and the name of his uppermost member, the "Holbrook sandstone" (now called Holbrook Member) is still used. Three members were recognized by Welles (1947), the lower and middle members of which were later named the Wupatki and Moqui Members, respectively (McKee, 1954, p. 19). The name Holbrook Member was adopted for the highest of the three members by McKee, who derived the name from Hager (1922). The nomenclature proposed by McKee was used by Akers, Cooley, and Repenning (1958) and Repenning, Cooley, and Akers (1969) and is used in this report (fig. 2, col. B).

WEST-CENTRAL AND CENTRAL NEW MEXICO

The earliest use of the name Moenkopi in New Mexico was by Darton (1910, 1922, 1928), but, as was first recognized by Bates and others (1942, p. 44–45, pl. 2), most of what Darton classified as Monekopi Formation is actually part of the stratigraphically higher Chinle Formation. A thin representative of the Moenkopi Formation, only a small part of Darton's original Moenkopi, probably does extend, however, into New Mexico (Bates and others, 1942; McKee, 1954; Cooley, 1957). This thin probable correlative of the Monekopi is referred to here as the Moenkopi(?) Formation (fig. 2, col. C).

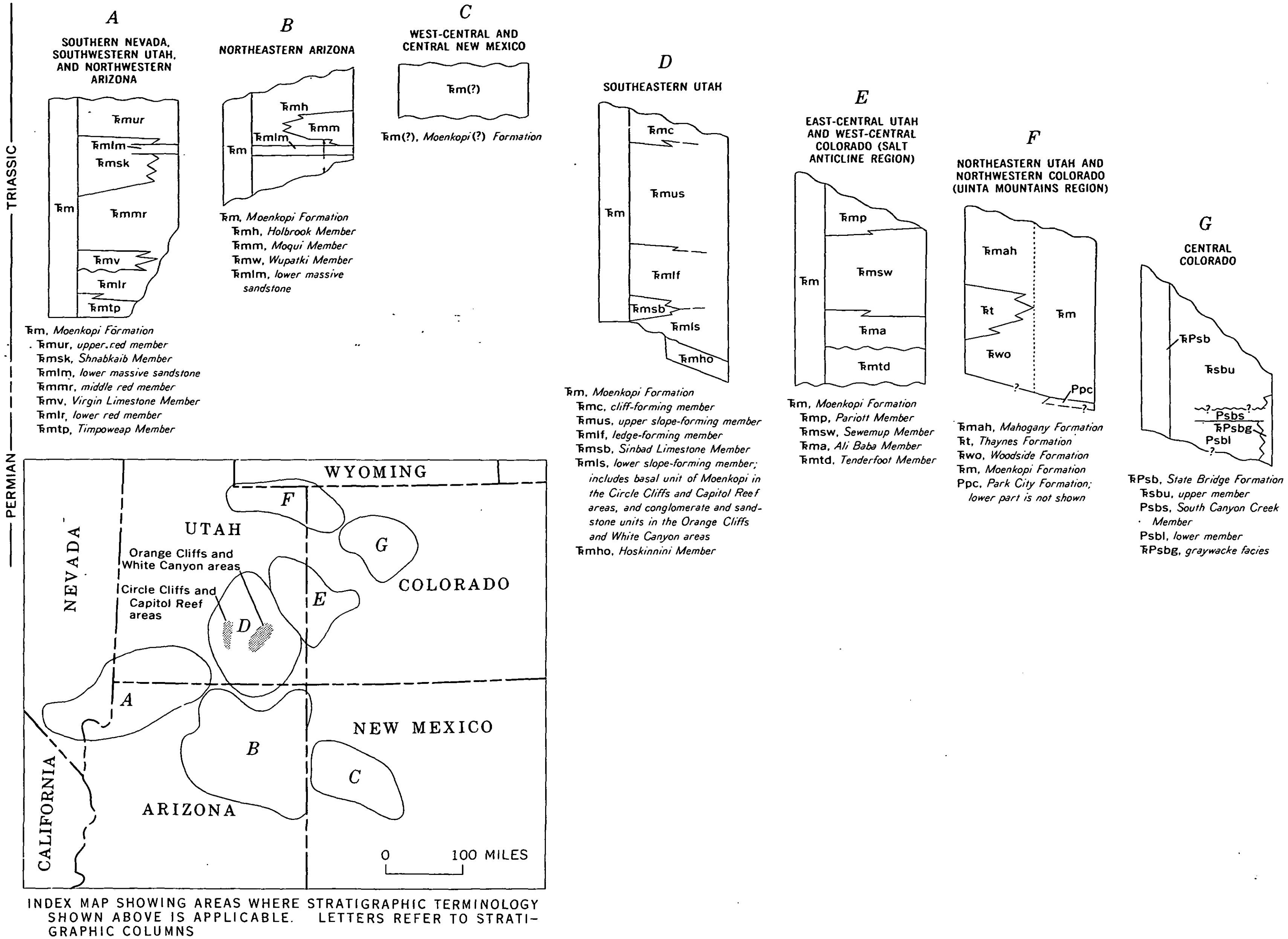

FIGURE 2.—Nomenclature of Moenkopi Formation and related strata in Colorado Plateaus province.

SOUTHEASTERN UTAH

The name Moenkopi Formation was first used in southeastern Utah by Woodruff (1912) and Gregory (1916, 1917), but the Moenkopi as now recognized lies entirely above what they considered Moenkopi. The work of Woodruff and Gregory was near the Arizona-Utah State line. In the western part of southeastern Utah, on the other hand, Emery (1918) and Moore (1922) applied the name Moenkopi to the same strata as that of this report. The miscorrelations of Woodruff and Gregory were perpetuated in part by Longwell, Miser, Moore, Bryan, and Paige (1923). As they recognized it, the Moenkopi Formation included what is now considered to be the Moenkopi as well as the underlying strata originally correlated with the Moenkopi by Woodruff and Gregory. Baker and Reeside (1929) corrected the miscorrelations of earlier workers, and the Moenkopi Formation as recognized by them is nearly the same as that recognized in this report. The only change from the usage of Baker and Reeside (1929) is that a unit they named the Hoskinnini Tongue of the Cutler Formation is now considered the basal member of the Moenkopi Formation (Stewart, 1959).

Other than the Sinbad Limestone Member, which was named by Gilluly and Reeside (1928), and the Hoskinnini Member, the members of the Moenkopi Formation recognized in southeastern Utah are given informal names (fig. 2, col. D).

EAST-CENTRAL UTAH AND WEST-CENTRAL COLORADO (SALT ANTICLINE REGION)

The name Moenkopi Formation was first applied to this region by Prommel (1923), although he did not separate the Moenkopi Formation from the underlying Cutler Formation. The contacts of the Moenkopi Formation in east-central Utah, as recognized by us, were first mapped by Baker, Dobbin, McKnight, and Reeside (1927), Baker (1933), Dane (1935), and McKnight (1940). In westernmost Colorado, the formation was first defined in detail by Cater (1955a, d) and by Shoemaker (1955, 1956).

The Moenkopi Formation was divided into members in this region by Shoemaker and Newman (1959), partly on the basis of earlier work by Cater (1955a, d) and Shoemaker (1955, 1956). These members were given the names, from bottom to top, of Tenderfoot, Ali Baba, Sewemup, and Pariott, and this nomenclature is used in this report (fig. 2, col. E).

NORTHEASTERN UTAH AND NORTHWESTERN COLORADO (UINTA MOUNTAINS REGION)

The names Woodside Shale (or Formation), Thaynes Formation (or Limestone), and Ankareh Shale (or Formation) have been commonly applied in the western part of the Uinta Mountains to strata laterally equivalent to the Moenkopi Formation (Mathews, 1931; Williams, 1945; Thomas and Krueger, 1946; Huddle and McCann, 1947a, b; Huddle and others, 1951). These terms were defined by Boutwell (1907), and later (1912) modified by him, as a part of his study of the Park City mining district in the Wasatch Mountains.

The names Woodside and Thaynes Formations are accepted for use in the western part of the Uinta Mountains (fig. 2, col. F), but the name Ankareh Formation is not. In the Wasatch Mountains, the Ankareh Formation includes not only the equivalents of the upper part of the Moenkopi Formation but also equivalents of the overlying Chinle Formation. In the Uinta Mountains, the name Ankareh generally has been applied only to lateral equivalents of the upper part of the Monekopi Formation; the Chinle Formation is considered to be a separate formation. Therefore, the name Mahogany Member, which was originally proposed by Kummel (1954) for the pre-Chinle part of the Ankareh Formation, is upgraded to formational rank in the Uinta Mountains in this report (see p. 42). The designation of the Mahogany as a member of the Ankareh continues in use in the Park City area and the Wasatch Mountains.

In the eastern part of the Uinta Mountains region, several different names have been applied to the Lower Triassic strata. The name Red Wash Formation was proposed by Williams (1945), and the term Woodside Shale was used by Thomas and Krueger (1946). Nonetheless, the name Moenkopi has been the most commonly used (Bartram, 1930; Thomas and others, 1945; Untermann and Untermann, 1949, 1950, 1954; Kinney, 1951, 1955; Kummel, 1954; Hansen, 1955, 1965), and is used in this report (fig. 2, col. F).

CENTRAL COLORADO

Various formal and informal terms were used by early workers in central Colorado to describe the strata that are herein called the State Bridge Formation, a unit equivalent, at least in part, to the Moenkopi Formation. Coffin, Perini, and Collins (1920, p. 40–44, pl. 3) included them in "Red Beds" of Triassic(?) age; Lee (1912) in the Maroon Conglomerate; Campbell (1922; p. 124–130, sheets 4 and 5) in sandstone considered to be Triassic in age; and Heaton (1933) in places in "unnamed red beds" of Triassic age and in other places in the Triassic part of the Wyoming Formation. The name State Bridge was informally introduced in 1936 in a Sc.D. thesis by H. F. Donner as the State Bridge Siltstone Member, an upper member of the Maroon Formation. In 1942, Brill proposed that the

State Bridge be considered a formation, and this practice was followed by him in subsequent work (Brill, 1944, 1952), by Sheridan (1950), and by us in this report (fig. 2, col. G).

The State Bridge Formation is divided into three members in central Colorado, but only the middle one (South Canyon Creek Member) is given a formal name. This member was originally defined as the South Canyon Creek Dolomite Member of the Maroon Formation (Bass and Northrop, 1950) and subsequently the "dolomite" was dropped from the official name by Hallgarth (1959), although he still considered it a member of the Maroon Formation. We apply the term State Bridge Formation to these three members, rather than include them in the upper part of the Maroon Formation. Thus, the South Canyon Creek Member along with lower and upper red-bed units are considered here as members of the State Bridge Formation.

STRATIGRAPHY OF MOENKOPI AND RELATED FORMATIONS

The Moenkopi Formation, including its lateral equivalents, is composed dominantly of fine-grained strata deposited in continental and marine environments and, in coastal areas, in mixed environments. Coarse fluvial sandstone units occur locally along the east edge of the formation. This east margin is mainly a limit of deposition, and the coarse units are derived from source areas near the site of deposition. Along the western part of the Colorado Plateau, marine limestone, dolomite, and siltstone predominate. Between the continental deposits on the east and marine strata on the west, the formation contains abundant ripple-laminated siltstone that probably was deposited on delta flood plains and perhaps in part on tidal flats or in a shallow sea. The marine strata in the Moenkopi and related formations were formed during repeated transgressions and regressions of the sea.

The Moenkopi Formation is underlain by rocks of Permian age throughout most of the Colorado Plateau (pl. 2). In northwestern and central Colorado, however, the State Bridge Formation, the upper part of which is a lateral equivalent of the Moenkopi Formation, rests on rocks of Pennsylvanian and Permian age, and locally on rocks of Precambrian age.

In much of the Colorado Plateau, the lower contact of the Moenkopi Formation is an unconformity representing part of Late Permian and part of Early Triassic time. Although the bedding in the rocks above and below the contact is parallel in most places, conglomerate lenses and small scours occur at many places along the contact. Locally in the salt anticline region, a conspicuous angular unconformity occurs at the base of the formation.

In the western and central parts of the Uinta Mountains in northeastern Utah, however, the Moenkopi Formation and equivalent strata may be conformable with underlying strata. Here the basal part of the Woodside and Moenkopi Formations may include rocks of Permian age and may be conformable with the underlying Park City Formation of Permian age. In the eastern Uinta Mountains it is difficult, owing to facies change (Schell and Yochelson, 1966), to distinguish between the Permian Park City Formation and the Triassic Moenkopi Formation. The Park City Formation, as redefined by Schell and Yochelson (1966), includes tawny-colored strata that were previously included in the overlying Moenkopi Formation. According to Schell and Yochelson (1966), their redefined contact between the Park City and Moenkopi Formations appears to be conformable.

The Moenkopi Formation is overlain by the Chinle Formation of Late Triassic age everywhere except at the extreme south limit of the Colorado Plateau in east-central Arizona, where the Dakota Sandstone of Cretaceous age rests on the formation. Everywhere this Moenkopi-Chinle contact appears to be unconformable. In most areas of the Colorado Plateau, a basal sandstone in the Chinle Formation fills small scours or deep channels cut into the Moenkopi Formation. Some of these channels are more than 100 feet deep and several hundred feet wide. In the Monument Valley area, broad shallow valleys or swales, 1–3 miles wide and about 40 feet deep, are cut into the Moenkopi Formation and are filled with strata of the Chinle Formation (Witkind, 1956). In spite of the abundant evidence of erosion along this contact, the strata above and below it are almost everywhere parallel. Locally in the salt anticline region an angular unconformity occurs at the top of the Moenkopi Formation. In several parts of the Plateau a thin zone of mottled purple, red, and gray siltstone occurs in the top few feet of the Moenkopi Formation or in the basal few feet of the overlying Chinle Formation; these "mottled strata" probably represent a fossil soil zone formed during the time of nondeposition between the Moenkopi Formation and the Chinle Formation. These mottled strata are discussed more fully by Stewart, Poole, and Wilson (1972), Schultz (1963, p. C43–C53), and Robeck (1956). In the San Rafael Swell, Robeck included most of these mottled strata in the Temple Mountain Member of the Chinle Formation.

The Moenkopi Formation contains many distinctive members and subdivisions (fig. 2). Most of them extend over a relatively small part of the Colorado Plateau, and in many places they grade laterally into sequences of strata than cannot readily be differentiated into members (pl. 3). Consequently, members recognized in one part of the Colorado Plateau generally do not correlate directly with members recognized in other parts.

The Moenkopi Formation, including laterally equivalent strata in northwestern Utah, extends throughout all of the western two-thirds of the Colorado Plateau (pl. 4). It thickens gradually to the west and northwest across the Plateau; near the west boundary of the Plateau it thickens abruptly into a trough that lay in western Utah and Arizona and eastern Nevada.

SOUTHERN NEVADA, SOUTHWESTERN UTAH, AND NORTHWESTERN ARIZONA

The Moenkopi Formation is extensively exposed in outcrops of Triassic strata in southern Nevada, southwestern Utah, and northwestern Arizona (pl. 1). The widest outcrops in this region form a belt extending from Cedar City, Utah, southward and eastward to Lees Ferry, Ariz. (loc. A83). In southern Nevada, although the formation is well represented, it has been studied by us only in outcrops in the Horse Spring valley area (loc. N1). Other outcrops of the formation in southern Nevada are only briefly mentioned here. The discussion presented is in part a review of the work of other geologists in the region (particularly Reeside and Bassler, 1922; Gregory, 1948, 1950a; McKee, 1954; Poborski, 1954) and in part new information.

Throughout most of the region, the Moenkopi Formation is composed of six members which are, in ascending order, the Timpoweap, lower red, Virgin Limestone, middle red, Shnabkaib, and upper red. The Timpoweap, Virgin Limestone, and Shnabkaib Members are distinctive units that are separated and overlain by the red-bed sequences of the lower, middle, and upper red members, respectively.

The Moenkopi Formation extends throughout the region, and it ranges in thickness from about 500 feet in the easternmost part (pl. 4) to reported thicknesses of about 1,200 to 2,100 feet in the west half of the region. The variation in reported thicknesses in the west half of the region probably results in part from structural complications that make accurate measurements difficult.

Throughout the region the Moenkopi Formation rests on the Kaibab Limestone (pl. 2). In southern Nevada (not shown on pl. 2) the Moenkopi locally rests on what has been called the Supai Formation in the Spring Mountains (Glock, 1929) and on red beds of Permian age in the southern part of Lincoln County (C. M. Tschanz, written commun., 1959). The contact between the Kaibab Limestone and Moenkopi Formation, although obscure in many places, nonetheless marks a major time break; the Kaibab Limestone in the region is dated (McKee, 1938a, p. 171) as Leonard in age (the second of four provincial series in the Permian), whereas the overlying Timpoweap Member of the Moenkopi Formation contains a *Meekoceras* fauna which is the middle fauna of the Early Triassic.

The top contact of the Moenkopi Formation is a well-defined erosional unconformity in southern Nevada, southwestern Utah, and northwestern Arizona. A channel 400 feet wide and 30 feet deep, cut into the Moenkopi and filled with sediment of the Shinarump Member of the Chinle Formation, 2 miles west of Paria, Utah, was noted by Gregory (1950a, p. 63). Similar channels occur elsewhere in the region.

TIMPOWEAP MEMBER

The Timpoweap Member was named and defined by Gregory (1950a, p. 54) for an exposure in Timpoweap Canyon near the Hurricane Cliffs, Washington County, Utah. Gregory used the term to describe a lithologically variable unit composed of red siltstone, gray limestone, and chert pebble conglomerate lying above known Permian rocks and below the red siltstone of the lower red member. The Timpoweap Member is composed of strata formed during and after the first transgression of the sea eastward during deposition of the Moenkopi Formation.

The Timpoweap Member extends throughout much of southwestern Utah (pl. 4), and probably extends a short distance into Arizona near the Utah-Arizona State line. It is most conspicuous along the Hurricane Cliffs from Cedar City southward to near the State line, and it crops out on the west side of the Kaibab Plateau and at Kaibab Gulch on the east (Gregory, 1948). The cephalopod *Meekoceras*, a fossil characteristic of the Timpoweap Member, occurs in the member along the Hurricane Cliffs (Gregory, 1950a, p. 55; 1950b, p. 35) and at Kaibab Gulch (Gregory, 1948).

The Timpoweap Member may also be present elsewhere in southwestern Utah and in Arizona and Nevada. In our St. George sections A and B (loc. U47, stratigraphic sections) for example, some limestone occurs in the lower red(?) member of the Moenkopi Formation, and this limestone may be laterally continuous with the Timpoweap Member. Similarly the lower 136 feet of strata assigned to the Moenkopi Formation at Horse Spring valley (loc. N1) may also be equivalent to the Timpoweap Member.

The Timpoweap Member extends northward from southwestern Utah, and correlative strata containing a *Meekoceras* fauna crop out near Minersville (McKee, 1938a, p. 214) and Marysvale, Utah (Kerr and others, 1957). The Sinbad Limestone Member of the Moenkopi

Formation of southeastern Utah also contains a *Meekoceras* fauna, and is considered to be the lateral continuation of the Timpoweap Member (pl. 3).

The Timpoweap Member is composed of a laterally variable sequence of gray limestone, yellowish siltstone and sandstone, and gray chert pebble conglomerate and breccia. At the Kanarraville stratigraphic section (loc. U22), the basal 169 feet of the unit is composed of conglomerate and limestone. The conglomerate is composed of granules, pebbles, and cobbles of chert as large as 9 inches in maximum diameter. A few quartz pebbles are present. This basal part of the Timpoweap Member contains all gradations from conglomerate composed of granules, pebbles, and cobbles of chert in a limestone matrix to a limestone free of gravel. Overlying the basal part of the member is a 281-foot-thick unit of yellowish-gray, horizontally laminated siltstone containing minor amounts of light-gray and yellowish-gray limestone. The Timpoweap Member at this section is exceptionally thick, but otherwise it is typical of the member.

The thickness of the Timpoweap Member is greatest near Kanarraville (table 2; pl. 4; loc. U22), where it is 450 feet; it is 385 and 206+ feet in nearby areas (Gregory and Williams, 1947), and it is 77 feet at Kaibab Gulch (Gregory, 1948).

The lower contact of the Timpoweap Member at the Kanarraville section, (loc. U22) is placed at the change from cherty limestone of the Kaibab Limestone (the beta member of the Kaibab Limestone as used by McKee, 1938a) to the chert pebble conglomerate of the Timpoweap. At this section, the contact is distinct and marks an abrupt change in lithology. The Timpoweap-Kaibab contact is not everywhere this distinct, and in many areas it is difficult to locate. Some of the conglomerate near the Moenkopi-Kaibab contact, as noted by Gregory (1950a, p. 54) and McKee (1954, p. 13), is actually Permian in age and assigned to the Kaibab Limestone. In much of the area near Zion National Park, Gregory (1950a, p. 56) was unable to place the Permian-Triassic contact with assurance.

The upper contact of the member is placed at or a short distance above—in most places 2–30 feet above—the top of the highest limestone of the Timpoweap. The contact is a plane that separates yellow siltstone below from red siltstone above. The contact is considered conformable and transitional (Gregory, 1950a, p. 61).

TABLE 2.—*Representative thicknesses, in feet, of the Moenkopi Formation and its members in southern Nevada, southwestern Utah, and northwestern Arizona*

[A, member absent; NE, member not exposed; leaders (----), member not recognized]

Locality	Loc. No. (pl. 1, table 1)	Members of Moenkopi Formation						Moenkopi Formation, total thickness
		Timpoweap	Lower red	Virgin Limestone	Middle red	Shnabkaib	Upper red	
NEVADA — Clark County								
Horse Spring valley	N1	A(?)	536	A	----------	393	887	1, 816
UTAH — Washington County								
Beaver Dam Mountains	U57	0–15(?)	280	170	425	715	510	2, 115
St. George	47a	A(?)	230	134	333	727	404	1, 828
Harrisburg Dome	58	A	335	160	435	630	475	2, 035
Little Creek Mountain	56	13+	220	8	520	377	409	1, 547+
Belted Cliffs	55	138	278	116	436	262	546	1, 776
Deadman Hollow	52	385	196	126	275	293	147	1, 422
Taylor Creek	53	206+	377	119	102	275	355	1, 434+
Iron County								
Kanarraville	U22	450±	305	115	336	416	249	1, 871±
Coal Creek Canyon	54	NE	NE	190	125	310–320	255–300	890+–925+
ARIZONA — Coconino County								
Vermilion Cliffs	A86	A	NE	NE	NE	111+	86	197+
	85	A	36+	<1(?)	150	113	165	465+
Soap Creek	23	A	----------	A	----------	A	----------	559
Vermilion Cliffs	84	A	----------	A	----------	A	----------	561
Lees Ferry	83	A	----------	A	----------	A	----------	480

LOWER RED MEMBER

The lower red member is a red-bed unit lying between the Timpoweap Member—or, where it is absent, the Kaibab Limestone—and the Virgin Limestone Member (pl. 3). This member can be distinguished from the middle red member only in areas where the intervening Virgin Limestone Member is present. Beyond the limit of the Virgin Limestone Member, near Lee Ferry (loc. A83), the lower and middle red members form a coalescent sequence of red beds. Also, in the Horse Spring valley section (loc. N1), the Virgin Limestone Member was not recognized, and there the lower and middle red members likewise are inseparable.

The lower red member consists mostly of grayish-red and light-brown horizontally laminated or, in some parts, structureless siltstone, that commonly contains very fine grained white mica. The member generally forms a slope between the cliff-forming Timpoweap Member below and the Virgin Limestone Member above. Gypsum is a common constituent of the lower red member. It occurs as horizontal laminae and thin beds, interstratified with siltstone, and also as veinlets cutting across stratification. In most sections studied gypsum constitutes 5–10 percent of the member.

Along a northwest-trending belt of outcrops 5 miles southwest of St. George, a variable sequence made up of red beds, gypsum, and sparse conglomerate and limestone is assigned tentatively to the lower red member. The lateral differences in lithology are conspicuous in these outcrops. In places, this lower red(?) member is dominantly red siltstone, but laterally within a few thousand feet it is entirely gypsum. Some or all of the strata in this sequence, may actually belong to the alpha member of the Kaibab Limestone (McKee, 1938a) in the St. George area (called Harrisburg Gypsiferous Member by Reeside and Bassler, 1922). The Harrisburg is lithologically similar, at least in places, to the lower red member and occurs at the top of the Kaibab Limestone directly below the Moenkopi Formation. Poborski (1954, p. 974, 977), in his study of the outcrops southwest of St. George, indicated that the Virgin Limestone Member rests directly on the Kaibab Limestone in some parts of the area and on the lower red member in other parts. Apparently he assigned the red siltstone to his Moenkopi "group" and referred the gypsum sequence to the alpha member of the Kaibab Limestone. More likely, however, the gypsum and siltstone are lateral variants of the same unit, and both lithologic types are tentatively assigned to the lower red member.

The thickness of the lower red member ranges from less than 135 feet (St. George stratigraphic section B, loc. U47) to 377 feet (loc. U53). The measured thicknesses vary widely from place to place and do not appear to show any systematic thinning. The differences in thickness probably result from one or all of the following factors (1) intertonguing of the lower red member and Timpoweap Member, (2) erosion of part of the lower red member at the reported unconformity at the top of the member, and (3) human differences in measurements and in selecting contacts.

The lower red member is recognized as a red-bed unit lying between units containing conspicuous amounts of limestone. The lower contact is placed at or slightly above the limestone of the Timpoweap Member; in general, it is 2–30 feet above the top of the highest limestone, at a change from yellowish-gray siltstone below to red siltstone above. The top contact is sharp and, near Kanab, was considered an unconformity by Walcott (1880, p. 222). Similar conclusions were reached in the Zion National Monument area by Gregory and Williams (1947, p. 231); in Zion National Park by Gregory (1950a, p. 61–62); in eastern Iron County by Gregory (1950b, p. 31); and in the St. George area by Poborski (1954, p. 974). Relief on the unconformity amounting to 10–15 feet in areas of less than an acre is described by Gregory (1950b, p. 61–62). A southward and westward beveling of the lower red member near Kanab that decreased the thickness of the lower red member by 100 feet in a distance of 3 miles is also described by Gregory (1950b).

VIRGIN LIMESTONE MEMBER

The Virgin Limestone Member was named by Reeside and Bassler (1922, p. 60) after Virgin City west of Zion National Park. A detailed study of this member in the St. George area was made by Poborski (1954, p. 974), who proposed that the member be upgraded to formational rank because it forms an easily mappable lithologic unit. He also suggested that the Moenkopi Formation in that area be raised to group rank. In order to maintain a consistent use of the term "Moenkopi Formation" throughout this report, Poborski's proposals are not adopted.

The Virgin Limestone Member is present throughout the St. George, Hurricane Cliffs, and Kanab areas (pl. 4). In addition, it was identified by Gregory (1948, p. 226–227) on the west side of the Kaibab Plateau and in House Rock Valley. McKee (1954, fig. 5, p. 113) tentatively correlated a 6-inch-thick bed of limestone at a section 13 miles west of Navajo Bridge with the Virgin Limestone Member. We did not recognize the member at Horse Spring valley, Nev. (loc. N1), although McKee (1954, p. 30) recognized it farther west in Nevada.

The Virgin Limestone Member is composed of an alternation of limestone and siltstone. The limestone is light gray to light olive gray, aphanitic to very finely crystalline, and horizontally laminated to thick bedded. Limestone makes up 34 percent of the member at the Kanarraville section (loc. U22), about 40 percent at the type section (Poborski, 1954, p. 974), and 20 percent in the St. George area (Poborski, 1954, p. 975). At St. George section A (loc. U47a, unit 12) the highest limestone contains contorted bedding, interpreted as penecontemporaneous slumping, and the second highest limestone (unit 10) contains a few parallel and cuspate ripple laminations. Poborski (1954, p. 976) reported that cross-stratification and mud cracks are common in limestone. He described one unit that is composed of broken stems and plates of crinoids, another unit that contains oolitic limestone, and a few units that contain chert. The limestone beds range in thickness from several inches to at least 20 feet. They weather to form ledges which are separated by slopes composed of siltstone. The siltstone is brownish gray, greenish gray, and light olive gray, and contains common very fine grained white mica. It is structureless in some places, horizontally thinly laminated to laminated in other place, and ripple-laminated in a very few places.

Marine fossils occur in both the limestone and siltstone units. These fossils consist of crinoids, pelecypods, gastropods, worms, crustaceans, and cephalopods (Poborski, 1954, p. 991–993). The ammonite *Tirolites* is reported by Poborski (1954, p. 992–993) from the member and represents the fourth highest of five ammonite zones in the Lower Triassic of Smith (1932).

The Virgin Limestone Member is thickest in the St. George area (pl. 4), where we measured a thickness of 134 feet (loc. U47a) and where Poborski (1954, p. 975) measured a thickness of 213 feet. The member thins irregularly southeastward and eastward to a limit somewhere on the south side of the Paria Plateau.

The lower contact of the Virgin Limestone Member is placed at the base of the lowest limestone in the sequence. The contact is sharp and is considered to be an unconformity by many geologists. (See discussion of lower red member, p. 18.)

The upper contact in most sections is placed at the top of the highest limestone. It is placed by Poborksi (1954, p. 974) at the top of the highest silty chert or limy siltstone layer, which occurs about 1–40 feet above the top of the highest limestone. The contact is conformable and intertonguing with overlying strata. Between St. George and Hurricane, the top 140 feet of the Virgin Limestone Member grades laterally into the lower part of the middle red member (Poborski, 1954, p. 976).

MIDDLE RED MEMBER

The middle red member fills the interval between the Virgin Limestone Member below and the Shnabkaib Member above (pl. 3), and as such is recognized only in areas where both these members occur. Beyond the limit of the Virgin Limestone Member, both to the east and south, the lower red and middle red members form an inseparable sequence of red beds.

The middle red member, like the lower red member, is composed of pale-reddish-brown, grayish-red, and moderate-brown, horizontally laminated or structureless siltstone. Gypsum, in layers ranging from thin laminae to thick beds, forms about 10–20 percent of the member. All gradations from limestone to gypsiferous siltstone are present.

The thickness of the middle red member ranges from 102 feet at Taylor Creek near locality U53 (Gregory and Williams, 1947, p. 234) to 520 feet at the Little Creek Mountains (Gregory, 1950a, p. 113–115). In general, the member is thickest, 300–500 feet, in the St. George area and the area east of Hurricane, and it thins northward to 100–150 feet near the Iron-Washington County line.

Both the upper and lower contacts of the member are conformable and intertonguing. Intertonguing at the base is described in the discussion of the Virgin Limestone Member. The upper contact, which is also gradational, is generally placed at a horizon where the strata change from dominantly siltstone below to dominantly gypsum and siltstone above. Both the middle red member and the overlying Shnabkaib Member, however, contain gypsum, and in many places it is difficult to distinguish between the two. From a distance, the middle red member appears red, in contrast to the Shnabkaib, which is a banded white and red unit. This color difference in many places is the best criterion on which to differentiate the two members. In many places, the middle red member grades upward into the Shnabkaib through a 100- to 300-foot-thick transitional interval. The position of the contact selected between the middle red and Shnabkaib, therefore, probably is considerably different from place to place.

SHNABKAIB MEMBER

The Shnabkaib Member was named by Reeside and Bassler (1922, p. 60) for an isolated mesa which lies about 5 miles east of St. George, Utah. The member is a thick sequence of red siltstone, white gypsum, and, in the western outcrops, gray limestone and dolomite. It forms a wedge of sedimentary rock, thickest on the west and northwest, and extends from southern Nevada to south of Lees Ferry, Ariz. (pl. 4). In the outcrops south of Lees Ferry, the member loses its identity and apparently grades to the east or southeast into red beds of the undifferentiated Moenkopi Formation.

In the vicinity of St. George, the type locality of the Shnabkaib, the member is composed of about 65 percent siltstone, 25 percent gypsum, and 10 percent limestone and dolomite. These three lithologic types are interstratified in thin to thick layers. The siltstone is greenish gray in the middle two-thirds of the unit and is moderate brown, grayish red, and locally greenish gray in the remaining parts of the unit. The siltstone contains very fine grained accessory white and dark-green mica, and is horizontally laminated where the stratification can be examined in detail. The gypsum is white and greenish gray, aphanitic to coarsely crystalline, and occurs as layers ranging from laminae to very thick beds or sets, interstratified with siltstone and dolomite or limestone. The thicker sets of gypsum are greenish gray, apparently because of admixtures of green siltstone, and are horizontally laminated. All gradations from pure gypsum to gypsiferous siltstone are present. The limestone and dolomite are white, light gray, and yellowish gray, aphanitic in some parts and oolitic in other parts, and horizontally laminated to very thin bedded. The limestone and dolomite occur as very thin to thick horizontal sets interstratified with gypsum and siltstone.

The Shnabkaib changes facies gradually both to the east and west of the St. George area. To the east the content of gypsum, limestone, and dolomite decreases and that of red siltstone increases. In this direction the Shnabkaib looks progressively more like the middle red member, and the contact between the two becomes progressively more difficult to recognize. At St. George (loc. U47), limestone and dolomite constitute about 10 percent of the member. Limestone makes up a large part of the Little Creek Mountain section of Gregory (1950a, p. 113–115), which lies along the Hurricane Cliffs 4 miles north of the Utah-Arizona State line. Some limestone shows also in Gregory's (1950a, p. 115–116) section on the Belted Cliffs near Virgin City, but limestone and dolomite are absent at our Kanarraville (loc. U22) and Shinarump Cliffs (loc. A11) sections. Probably limestone and dolomite do not extend more than 25 miles east or more than 20 miles northeast of the St. George area.

Gypsum decreases in quantity eastward from St. George, but the amount of decrease is difficult to estimate. The amount of greenish-gray siltstone also decreases to the east and northeast, whereas the amount of reddish-brown siltstone increases. At St. George about 70 percent of the Shnabkaib is greenish gray, whereas at Kanarraville about 40 percent is greenish gray

To the southwest of St. George, the amount of limestone and dolomite in the Shnabkaib Member increases, probably by lateral change from siltstone and gypsum. At Horse Spring valley (loc. N1) about 20 percent of the Shnabkaib Member is limestone or dolomite, whereas at St. George only about 10 percent is limestone or dolomite. Otherwise, the Shnabkaib Member in these two areas is lithologically similar. The amount of limestone and dolomite in the member apparently continues to increase west from Horse Spring valley, for the middle member of the Moenkopi Formation as used by Hewett (1931) in the Spring Mountains (about 75 miles west of Horse Spring valley at loc. N7) may correlate with the Shnabkaib Member. This middle member is composed dominantly (60–70 percent) of limestone.

On the south side of the Paria Plateau, a ledge-forming gypsiferous sandstone unit occurs near the top of the Shnabkaib Member. This unit is referred to informally as the lower massive sandstone, a term introduced by McKee (1954, p. 19). This sandstone extends beyond the limit of the Shnabkaib Member to the east and crops out throughout much of the valley of the Little Colorado River (McKee, 1954, p. 19–20), where it occurs in the Wupatki Member of the Moenkopi Formation; there it is a light-brown very fine grained sandstone. The lower massive sandstone has been correlated by McKee (1954, fig. 5) as far west as Kanab, Utah, but this correlation is considered by us to be uncertain because of a large gap in outcrop across the Kaibab Plateau and because the rock contains no recognizable diagnostic features.

On the south side of the Paria Plateau, the lower massive sandstone is yellowish gray or light greenish gray and contains abundant gypsum both as discrete grains and as interstitial cement. At a locality 13 miles west of Navajo Bridge, McKee (1954, p. 51, 113) reported the entire lower massive sandstone to be a gypsum unit which is cross-stratified on a large scale.

The Shnabkaib Member is more than 700 feet thick at St. George (loc. U47a) and at the Beaver Dam Mountains (loc. U57, pl. 4); it decreases in thickness eastward and northeastward from these localities.

The lower contact of the Shnabkaib Member is gradational and intertonguing. (See description of middle red member, p. 19.) The upper contact is placed at the change from gypsiferous strata below to red siltstone and sandstone above. In our Kanarraville (loc. U22), St. George (loc. U47a), and Horse Spring valley (loc. N1) sections, the top contact of the Shnabkaib Member is placed at the base of ledge-forming, ripple-laminated, and, in places, cross-stratified, reddish-brown sandstone and sandy siltstone that are characteristic of the upper red member. The contact also corresponds approximately with the highest gypsiferous strata in the Shnabkaib Member. In the area from Kanab to Lees Ferry, the top contact of the Shnabkaib is placed at the change from light-greenish-gray gypsiferous strata below to reddish-brown nongypsiferous strata above. The top 20–80 feet of the Shnabkaib in this area generally contains ripple-laminated and cross-stratified sandstone and sandy siltstone that are lithologically similar to the beds of the upper red member, but that differ in color and gypsum content.

To the east, the Shnabkaib grades laterally into reddish-brown siltstone (pl. 3), as can be seen in outcrops between House Rock Valley and Echo Cliffs. At House Rock Valley, the Shnabkaib Member is composed of light-greenish-gray siltstone and lenses and concretions of gypsum, and forms a conspicuous greenish unit on the outcrop. Eastward from House Rock Valley the Shnabkaib grades gradually from typical green beds to red beds that are typical of the Moenkopi along Echo Cliffs. About 10 miles west of Lees Ferry, the lateral gradation is complete except for the lower massive sandstone which extends across this area of facies change and southeastward for almost 200 miles.

UPPER RED MEMBER

The upper red member, like the lower and middle red members, is a red-bed unit, but unlike those members it contains more ripple-laminated siltstone and a few beds of cross-stratified sandstone. The member is distinguished only where the underlying Shnabkaib Member is present, and therefore its area of distribution is identical with that of the Shnabkaib Member.

The upper red member is composed of three main lithologic types, which are interstratified in very thin to thick layers:

(1) Structureless to horizontally laminated siltstone, which weathers to form slopes, forms about half to three-quarters of the member. It is grayish red with some light brown or moderate brown parts and contains some very fine grained accessory white mica. In some places the siltstone apparently is structureless, but in other places it is horizontally stratified.

(2) Ripple-laminated siltstone, which occurs in thin to thick sets that generally weather to form small ledges, comprises 10–40 percent of the member. Its colors are the same as the structureless to horizontally laminated siltstone, but it contains more mica and is coarser. Ripple marks are of both parallel and cuspate types but are predominantly of the parallel type.

(3) Horizontally laminated or cross-stratified sandstone or sandy siltstone comprises about 10 percent or less of the member and generally weathers to form ledges. This rock is light brown or yellowish brown and the sand fraction is very fine. In some places it is horizontally laminated, and in other places it is composed of thin to thick wedge planar sets or small- to medium-scale low-angle cross-laminae and cusp ripple-laminae.

Gypsum and limestone-siltstone pebble conglomerate are present locally in the member. Gypsum constitutes about 3 percent at Horse Spring valley (loc. N1). It occurs as horizontal laminae and as very thin beds interstratified with the siltstone. In the Spring Mountains (loc. N7), Valley of Fire (loc. N5), and Horse Spring valley (loc. N1) areas, thin to thick layers of limestone-siltstone pebble conglomerate, interstratified with red siltstone, are present near the top of the member. This conglomerate is light gray, greenish gray, or grayish yellow green, and is composed of medium-sand- to pebble-sized fragments of limestone and, to a lesser extent, siltstone in a lime matrix.

A thin unit of variable lithology occurs at the top of the upper red member in the Spring Mountains, Valley of Fire, and Horse Spring valley areas in southern Nevada. This unit lies above the limestone-siltstone pebble conglomerate described above. It is, in many respects, more similar lithologically to the Chinle Formation than to the Moenkopi Formation, but arbitrarily it is included with the Moenkopi Formation in this report. It underlies the Shinarump Member of the Chinle Formation at the localities in southern Nevada studied by us. This unit, which is poorly exposed in many places, has not been described previously by other geologists and has apparently been included by them in the Moenkopi Formation.

The thin unit of questionable assignment is composed of grayish-red silty claystone at Spring Mountains, of grayish-red-purple siltstone at Valley of Fire, and of greenish-gray claystone to clayey sandstone at Horse Spring valley. The claystone in the Spring Mountains and at Horse Spring valley is composed of clay which swells in water and apparently belongs, at least in part, to the montmorillonite group. The thickness of the unit apparently decreases to the east, for it is about 55 feet at Spring Mountains, 20 feet at Valley of Fire, and 8 feet at Horse Spring valley.

Swelling clay and clayey sandstone in this uppermost Moenkopi unit and the grayish and purplish colors are much more characteristic of the Chinle Formation than of the upper red member of the Moenkopi Formation, which mostly contains nonswelling clay and is reddish-brown. This unit might, however, represent an altered zone, possibly a soil interval, at the top of the Moenkopi Formation. Further study of this unit is necessary before its relation to the underlying and overlying rocks are completely understood.

The lower contact of the upper red member is placed at the change from gypsiferous strata below to red siltstone and sandstone above (discussion under Shnabkaib Member). The upper red member is overlain unconformably by the Shinarump Member of the Chinle Formation, except locally where the Shinarump Member is missing and the bentonitic claystone and clayey sandstone of the Petrified Forest Member rests directly on the Moenkopi Formation. The contact is a surface of erosion and is marked by channels cut into the Moenkopi Formation and filled with sedimentary rocks of the Shinarump Member. If the thin unit questionably assigned to the uppermost part of the upper red member proves to be part of the Chinle Formation, the contact between the Chinle and Moenkopi Formations would lie lower in the stratigraphic sequence. The contact below this thin unit is not well exposed but probably is flat.

The upper red member is similar lithologically to the cliff-forming member of the Moenkopi Formation in southeastern Utah, and both units are marked by an abundance of ripple-laminated strata which are largely missing in the underlying members. Possibly the upper red member and the cliff-forming member are physically continuous with one another, but, because of large concealed areas between outcrops and a lack of distinguishing lithologic characteristics, this correlation is very uncertain (pl. 3).

NORTHEASTERN ARIZONA

The Moenkopi Formation crops out extensively in northeastern Arizona. It is exposed widely within the belt of Triassic outcrops extending from Lees Ferry southward and southeastward through Cameron, Winslow, and Holbrook, to St. Johns (pl. 1). It also crops out in the southern part of the Defiance uplift, and locally along the Mogollon Rim, in Sycamore Canyon, and near Flagstaff. It crops out in the Monument Valley area, Arizona, but exposures there are continuous with those in southeastern Utah and so are included in the section on the stratigraphy of southeastern Utah.

The Moenkopi Formation in this region has been extensively studied by McKee (1954), Akers, Cooley, and Repenning (1958), Cooley (1957, 1959a), and Repenning, Cooley, and Akers (1969). The type locality of the formation (Ward, 1901) is at Moenkopi Wash near Cameron, sites of vertebrate remains are near Holbrook, Winslow, and Cameron (Camp and others, 1947; Welles, 1947), and sites of vertebrate trackways are at Cameron and elsewhere in the region (Peabody, 1948). The discussion that follows is mostly a summary of the work of these geologists but emphasizes new information obtained by us.

Three members are recognized in the Moenkopi Formation in this region. These members are, in ascending order, the Wupatki Member (a red siltstone member), the Moqui Member (a gypiferous member), and the Holbrook Member (a red siltstone member containing conspicuous sandstone beds in the area near Holbrook and Winslow). In the southern Echo Cliffs these members grade northward into undifferentiated red beds.

The Moenkopi Formation thins eastward across northeastern Arizona, from more than 500 feet in the western part to about 100 feet along the east border near Lupton. It is present in outcrops along the southern part of the Defiance uplift, but pinches out northward within 12 miles south of Fort Defiance and is absent in outcrops in the northern two-thirds of the Defiance uplift.

Along the Mogollon Rim south of Winslow, the Moenkopi was removed by erosion prior to the deposition of the Dakota Sandstone of Early (?) and Late Cretaceous age (Darton and others, 1924). The thinning and truncation of the Moenkopi in this area by pre-Dakota erosion is not shown on plate 4.

Both the upper and lower contacts of the formation are unconformities. In the western part of the region the Moenkopi overlies the Kaibab Limestone, around Holbrook it overlies the Coconino Sandstone, and near St. Johns it overlies the San Andres Limestone (a correlative in part of the Kaibab Limestone). In the southern part of the Defiance uplift, it overlies the De Chelly Sandstone, the upper part of which is probably laterally continuous with the Coconino Sandstone (McKee, 1934; Read and Wanek, 1961). In many areas this lower contact is flat with local relief of only a few feet (McKee, 1938a, p. 56, table 5; McKee, 1954, p. 35; Cooley, 1957), but in the Lees Ferry area channels as deep as 15 feet have been cut into the underlying Kaibab Limestone (Akers and others, 1958). These channels are filled with chert and limestone fragments as large as 8 inches in diameter and with sandstone fragments as large as 3 feet in diameter.

The evidence of an unconformity at the base of the Moenkopi Formation in this region is supported by faunal evidence. To the west, in the Kaibab Plateau, the lowest beds of Moenkopi Formation contain middle Early Triassic fossils whereas the Kaibab Limestone contains fossils of Leonard age (the second of four provincial series in the Permian). A long break in deposition is indicated, therefore, between these formations in north-central Arizona. The Moenkopi Formation appears to have onlapped Permian strata southeastward in Arizona (McKee, 1954), and therefore the basal beds of the Moenkopi Formation in east-central Arizona are probably younger than those in northwestern Arizona. Thus the time lapse between the Kaibab Limestone and Moenkopi Formation is probably greater in east-central Arizona than in northwestern Arizona.

The Moenkopi Formation is overlain unconformably by the Chinle Formation throughout northeastern Arizona. Channels were cut into the Moenkopi Formation and filled with sandstone and conglomerate of the Shinarump Member of the Chinle Formation in many places. They are especially numerous near Lees Ferry and Cameron. Near Lees Ferry the Shinarump Member fills a broad swale or valley cut into the Moenkopi Formation. This swale is at least 11 miles wide and about 175 feet deep at its lowest point.

WUPATKI MEMBER

The Wupatki Member was named by McKee (1954, p. 19) for exposures near Wupatki Ruin, Wupatki National Monument, 30 miles south of Cameron.

This member crops out in the valley of the Little Colorado River from about 20 miles southeast of Holbrook to about 15 miles northwest of Cameron. The limit of the member southeast of Holbrook is indefinite as it is thin in this area and probably grades laterally into strata assigned to the Holbrook Member. The limit northwest of Cameron is also indefinite; in this area the Wupatki, Moqui, and Holbrook Members grade to the northwest into an undifferentiated sequence of red beds. This lateral change is gradual, however, and exact limits to the members are difficult to place. The Wupatki also occurs as outcrops on East Sunset Mountain (loc. A12) and along Sycamore Canyon (near loc. A21), 20 miles southwest of Flagstaff.

The Wupatki Member is composed dominantly of pale-reddish-brown, micaceous, horizontally and ripple-laminated siltstone that weathers to slopes. This type of siltstone is common in the Moenkopi Formation in many other parts of the Colorado Plateau.

The Wupatki Member contains one particularly distinctive rock unit—a thin widely distributed sandstone. This bed has been described (McKee, 1954) in detail and referred to as the lower massive sandstone.

The lower massive sandstone is correlated across a large part of northern Arizona (McKee, 1954). It occurs everywhere the Wupatki Member is recognized and, in some areas, beyond. It probably is present in Sycamore Canyon southwest of Flagstaff, although it is not clear which of the several sandstone beds in that locality is the exact correlative. It is not recognized in the St. Johns area, nor in the area in the southern part of the Defiance uplift. North of Cameron to the south side of Paria Plateau it extends beyond the limit of the Wupatki Member. On the south side of the Paria Plateau, the lower massive sandstone is present in the upper part of the Shnabkaib Member. The lower massive sandstone has been traced by McKee (1954) as far west as Kanab, where it may be present in the upper part of the Shnabkaib Member, although this correlation is considered uncertain. (See discussion of southern Nevada, southwestern Utah, and northwestern Arizona, p. 20.) It is not recognized in the Monument Valley area of Arizona and Utah, nor in southeastern Utah.

The lower massive sandstone is laterally separated into two lithologic facies: one from Cameron south and east along the Little Colorado River valley and the other from Cameron north along Echo Cliffs. From Cameron south and east along the Little Colorado River valley it is grayish yellow to reddish brown, and characteristically weathers reddish brown. It is composed of very fine grained, silty, well-sorted sandstone and is horizontally laminated or very thin to thick bedded. Locally a few thin to thick trough and tabular planar sets of small- to medium-scale cross-laminae are present. The stratification as a whole is very regular, and the top and bottom contacts of the unit are generally flat.

From Cameron north along Echo Cliffs the lower massive sandstone is grayish-yellow, very fine grained, well-sorted sandstone, and is slightly coarser and less silty than south and east of Cameron. The bedding is dominantly thin to thick with shallow trough and tabular planar sets of small- to medium-scale cross-strata. Horizontally stratified units are locally common, but are much less abundant than south and east of Cameron. In addition, this sandstone in the area north of Cameron fills small scours cut into the underlying part of the Moenkopi Formation, whereas south and east of Cameron the basal contact of the lower massive sandstone is flat.

The lower massive sandstone characteristically forms a ledge; in most places in this region, it forms the most prominent ledge in the Moenkopi Formation. In the area from Wupatki National Monument to Holbrook, it lies near the base of the Moenkopi Formation and forms long dip slopes.

The thickness of the lower massive sandstone ranges from about 10 to 60 feet (table 3). Southeast of Cameron the thickness is about 10–25 feet, between Cameron and The Gap (loc. A24) it is generally 40–60 feet, and north of The Gap, 20–30 feet.

The lower massive sandstone is much closer to the base of the Moenkopi Formation in eastern than in western Arizona (table 3). At Kanab, the unit correlated by McKee (1954) with this sandstone, a correlation considered uncertain in this report, lies about 965 feet above the base of the formation. At Lees Ferry (loc. A23), the lower massive sandstone lies about 460 feet above the base of the Moenkopi Formation; at Cedar Ridge (loc. A18), 301 feet; at The Gap (loc. A24), 146 feet; near Cameron (locs. A19 and A77), from 70 to 80 feet; at Leupp, 27 feet; and near Winslow and eastward, from a few feet to about 20 feet above the base of the formation.

TABLE 3.—*Representative thicknesses, in feet, of lower massive sandstone of Moenkopi Formation and underlying part of Moenkopi Formation in Arizona*

Locality	Locality No. (pl. 1; table 1)	Lower massive sandstone	Underlying part of Moenkopi Formation
Fredonia	A87	16(?)	965±
Soap Creek (near Lees Ferry)	23	28	464
Cedar Ridge	18	27	301
The Gap	24	41	146
Big Canyon	15	39	168
Winslow	70	14	2
Holbrook	60	19	6
Woodruff Butte	69	11	14

The thickness of the Wupatki Member as a whole decreases southeastward from about 150 feet near Cameron to about 25 feet near Holbrook (table 4). The member is 154 feet thick at East Sunset Mountain (loc. A12) southwest of Winslow, and rocks tentatively identified as Wupatki Member in Sycamore Canyon (loc. A21), southwest of Flagstaff, are 202 feet thick.

TABLE 4.—*Representative thicknesses, in feet, of Wupatki, Moqui, and Holbrook Members of Moenkopi Formation in Arizona*

[A indicates member absent]

Locality	Locality No. (pl. 1; table 1)	Wupatki Member	Moqui Member	Holbrook Member
Northwest of Cameron	A79	149	66	73
Coconino Point	19	143	162(?)	67
Poverty Tank	77	118	96	122
West of Black Point	75	102	144	109
Ott Mountain	21	202(?)	130(?)	64+
Winslow	70	81	55	114
East Sunset Mountain	12	154	175	115
Holbrook	60	25	85	48
St. Johns	9	A	A	50
Black Creek	1	A(?)	A(?)	169

The lower contact of the Wupatki Member is an unconformity. It is distinct and marks a change from limestone of the Kaibab Limestone or sandstone of the Coconino Sandstone to reddish-brown siltstone of the Moenkopi Formation.

The upper contact of the Wupatki Member is conformable and gradational, and therefore it must be located arbitrarily. It is normally placed at the base of gypsiferous strata that characterize the overlying Moqui Member. That member is dominantly reddish brown and is characterized by thin to thick greenish-gray and dusky-yellow bands that give it a distinctly banded appearance in contrast with the uniform reddish brown of the Wupatki Member.

The upper contact of the Wupatki Member in the Winslow-Holbrook area apparently has not been consistently located by different geologists, probably because of intertonguing of the Wupatki and Moqui Members coupled with slightly different criteria used by the different geologists in placing the contact. In most areas the contact lies 30–50 feet above the top of the lower massive sandstone, but at Holbrook (loc. A60) the contact is placed at the top of the lower massive sandstone, and at East Sunset Mountain (loc. A12) it lies at least 103 feet, and possibly as much as 143 feet, above the base of the lower massive sandstone.

MOQUI MEMBER

The Moqui Member was named by McKee (1954, p. 19) for exposures near Moqui Wash, 8 miles west of Winslow, Ariz.

This member is present in outcrops along the valley of the Little Colorado River from near Holbrook to near Cameron (pl. 4). The Moqui Member is distinguished as a unit containing gypsum or gypsiferous siltstone, and the margins of the member are placed at the limit of occurrence of these distinctly gypsiferous beds. Such a limit is reached southeast of Holbrook. The Moqui Member is well defined near Holbrook and occurs as a small outcrop at the "Sinks" (loc. A67) about 22 miles south of Holbrook. At the "Sinks" we assign most of what McKee (1954, p. 83) called Holbrook Member (units 2–8) to the Moqui Member, and assign the top unit of his Holbrook Member (unit 1) and the unit he called Shinarump(?) Conglomerate to the Holbrook Member. The Moqui Member, if present, at Woodruff Butte (loc. A69; McKee, 1954, p. 85–86) is covered, but no gypsiferous strata are present in outcrops along the Little Colorado River 33 miles southeast of Holbrook (loc. A68; McKee, 1954, p. 84–85) and at Mesa Redondo, so the Moqui Member is considered to be absent at those places. The exact limit of the Moqui Member, however, is not known because outcrops southeast and south of Holbrook are incomplete.

North of Cameron, the Moqui Member grades laterally into reddish-brown siltstone indistinguishable from the rest of the Moenkopi Formation. The member is easily distinguished in outcrops near Cameron, as it contains thin seams of gypsum and distinct light color bands considered typical of the member. The member has been identified (McKee, 1954, p. 99–102) 12 miles northwest of Cameron and 20 miles west of Shadow Mountain (probably same as Big Canyon lithofacies section, loc. A15), but no primary gypsum occurs at these sections. Because gypsum is the most distinguishing characteristic of the Moqui Member and gypsum is not present in these sections, we have not included any strata at these sections in the Moqui Member. Such a scheme is arbitrary, but we feel that the lithologic continuity of the member is better maintained if it is restricted to gypsiferous strata.

In the Winslow area, where the Moqui Member is typically represented, it is composed of pale-reddish-brown structureless, horizontally laminated, and locally ripple-laminated siltstone. The member contains many thin to thick color bands of greenish-gray and dusky-yellow siltstone. Interstratified with the siltstone is white gypsum as very thin to thin horizontal beds and also as very thin seams crosscutting the stratification. In the Winslow area this gypsum, in both beds and seams, makes up about 10 percent of the member.

Away from the Winslow area, the amount of gypsum in the Moqui Member decreases, and at the margins of the member, both near Holbrook and in the Cameron area, gypsum probably constitutes less than 1 percent of the member. Near the margin, this member is composed dominantly of reddish-brown siltstone and it contains thin to thick greenish-gray and dusky-yellow color bands. The siltstone is dominantly structureless with only a few percent of ripple-laminated strata. Both cusp and parallel ripples occur.

The Moqui Member ranges in thickness from a few to 175 feet (pl. 4; table 4). The thicknesses reported by various geologists differ greatly from place to place and reflect intertonguing of the Moqui Member with overlying and underlying members. The thicknesses probably also result partly from different opinions as to where the member contacts should be placed.

The upper and lower contacts of the Moqui Member are conformable and probably are intertonguing. In this investigation they have been placed where they separate the gypsiferous strata of this member from the nongypsiferous strata of the underlying and overlying members. In general, the Moqui Member forms a reddish-brown slope banded with thin greenish-gray or yellowish-gray beds and contrasts with the reddish-brown siltstone and sandstone of overlying and underlying members.

The Moqui Member is similar lithologically to the Shnabkaib Member of southwestern Utah and northwestern Arizona, but apparently represents a younger deposit than the Shnabkaib. The lower massive sandstone lies entirely below the Moqui Member, whereas farther west it seems to lie near the top of the Shnabkaib Member. Thus most, if not all, of the Moqui and Shnabkaib Members must be separate units. Both of these members, however, could be tongues of a thicker and more inclusive parent unit lying to the west or southwest of the Colorado Plateau.

HOLBROOK MEMBER

The Holbrook Member was named by Hager (1922, p. 73) for exposures near Holbrook, Ariz. It was further described and defined by McKee (1954, p. 19).

The Holbrook Member is present in outcrops in the valley of the Little Colorado River from near St. Johns to Cameron. The member is also tentatively identified in the southern part of the Defiance uplift. It is the only part of the Moenkopi Formation that occurs in the St. Johns area and the southern part of the Defiance uplift.

This member, typically represented at Holbrook, consists predominantly of interstratified and interfingering layers of sandstone and siltstone. Locally, the sandstone contains interstratified 10- to 20-foot-thick layers of conglomerate that is composed of coarse sand grains to small pebbles of siltstone and limestone. The sandstone is pale brown, dark yellowish brown, or pale red and very fine to medium grained; it contains silt and abundant fine- to coarse-grained, dark-green mica. The individual layers of sandstone are highly variable in thickness, and they interfinger irregularly with the associated siltstone. Cross-stratification is dominant in the sandstone, but thin to very thin horizontal beds are common locally. The cross-strata are mostly in trough sets and are on a small to medium scale.

The interstratified siltstone is pale reddish brown and grayish red. It is dominantly structureless, although thin to thick horizontal beds and ripple-laminated sets are common locally.

The very fine to medium-grained sandstone layers that typify this member in the Holbrook area decrease in quantity to the west and are very sparse or absent in the Cameron area. Locally, coarse siltstone or silty to very fine grained sandstone crops out in the Holbrook Member near Cameron, but these rocks, in addition to having a fine texture, are dominantly pale reddish brown, fairly well to well cemented, and horizontally laminated or ripple laminated.

In the St. Johns area, the Holbrook Member is much coarser than elsewhere. Commonly more than half of the member is sandstone, and locally, as at our St. Johns section (loc. A9), almost the entire member is sandstone. The amount of sandstone, however, differs greatly from place to place, and about half a mile from the section at St. Johns, only about 40 percent of the member is sandstone.

In the St. Johns area, conglomerate layers locally interfinger with sandstone. Commonly the conglomerate is composed of granules and pebbles of limestone or limy siltstone, but some conglomerate layers contain a few clasts of quartz, quartzite, or chert. The pebbles are all small, rarely larger than half an inch in maximum diameter.

In the southern part of the Defiance uplift, the Holbrook Member consists of a sequence of alternating siltstone and sandstone beds which, in general, are similar to those of the same member near Holbrook. Here, however, sandstone units are somewhat finer grained, and limestone pebble conglomerate is less common than near Holbrook.

The thickness of the Holbrook Member ranges from 48 to 122 feet (table 4). Much of the variation in thickness probably is due to erosion of part of the member prior to deposition of the overlying Chinle Formation, to intertonguing of the member with the underlying Moqui Member, and to inconsistent placing of the contact by geologists. One of the thinnest measured sections of the Holbrook Member is 2 miles south of Holbrook (loc. A60), where the member is 48 feet thick, but here the top of the member probably has been eroded prior to deposition of the overlying Shinarump Member of the Chinle Formation.

The lower contact of the Holbrook Member is located, in most places, at the top of the highest gypsiferous strata that characterize the underlying Moqui Member. In the Holbrook area this contact locally corresponds with the base of the lowest sandstone lens of the Holbrook Member, whereas in other places a unit of slope-forming siltstone lies at the base of the Holbrook Member. Near Holbrook, the ledge-forming Holbrook Member contrasts topographically with the slope-forming Moqui Member. In the St. Johns area, the Holbrook lies directly on the San Andres Limestone (Kaibab Limestone).

The upper contact of the member is marked by the widespread unconformity at the base of the Chinle Formation. In some areas, near Cameron for example, prominent channels are cut into the Holbrook Member and filled with sandstone and conglomerate of the Shinarump Member. In other areas, such as near Woodruff Butte (loc. A69) and St. Johns, strata in the basal part of the Chinle Formation are lithologically similar to strata of the Holbrook Member, and in these areas differentiating the two formations is difficult. Locally the contact between the two cannot be placed with assurance.

In the St. Johns area and in the southern part of the Defiance uplift, the entire Moenkopi Formation is lithologically similar to the Holbrook Member, although the formation in these areas may contain unrecognized lateral equivalents of the Wupatki and Moqui Members, as well as of the Holbrook Member.

UNDIFFERENTIATED MOENKOPI FORMATION FROM NEAR CAMERON TO LEES FERRY

The Moenkopi Formation from near Cameron to Lees Ferry, Ariz., lies between areas where members of the Moenkopi of southwestern Utah (Timpoweap, lower red, Virgin, and others) are recognized and the areas where the members of the Moenkopi along the Little Colorado River (Wupatki, Moqui, and Holbrook) are recognized.

The Moenkopi Formation in this area is divisible into three units. The middle unit is the lower massive sandstone (description under Wupatki Member), and it forms a prominent ledge. The lower and upper units are largely slope forming and are lithologically similar. They consist mostly of pale-reddish-brown horizontally and ripple-laminated siltstone. Fissile evenly bedded siltstone is characteristic. Molds of salt crystals and mud cracks are present (McKee, 1954, p. 103). The lower unit contains a small amount of gypsum near Lees Ferry. The upper unit is distinctly darker and contains more ledge-forming beds than the lower. The upper unit locally contains cross-stratified sandstone.

WEST-CENTRAL AND CENTRAL NEW MEXICO

Strata referred to here as the Moenkopi(?) Formation are exposed in outcrops 12 miles southwest of Zuni and on the northeast and southwest flanks of the Zuni uplift. They are also considered provisionally to be present in outcrops in the Lucero uplift and Riley areas and on isolated outcrops 16 miles northeast of Socorro (Sevilleta Grant; loc. NM17).

The Moenkopi(?) Formation as recognized here is only a small basal part of the unit called Moenkopi Formation by Darton (1922, 1928). Most of the Moenkopi Formation of Darton, as pointed out by Bates and others (1942), correlates with the lower part of the Chinle Formation. The strata recognized in New Mexico by McKee (1954) and by Cooley (1959a), and considered equivalent to the Moenkopi Formation, are virtually the same as the Moenkopi(?) Formation of this report, although McKee did not recognize the Moenkopi as far east in New Mexico as we do. A unit tentatively recognized by us as Moenkopi(?) Formation in outcrops in the Lucero uplift has previously been included by Kelley and Wood (1946) in the Shinarump Conglomerate. The strata considered by us to be the Moenkopi(?) Formation in the Sevilleta Grant area (loc. NM17) northeast of Socorro were included by Wilpolt and Wanek (1951) in the lower part of the Dockum Formation.

The Moenkopi(?) Formation in New Mexico probably originally formed a thin blanket of sediment extending throughout west-central New Mexico. The formation, however, may be absent in Triassic outcrops at some localities in the Zuni uplift. At a locality about 12 miles southeast of Fort Wingate on the northeast flank of the Zuni uplift, for example, the Chinle Formation appears to rest directly on the San Andres Limestone, and the Moenkopi(?) Formation is apparently absent. The eastward limit of the formation in New Mexico is not known. We tentatively traced the formation as far east as 16 miles northeast of Socorro, but did not examine outcrops east of this area. The Moenkopi(?) Formation is not present in the Nacimiento Mountains, San Pedro Mountains, or Rio Chama area in north-central New Mexico, and it must reach a north limit between the Lucero uplift and the Nacimiento Mountains in an area where Triassic strata are covered by younger formations.

The Moenkopi(?) Formation consists of layers of ledge-forming sandstone within slope-forming siltstone. Locally conglomeratic sandstone or conglomerate is present. The different lithologic types intergrade and intertongue. The sandstone, including conglomeratic parts, constitutes about one-third of the formation and is present as layers 2–20 feet thick. It is pale red with subordinate grayish red or light brownish gray, and grades from very fine to medium grained, although in most places it is fine grained. In some places, it is horizontally laminated to thin bedded, and in others it is cross-stratified and contains interstitial silt layers. The cross-strata are in thin to thick trough and small planar sets and are small to medium scale. Locally, cuspate ripple marks are present. Granules and pebbles are scattered through some of the sandstone lenses; they constitute as much as 50 percent of a few units but less than 5 percent of most. The granules and pebbles are composed of siltstone and limestone in some places, quartz, quartzite, and chert in others, and they are mixed in still others. Chert constitutes about 70 percent of the siliceous granules and pebbles, and quartz and quartzite are in about equal proportions in the remaining fraction. The granules and pebbles are mostly one-fourth to one-half inch in diameter, and average about one-fourth inch. At Mesa Gallina (loc. NM20) in the Lucero uplift area, a few small poorly preserved and indeterminate bone fragments occur in a conglomerate composed of coarse sand grains and pebbles of siltstone and limestone.

The siltstone, which is interstratified with sandstone and conglomerate, is grayish red and pale reddish brown, micaceous, and structureless, horizontally laminated, very thin or thin bedded, and, in a few places, ripple laminated.

The Moenkopi(?) Formation changes in thickness irregularly in the Zuni Mountains area. Both the upper and lower contacts of the formation are unconformities, and the irregularities caused by these probably account for part of the variation in thickness. The formation is generally less than 50 feet thick in the Zuni Mountains area, but 3 miles south of Fort Wingate (loc. NM3) it is 103 feet thick and 5 miles south of Grants it is 110 feet thick. It is 212 feet thick at Mesa Gallina (loc. NM20) in the Lucero uplift, 161 feet thick near Riley (loc. NM16), and 101 feet thick on the Sevilleta Grant 16 miles northeast of Socorro (loc. NM17).

The Moenkopi(?) Formation in this region unconformably overlies the San Andres Limestone of Permian age except in some places on the northwest flank of the Zuni uplift where it locally overlies the Glorieta Sandstone of Permian age. In the Fort Wingate–Grants area and in the Lucero uplift, the top beds of the San Andres are limestone, and they contrast with the red siltstone and sandstone of the Moenkopi(?) Formation. In the Riley area, the top beds of the San Andres are gypsum, limestone, and red siltstone, and the contact is placed at the top of a 16-foot-thick unit composed of gypsum and subordinate siltstone (Riley, loc. NM16). The contact at Riley is not well defined, but some gypsum occurs in the San Andres Limestone, whereas it is absent in the Moenkopi(?) Formation in that area. At Sevilleta Grant (loc. NM17), 16 miles northeast of Socorro, the San Andres is composed of limestone overlain by a 24-foot-thick unit of pale-reddish-brown, structureless, sandy siltstone (called the upper member of the San Andres by Wilpolt and Wanek, 1951). The basal strata of the Moenkopi(?) Formation contain ripple-laminated and horizontally laminated beds in contrast with the structureless strata at the top of the San Andres.

In the Fort Wingate–Grants area, channels cut into Permian strata and filled with strata of the Moenkopi(?) Formation are common. The channels are as deep as 50 feet and locally cut through the limestone of the San Andres Limestone and into the underlying Glorieta Sandstone (Cooley, 1959a, p. 66).

In the Fort Wingate–Grants area, irregularities with a local relief of as much as 30 feet indicate that a karst topography was developed on the top of the San Andres Limestone prior to deposition of the Moenkopi(?) Formation (Cooley, 1959a, p. 66). Cavities and "lows" in the limestone are filled with rubble breccia of limestone derived from the San Andres and cemented with impure calcareous material. In other places silty and sandy material of the Moenkopi(?) Formation fill the depressions. A cave formed in the San Andres was observed by Cooley (1959b) at one exposure west of Bluewater Lake and south of Thoreau. The cave is filled with silty sandstone, mudstone, and claystone, and locally it contains limestone fragments bonded together by a calcareous cement. Partly carbonized logs of petrified wood

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3–8 inches in diameter lie at the base of this cave (Cooley, 1959b).

In the Lucero uplift, Riley, and Sevilleta Grant areas, the contact of the Moenkopi(?) Formation and San Andres Limestone is relatively uniform; irregularities suggesting a buried karst topography were not observed.

The Moenkopi(?) Formation is unconformably overlain in New Mexico by the Chinle Formation. At Fort Wingate (loc. NM3), near Prewitt (loc. NM1), and on Mesa Gallina (loc. NM20), mottled strata occur at the base of the Chinle Formation. These strata are characterized by a peculiar mottled red, purple, and gray coloration and have been recognized locally at the base of the Chinle Formation or in the top few feet of the Moenkopi Formation in many areas of the Colorado Plateau. These mottled strata are considered to be beds altered during the formation of a soil zone. The alteration in places affected the topmost beds of the Moenkopi Formation, and in other places affected the basal beds of the Chinle Formation. These altered beds at the base of the Chinle Formation may represent a lag deposit formed during the time when little deposition occurred between the Moenkopi Formation and the main part of the Chinle Formation.

At Fort Wingate, a thin sandstone and conglomerate unit, questionably correlated with the Shinarump Member, overlies the mottled strata; near Prewitt and on Mesa Gallina, variegated bentonitic silty claystone of the Chinle Formation overlies them. Near Riley (loc. NM16), variegated bentonitic clayey siltstone of the Chinle Formation directly overlies red siltstone of the Moenkopi Formation.

A 30-mile-wide gap in outcrops of the Moenkopi Formation and its probable equivalents exists between the Defiance uplift in Arizona and Fort Wingate, N. Mex. Correlation of the Moenkopi Formation across this gap is made on the basis of the lithologic similarity of the unit in west-central New Mexico to the known Moenkopi Formation in east-central Arizona, both of which are composed of red siltstone and sandstone and contain locally cross-stratified and ripple-marked strata. Some lithologic differences between the two areas have been recognized by Cooley (1959a, p. 69). The conglomeratic units containing quartz, quartzite, and chert pebbles recognized in the Zuni Mountains are not present in the Moenkopi Formation in the Defiance uplift 25 miles to the west, although they are present southwest of the pueblo of Zuni (40 miles southwest of the Zuni Mountains) and in the St. John area (80 miles southwest of the Zuni Mountains). The limestone pebble conglomerate typical of the Moenkopi Formation in east-central Arizona, as noted by Cooley (1959a, p. 69) is not present in the Moenkopi(?) Formation of the Zuni Mountains of New Mexico. Some of this type of conglomerate was noted by us near Prewitt (Chavez-Prewitt section, loc. NM1, unit 2) and farther east at Mesa Galina (loc. NM20) and Riley (loc. NM16). Petrified wood has been found in outcrops of the Moenkopi(?) Formation in the Zuni Mountains area, but not in any place from the Moenkopi Formation in the Little Colorado River area of east-central Arizona, according to Cooley (1959a, p. 69). The occurrence of a few specimens in Moqui Wash near Winslow and at Cameron are reported by McKee (1954, p. 73), however.

The presence of the Moenkopi(?) Formation in New Mexico is further indicated by its stratigraphic position between a limestone unit, the San Andres, below, and rocks believed to be Chinle, including mottled strata, conglomerate, siltstone, and claystone, above. In most of northeastern Arizona the Moenkopi Formation occupies a similar stratigraphic position between the Kaibab Limestone (a correlative in part of the San Andres) below and the Chinle Formation above.

SOUTHEASTERN UTAH

The Moenkopi Formation crops out in southeastern Utah on and around the Monument uplift, along the Colorado, Dirty Devil, and Green Rivers, in the Circle Cliffs and Capitol Reef areas, and in the San Rafael Swell. Outcrops in the formation in the Monument Valley area, Arizona, are included in this section as they are continuous with outcrops of the formation in southeastern Utah. Part of the stratigraphic relationships presented here have been previously discussed by Stewart, Williams, Albee, and Raup (1959) and by Stewart (1959).

Six members are recognized in the Moenkopi Formation in southeastern Utah. These members are, in ascending order, the Hoskinnini Member, lower slope-forming member, Sinbad Limestone Member, ledge-forming member, upper slope-forming member, and cliff-forming member. The Hoskinnini Member was originally named and defined as a member of the Cutler Formation by Baker and Reeside (1929) in the Monument Valley area, Utah. Later it was correlated northward into areas where it had not previously been recognized (Mullens, 1960; Stewart, 1959), and this work led to the redefinition of the Hoskinnini as a member of the Moenkopi Formation (Stewart, 1959). The Sinbad Limestone Member was named by Gilluly and Reeside (1928) in the San Rafael Swell, Utah. The other members, which were first recognized in part by Smith, Huff, Hinrichs, and Luedke (1963) in the Capitol Reef area, Utah, are given informal names.

Thin conglomerate and sandstone units occur at the base of the Moenkopi Formation in some areas and within the formation in the eastern part of the White Canyon area (near loc. U278). Assignment of these units to any one member, as well as correlation of these units, is uncertain, and they are discussed as a separate topic.

The Moenkopi Formation extends throughout most of southeastern Utah. It ranges in thickness from more than 800 feet in the western part of southeastern Utah (Capitol Reef area) to a margin near the Colorado-Utah border (table 5).

In southeastern Utah the Moenkopi Formation overlies strata of Permian age. It rests on the "Kaibab Limestone" in the San Rafael Swell, Capitol Reef, and Circle Cliffs areas, and on the Cutler Formation in the rest of southeastern Utah (pl. 2). Locally, in the San Rafael Swell the "Kaibab" has been removed by pre-Moenkopi erosion, and the Moenkopi Formation rests directly on the "Coconino Sandstone" (Baker, 1946, p. 51). Various members of the Cutler Formation underlie the Moenkopi in the eastern part of southeastern Utah (pl. 2).

The basal contact of the Moenkopi Formation is probably an unconformity in the San Rafael Swell, Capitol Reef, and Circle Cliffs areas. In these places, the basal few feet of the formation is commonly a conglomerate containing pebbles of chert reworked from the underlying "Kaibab Limestone." Farther east in some parts of the White Canyon and Dirty Devil River areas and

TABLE 5.—*Thickness, in feet, of Moenkopi Formation and its members in southeastern Utah*

[A, absent; NM, not measured]

Locality	Loc. No. (pl. 1; table 1)	Moenkopi Formation, total thickness	Basal conglomerate and sandstone units	Hoskinnini Member	Lower slope-forming member	Sinbad Limestone Member	Ledge-forming member	Upper slope-forming member	Cliff-forming member
Emery County									
Mexican Bend	U48	883.4	A	A	189.6	45.0	108.8	311.8	228.2
Straight Wash	7	486.8	1.8	A	65.2	36.5	256.8	126.5	A(?)
Block Mountain	2	604.0	A	A	116.2	61.2	259.9	166.7	A(?)
Temple Mountain	8	613.6	4.4	A	114.1	47.3	220.9	226.9	A(?)
Muddy River	6	821.0	4.1	A	125.5	86.1	329.6	161.7	114.0
Wayne County									
Chimney Rock	43	921.2	A	A	92.4	156.2	278.8	269.6	124.2
Capitol Wash	42	832.9	31.5	A	67.3	80.4	209.1	307.1	137.5
Garfield County									
Horse Canyon	10	612.6±	[1] 15±	A	7.9	44.3	250.4	221.4	73.6
Muley Twist	11	483.1	15.6	A	A	A	182.3	232.0	53.2
Buckacre Point	9	379.3	29.4	A	52.8	11.0	170.1	116.0	A
Range Canyon	13	369.6	33.6	A	91.4	16.7	137.9	90.0	A
San Juan County									
Shafer Canyon	50	492.4±	A	NM (100 estimated)	141.0	2.0(?)	140.0	109.4	A
Steer Mesa	38	527.3	20.3	58.7	196.7	2.1	40(?)	209.5(?)	A
Lockhart Canyon	32	386.4	A	114.8	(undifferentiated post-Hoskinnini is 271.6 ft thick)				
North Sixshooter Peak	35	405.5	A	110.8	100.0±	A	102.7±	92.0±	A
Bridger Jack Mesa	26	328.4	A	111.5	37.1	A	132.4	47.4	A
Cottonwood Creek	28	267.5	A	88.4	61.8	A	111.3	6.0	A
Milk Ranch Point	33	331.0	A	93.4	58.6	A	78.4	100.6	A
Bears Ears	25	288.8	A	66.9	[2] 26.5	A	141.7	53.7	A
Jacobs Chair	30b	362.4	A	102.1	[2] 19.6	A	155.8	84.9	A
Hite	29	287.7	6.0	A	A	A	120.3	161.4	A
Red Canyon	208	324.7	A	81.4	39.2	A	134.9	69.2	A
The Rincon	37	64.1	11.1	A	A	A	A	53.0(?)	A
Monitor Butte	34	400.7	A	90.3	46.8	A	92.7	170.9	A
Comb Wash	27	254.5	A	52.0	48.0±	A	45.3±	109.2	A
Poncho House	36	166.1	A	51.7	(undifferentiated post-Hoskinnini is 114.4 ft thick)				

[1] Basal cherty limestone, locally conglomerate.
[2] Thin sandstone units, locally containing chert pebbles, included at base of member.

also at The Rincon (loc. U37) on the Colorado River near the junction of the San Juan and Colorado Rivers, a scour at the base of the Moenkopi Formation and the occurrence of conglomerate above this scour suggest an unconformity. East of these areas, the basal contact of the Moenkopi Formation probably is conformable in most places.

The Chinle Formation (Late Triassic) unconformably overlies the Moenkopi Formation everywhere in southeastern Utah. Locally channels occur at the top of the Moenkopi and are filled with sandstone and conglomerate of the overlying units of the Chinle Formation.

In the northeast-trending area extending roughly along the Colorado River from the Arizona-Utah State line to Hite, Utah, the Moenkopi Formation is thin and only one or two of its members are represented. At The Rincon (loc. U37), the Moenkopi Formation is 64 feet thick (pl. 4) and is considered to consist of the upper slope-forming member only, except for a thin conglomerate layer at the base. The Hoskinnini, lower slope-forming, ledge-forming, and cliff-forming members are missing. Near Hite, only the ledge-forming and upper slope-forming members are present, and the formation as a whole is less than 300 feet thick (pl. 4). The area along the Colorado River where the Moenkopi Formation is notably thin and, where many of its members are missing, is considered to have been a positive area during deposition of the lower part of the Moenkopi Formation.

CONGLOMERATE AND SANDSTONE UNITS

Conglomerate and sandstone units, most of which are thin, occur at or near the base of the Moenkopi Formation in much of southeastern Utah. In Circle Cliffs, Capitol Reef, and San Rafael Swell, these units differ greatly in lithologic type from place to place, ranging from chert pebble conglomerate and sandstone to siltstone and limestone containing scattered chert pebbles. These units commonly are not more than a few feet thick and probably represent local reworking of the underlying strata.

At The Rincon near the junction of the San Juan and Colorado Rivers (loc. U37), a chert conglomerate containing fragments as large as 6 inches across occurs at the base of the Moenkopi Formation.

Sandstone and conglomerate units also occur at the base of the Moenkopi Formation at Range Canyon (loc. U13) and in nearby parts of the southern Orange Cliffs area (fig. 3). These units are as thick as 30 feet and are composed of light-olive-gray, fine- to medium-grained sandstone and of chert pebble conglomerate.

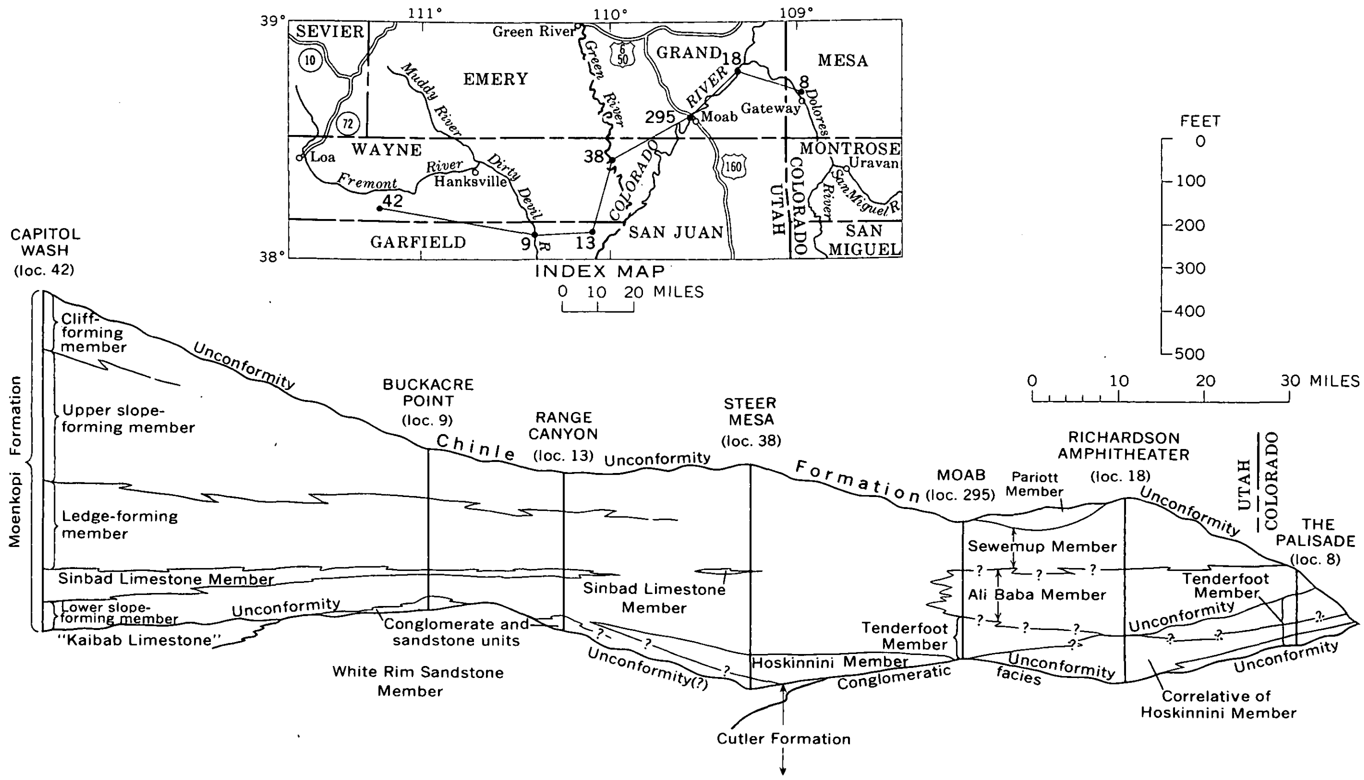

FIGURE 3.—Sections and correlations of Moenkopi Formation across southeastern Utah and west-central Colorado. Heavy lines indicate formation boundaries.

These units occur below the Hoskinnini Member, but extend beyond the limit of the Hoskinnini, where they lie below the lower slope-forming member (fig. 3).

In the eastern part of the White Canyon area (near loc. U278), a conglomerate and sandstone unit occurs directly above the Hoskinnini Member. This same unit in the western part of the White Canyon area and along the Dirty Devil River, however, beyond the margin of the Hoskinnini Member, lies directly at the base of the Moenkopi Formation. The unit is composed of yellowish-gray and light-gray conglomerate, conglomeratic sandstone, and sandstone. The conglomeratic parts consist of granules, pebbles, and locally a few cobbles of gray chert set in a fine to medium sand matrix. The sandstone is fine to medium grained. Most of the unit is crudely stratified with horizontal laminae and thin beds, but part of it is structureless; locally a few small-scale cross-strata occur. The lower contact is a scour surface with channels generally a few feet deep. The unit ranges in thickness from a fraction of a foot to as much as 30 feet, and locally is absent.

HOSKINNINI MEMBER

The Hoskinnini Member is exposed in an elongate strip extending from the Monument Valley area in northernmost Arizona to a point about 6 miles southwest of Moab (Stewart, 1959). Farther north, the nomenclature of strata in the basal part of the Moenkopi Formation is different. In the salt anticline region, the term "Tenderfoot Member" is used for strata that are, in part at least, physically continuous with the Hoskinnini Member (pl. 3). On the west, the Hoskinnini pinches out in outcrops of the White Canyon (loc. U278) and Range Canyon (loc. U13 and U274) areas, and the west margin is along a north-northeast line through these areas. On the south, the margin is south of the Monument Valley area, Arizona, but cannot be located accurately because the Moenkopi Formation is there covered by younger strata. On the east, the limit lies east of outcrops along Comb Ridge, Elk Ridge, and Lockhart Canyon (near loc. U32), but here also the member is covered by younger strata, and the margin cannot be placed accurately.

The Hoskinnini Member is a pale-reddish-brown, mainly poorly sorted sandy siltstone and silty very fine grained sandstone; it contains minor quantities of fine, medium, and coarse sand grains. The coarser grains generally are well rounded and are mostly disseminated in the siltstone or sandstone, but locally they are concentrated as lenticular or irregular masses ¼–1 inch thick and ½–2 inches long. The Hoskinnini is composed of indistinct horizontal beds, mostly 1–2 feet thick. Within these beds, stratification is irregular and difficult to see and appears to be composed chiefly of discontinuous wavy laminae bounded by grayish-red claystone or siltstone films. The Hoskinnini is well indurated and weathers to form a nearly vertical cliff which contains many smooth and rounded surfaces. Commonly the rock chips off as thin rounded spalls from weathered surfaces.

In the White Canyon (loc. U278) and Red Canyon (loc. U109) areas near the west edge of the Hoskinnini, the member contains a few lenses of chert pebble conglomerate and some of intraformational conglomerate composed of locally derived material. Within a mile or two of the exposed edge of the member in the White Canyon area, it is dominantly fine- to medium-grained sandstone, whereas elsewhere it is dominantly sandy siltstone or very fine grained sandstone.

The two most characteristic features of the Hoskinnini Member are the medium to coarse quartz grains scattered through the siltstone and the very fine grained sandstone and the characteristically poor stratification, including thin indistinct wavy laminae. These features of the Hoskinnini are very uncommon in other units of the Permian and Triassic sequence of the region and serve as the main basis of distinguishing the Hoskinnini from the related units. Unfortunately, in much of southeastern Utah, the top 10–30 feet of the Hoskinnini (Bridger Jack Mesa, loc. U26, and Lockhart Canyon, loc. U32) does not contain the medium to coarse quartz grains typical of the member. The uppermost strata however, resemble the Hoskinnini otherwise, and are included with it.

A distinctive bed with "crinkly" bedding occurs in the Hoskinnini in most areas, and, although correlation of this bed is uncertain, a single unit may be represented throughout southeastern Utah. It is a few inches to 2 feet thick and is composed dominantly of light-colored rock of various types with small-scale wavy or "crinkly" stratification. From a distance it appears as a light-colored band. It differs in composition from place to place and includes sandy siltstone, limy sandstone, finely crystalline gypsum, and limestone. The limestone and limy sandstone commonly contain irregular lenses of orange chert, a few inches in diameter and one-fourth inch thick. This bed has been described by Baker (1936, p. 39) in the Monument Valley area, where it lies near the top of the Hoskinnini Member. To the north, it occurs progressively lower in the section, and in the area near the junction of the Green and Colorado Rivers is near the top of the bottom third of the Hoskinnini.

The Hoskinnini Member ranges in thickness (table 5) from 0 to 130 feet but in most areas is 50–120 feet thick. The maximum measured thickness of about 130 feet is in the Clay Hills area near the San Juan River in southeastern Utah. Along the cliffs on the south side of White Canyon (loc. U278), the Hoskinnini thickens from the margin to 60 feet a quarter mile farther east, and to 110 feet 2 miles to the east (Stewart, 1959, fig. 4). At many other exposures the western thinning of the member takes place within a similar short distance.

The Hoskinnini Member overlies the Organ Rock tongue of the Cutler Formation in most of southeastern Utah. It overlies the De Chelly Sandstone Member of the Cutler Formation in and near the Monument Valley area and overlies the White Rim Sandstone Member of the Cutler Formation near the junction of the Green and Colorado Rivers and southward into the White Canyon area. Directly east of the junction of the Green and Colorado Rivers, and northward almost to Moab, it overlies arkosic strata of the Cutler that have not been differentiated into members.

The basal contact of the Hoskinnini Member is sharp in most places and is in part along an erosion surface. At its margin in White Canyon (Stewart, 1959, fig. 4), it truncates underlying rocks and in some parts of the Elk Ridge area its basal beds fill depressions a few inches to possibly a foot deep in the underlying unit (Bears Ears, loc. U25). In most other places the contact appears to be conformable.

The contact of the Hoskinnini Member with the overlying part of the Moenkopi appears conformable. Locally, in the White Canyon area (loc. U278), the unit overlying the Hoskinnini consists of sandstone and conglomeratic sandstone that fill channels cut into the Hoskinnini. Most of the channels are less than a foot deep, and the surface of erosion formed by them probably represents only a local break in deposition. In places where the top 10–30 feet of the Hoskinnini does not contain characteristic disseminated medium to coarse quartz grains, the upper contact of the member is difficult to recognize and has been located entirely on the basis of type of stratification and topographic expression.

LOWER SLOPE-FORMING MEMBER

The lower slope-forming member is a relatively thin, nonresistant even-laminated unit of siltstone. In the western part of the southeastern Utah region, it lies at the base of the formation, or is separated from the base by thin conglomerate or sandstone units (fig. 3). In the eastern part of the region, it overlies the Hoskinnini Member. In the western area, it is overlain by the Sinbad Limestone Member and in the eastern part by the ledge-forming member (pl. 3).

Although the lower slope-forming member is present throughout most of southeastern Utah, it is absent in a northeast-trending area (inferred to have been a "high" during deposition of the member) extending roughly along the Colorado River from the Arizona-Utah State line to Hite, Utah. The Circle Cliffs area is at the northwest margin of this former "high" for the member extends only into the northwesternmost part of Circle Cliffs. The member is absent in outcrops at Hite at the northeasternmost limit of the high area. In the Lockhart Canyon area (loc. U32), in the area northwest of the junction of the Green and Colorado Rivers, and in the southern part of the Monument Valley area, separation of the member from the overlying ledge-forming member is difficult, if not impossible.

The lower slope-forming member is composed of grayish-red, yellowish-gray, and light-greenish-gray, horizontally laminated to thin-bedded siltstone and sandy siltstone. Ripple-laminated layers are fairly common. The gray siltstone is generally petroliferous; its color is inferred to be caused by reduction of an original red pigment (probably hematite) to a gray iron oxide. The member is gray throughout most, if not all, of the San Rafael Swell, and is commonly partly gray elsewhere.

The member ranges in thickness (table 5) from 65 to 190 feet in the San Rafael Swell, it thins southward to consistently less than 100 feet in the Capitol Reef area, and it pinches out in the northernmost part of the Circle Cliffs area. It is less than 50 feet thick in the eastern part of the White Canyon area and in the Elk Ridge, Clay Hills, Comb Ridge, and Monument Valley areas. The member thins gradually westward in the White Canyon area toward the "high" described previously and is absent at Hite. North of the Elk Ridge and Dirty Devil River areas, the member thickens gradually to about 200 feet at Steer Mesa (loc. U138).

The well-bedded siltstone of the lower slope-forming member contrasts with coarser or less well-bedded units both above and below. Where the member lies at the base of the Moenkopi Formation, the contact is marked by easily recognizable lithologic changes from limestone of the Kaibab Limestone or sandstone of either the Cutler Formation or Coconino Sandstone to the siltstone of the lower slope-forming member. Where the member rests on the Hoskinnini Member, the contact is marked by a change from the characteristic siltstone or silty sandstone of the Hoskinnini containing disseminated fine, medium, and coarse sand and "wavy" laminae, to the well-bedded or ripple-laminated siltstone of the lower slope-forming member. The upper contact occurs at a change from siltstone to limestone in areas where the Sinbad Limestone Member is present. This contact is transitional for 10 feet or more in many places. In areas where the Sinbad is absent, the ledge-forming member overlies the lower slope-forming member, and the contact is placed at the line of change from well-bedded siltstone below to coarser, ledgy, locally cross-stratified siltstone or very fine grained sandstone above.

SINBAD LIMESTONE MEMBER

The Sinbad Limestone Member is an eastward-thinning wedge of marine limestone and dolomite (pls. 3, 4; fig. 3). It overlies the lower slope-forming member except in parts of the Circle Cliffs area where it either lies at the base of the Moenkopi Formation or is separated from the base by a thin conglomerate or cherty limestone unit.

The Sinbad Limestone Member occurs throughout the San Rafael Swell and Capitol Reef areas. It is present throughout the northwestern part of the Circle Cliffs area, is discontinuous southeastward, and is absent in most places in the southeastern part of the area (Davidson and others, 1957). The member is locally present in the Orange Cliffs and interriver areas (Buckacre Point, loc. U9, Range Canyon, locs. U13 and U274, and Steer Mesa, loc. U38). In these areas, near its southeast margin, it is thin. It has not been recognized in any outcrops southeast of the Colorado River.

The Sinbad Limestone Member is composed of limestone and dolomite and small amounts of siltstone. The carbonate rocks are yellowish gray, pale yellowish orange, or light olive gray and generally aphanitic. The member also characteristically contains medium to coarse, oolitic limestone layers. The limestone is mostly horizontally laminated or thinly bedded, but it locally contains thin trough sets of low-angle, small-scale cross-laminae. Siltstone comprises 5–20 percent of the member. It generally has the same color as the carbonate rocks and occurs as thin to very thick, horizontally laminated sets, interstratified with the carbonate rock. The member forms a cliff.

In the San Rafael Swell and Capitol Reef areas (pl. 4), the Sinbad Limestone Member ranges in thickness from 12 feet (Baker, 1946, p. 55) to a maximum of 156 feet (Chimney Rock section A, loc. U43). The size of this range probably is caused mainly by intertonguing of the member with underlying and overlying strata. The member is thin, less than 40 feet, in most of the northern part of the Circle Cliffs area, and it thins to the southeast, where it is discontinuous. It is absent in most places in the southeasternmost part of Circle Cliffs; it is discontinuous in the Orange Cliffs and interriver areas, where its maximum thickness is about 17 feet.

The contacts of the Sinbad Limestone Member with the underlying lower slope-forming member and the overlying ledge-forming member are gradational across 10 feet or more. These contacts are placed, respectively, at the base of the lowest limestone and the top of the highest limestone of the Sinbad Limestone Member.

The Sinbad Limestone Member is correlated (pl. 3), on the basis of the ammonite *Meekoceras* and associated fauna, with the Timpoweap Member in southeastern Utah and with part of the Thaynes Formation in northern Utah. It is also correlated with a unit erroneously called the Virgin Limestone Member of the Moenkopi Formation (Kerr and others, 1957, p. 12, 13) in the Marysvale area, Utah, for that unit also contains *Meekoceras*. The easternmost extension of the Sinbad Limestone Member may be in Salt Valley north of Moab, where faulted outcrops of the Moenkopi Formation contains questionable *Meekoceras* (Shoemaker and Newman, 1959, p. 1849).

LEDGE-FORMING MEMBER

The ledge-forming member is composed of siltstone and very fine grained sandstone and forms a ledgy sequence in the middle of the Moenkopi Formation. It overlies the Sinbad Limestone Member in the San Rafael Swell area, Capitol Reef area, most of the Circle Cliffs area, and in parts of the Orange Cliffs area. In most of the eastern part of southeastern Utah, it overlies the lower slope-forming member. It is in turn overlain by the upper slope-forming member.

The ledge-forming member occurs throughout almost all of southeastern Utah (pl. 4). Everywhere it is difficult to distinguish this member from overlying and underlying members, and locally in the southern part of the Monument Valley area in the area northwest of the junction of the Green and Colorado Rivers, and in the area near Lockhart Canyon (loc. U32), it is difficult or impossible.

The ledge-forming member is absent at The Rincon (loc. U37) near the junction of the San Juan and Colorado Rivers. Here the upper slope-forming member is the only unit within the Moenkopi Formation except for a thin basal conglomerate. This locality lies at or near the highest part of a presumed "high" area that extended roughly along what is now the Colorado River from the Arizona-Utah State line to Hite, Utah.

The ledge-forming member is composed of siltstone and of sandy siltstone and sandstone. The siltstone is grayish red and pale reddish brown, and contains both horizontally laminated and ripple-laminated strata; both cusp and parallel ripple marks occur. This siltstone generally weathers to slopes between the more resistant sandy siltstone and sandstone units in the member.

The sandy siltstone and very fine grained sandstone units are grayish orange, olive gray, pale red, and pale reddish brown and are horizontally laminated, ripple laminated, or cross-stratified on a small scale. Individual units of sandy siltstone and sandstone range in thickness from less than a foot to about 30 feet and are distributed irregularly throughout the member. Some of these units fill small scours cut into the underlying strata. These units weather into ledges and give the member its overall ledgy character.

Petroliferous material is common in the ledge-forming member, and is most common in the sandy siltstone and sandstone units. Such units are commonly olive gray. Locally the entire member is petroliferous and gray.

The member ranges in thickness from more than 300 feet in the western part of southeastern Utah to 100 feet or less in the eastern part (pl. 4).

The contact between the ledge-forming member and the underlying Sinbad Limestone Member is placed at the top of the highest limestone of the Sinbad Limestone Member. Where the Sinbad is absent, the ledge-forming member rests on the lower slope-forming member, and the contact is placed at the change from even-bedded slope-forming siltstone below to a more heterogeneous sequence of slope- and ledge-forming siltstone and sandstone beds above. These upper beds contain, in most places, units of cross-stratified sandstone.

The contact between the ledge-forming member and the overlying upper slope-forming member is placed at a change from ledgy, diversely stratified, commonly coarse grained strata below to even-bedded slope-forming strata above. The upper contact is arbitrary in many places and transitional across as much as 100 feet. The somewhat erratic variation in thickness of the ledge-forming member is probably caused largely by inconsistencies in locating the contact within the transitional unit at the top of the member. The contact was placed at the horizon where the most prominent change in lithologic type occurred, but this horizon undoubtedly was not exactly the same from place to place.

The ledge-forming member probably has no lithologic equivalent outside of southeastern Utah. To the southwest it probably changes facies and is represented somewhere in the lower red, Virgin Limestone, middle red, and Shnabkaib, all members in southwestern Utah (pl. 3). To the northeast, toward Moab, differentiating the ledge-forming member from overlying and underlying members is difficult or impossible. The Ali Baba Member of the Moenkopi Formation, which occurs in the salt anticline region and is questionably recognized at Moab, may be a correlative of the ledge-forming member, as it also is a coarse-grained ledge-forming unit lying between slope-forming units. Available evidence suggests (Shoemaker and Newman, 1959), however, that the Ali Baba Member underlies beds containing a probable *Meekoceras* fauna, the same fauna that occurs in the Sinbad Limestone Member. Because the ledge-forming member overlies the Sinbad Limestone Member in southeastern Utah, it is apparently younger than the lithologically similar beds of the Ali Baba.

UPPER SLOPE-FORMING MEMBER

The upper slope-forming member of the Moenkopi occurs throughout almost all of southeastern Utah, but it is recognized only with difficulty or is indistinguishable from underlying or overlying units in areas where the ledge-forming member is relatively fine grained.

This member is typically composed of a homogeneous, grayish-red and pale-reddish-brown siltstone that is horizontally laminated or, in places, very thin to thick bedded, and that weathers to form smooth earthy slopes. Ripple-laminated layers are sparse, whereas they are common in the lower slope-forming member. The amount of ripple-laminated ledge-forming strata increases eastward in the member. Laminae, beds, and crosscutting veinlets of gypsum occur in the member in the western part of the region.

The member is 200–300 feet thick in most of the San Rafael Swell, Capitol Reef, and Circle Cliffs areas (table 5). It is thinnest in the eastern part of southeastern Utah, where it ranges in thickness from a few feet to about 170 feet.

At the Straight Wash (loc. U7), Block Mountain (loc. U2), and Temple Mountain (loc. U8) sections in the middle segment of the San Rafael Swell, the upper slope-forming member contains more thin, ledge-forming, ripple-marked units than in the northern or southern parts of the Swell. At Straight Wash and Block Mountain, the member is thinner, 120–170 feet, than elsewhere in the Swell. In addition, the cliff-forming member, which is the top member of the Moenkopi Formation, cannot be recognized in these places, yet it is thick and widespread in the northern and southern parts of the Swell. These relationships suggest either (1) that the central segment of the Swell was a slightly uplifted positive area during the time of deposition of the upper slope-forming and cliff-forming members, allowing less total deposition, or (2) that the upper slope-forming and cliff-forming members once were of normal thickness throughout the Swell, and pre-Chinle erosion removed the cliff-forming member and part of the underlying upper slope-forming member in the central segment of that area. In either event, the central part of the Swell was probably a slightly elevated area. The great abundance of ripple-marked strata in the Straight Wash, Block Mountain, and Temple Mountain sections suggests that the upper slope-forming member may have been deposited in a slightly elevated part of the sea floor where currents might have been strong and the formation of ripple marks might be more likely. Deposits elsewhere may have formed in deeper quiet water where currents were slight.

The lower contact of the upper slope-forming member is placed at a surface that marks the change from ledgy ripple-marked and cross-stratified siltstone and sandstone units below to homogeneous, horizontally stratified, slope-forming siltstone above. The upper contact is with the cliff-forming member in the San Rafael Swell, Capitol Reef, and Circle Cliffs areas, and elsewhere it is with the Chinle Formation. The contact with the cliff-forming member marks a subtle change from horizontally stratified strata below to ripple-laminated and horizontally laminated, slightly coarser strata above. It is transitional across many tens of feet and has not been located consistently from place to place. Where the upper contact is with the Chinle Formation, it is marked by a change from red, fairly homogeneous siltstone to either mottled strata, cross-stratified sandstone or conglomerate, or bentonitic claystone.

The upper slope-forming member probably merges southwestward into the lower red, Virgin Limestone, middle red, and Shnabkaib members in southwestern Utah (pl. 3). To the northeast it probably merges into most or all of the lithologically similar Sewemup Member in the salt anticline region (fig. 3).

CLIFF-FORMING MEMBER

The cliff-forming member of the Moenkopi is recognized in only part of the San Rafael Swell, but it is recognized throughout the Capitol Reef and Circle Cliffs areas. The member is composed of pale-reddish-brown and grayish-red horizontally laminated, structureless, or ripple-laminated siltstone. The ripple-laminated strata are in thin to very thick layers interstratified with the horizontally laminated or structureless siltstone and comprise 30–50 percent of the member. Both parallel and cusp ripple marks occur. The ripple-laminated layers are relatively resistant to weathering, and as a result the member as a whole forms a cliff, particularly where protected by resistant strata at the base of the overlying Chinle Formation. The member ranges in thickness from a thin edge to about 230 feet (table 5). In the central part of the San Rafael Swell, as well as in eastern Utah, it either is absent or cannot be recognized.

The contact between the cliff-forming member and the underlying upper slope-forming member is placed at a change from horizontally laminated or structureless siltstone below to siltstone containing abundant ripple-laminated layers above. This contact is transitional across many tens of feet. The upper contact of the member marks a change from red siltstone below to either mottled strata, cross-stratified sandstone, or bentonite claystone of the Chinle Formation above.

The cliff-forming member has not been distinguished east of the San Rafael Swell, Capitol Reef, and Circle Cliffs areas. Along the Colorado River, the upper slope-forming member contains more ripple-laminated strata than to the west where the cliff-forming member is recognized. At the top of the Moenkopi Formation along the Colorado River, perhaps the cliff-forming member is present, but it is indistinguishable from the upper slope-forming member. On the other hand, the cliff-forming member may have been removed by pre-Chinle erosion or may never have been deposited east of the San Rafael Swell, Capitol Reef, and Circle Cliffs areas.

The cliff-forming member possibly correlates with the upper red member of the Moenkopi Formation in southwestern Utah. Both members are characterized by abundant ledge-forming ripple-marked siltstone.

EAST-CENTRAL UTAH AND WEST-CENTRAL COLORADO (SALT ANTICLINE REGION)

In east-cental Utah and west-central Colorado (salt anticline region) the Moenkopi Formation crops out in and around a series of northwest-trending faulted anticlines in Moab, Salt, Castle, Fisher (loc. U128), Sinbad (loc. C37), and Paradox (loc. C15) Valleys (fig. 4). The formation also occurs along the Colorado River in Utah and the Dolores River and the southwest flank of the Uncompahgre Plateau in Colorado.

In the salt anticline region of east-central Utah and west-central Colorado, the Moenkopi was first delimited by Baker, Dobbin, McKnight, and Reeside (1927, p. 796–798), and was subsequently mapped by Baker (1933), Dane (1935), McKnight (1940), Shoemaker (1955, 1956), and Cater (1955a, d). Later, four members within the formation were recognized (Shoemaker and Newman, 1959), which are, in ascending order: the Tenderfoot, Ali Baba, Sewemup, and Pariott Members. The lower three are widely distributed in the region, but the Pariott Member occurs only in and near Castle Valley and in two other isolated areas.

Each of the anticlines along which the Moenkopi Formation crops out is underlain by a thickened mass of salt, gypsum, and clastic sedimentary rock, formed of the Paradox Member of the Hermosa Formation of Pennsylvanian age. These salt anticlines started to form during Pennsylvanian time (Elston and Landis, 1960) and were well formed by Triassic time. Uplift of the salt anticlines during Triassic time effected deposition of the Moenkopi Formation. As the salt masses rose, salt was squeezed from beneath peripheral areas

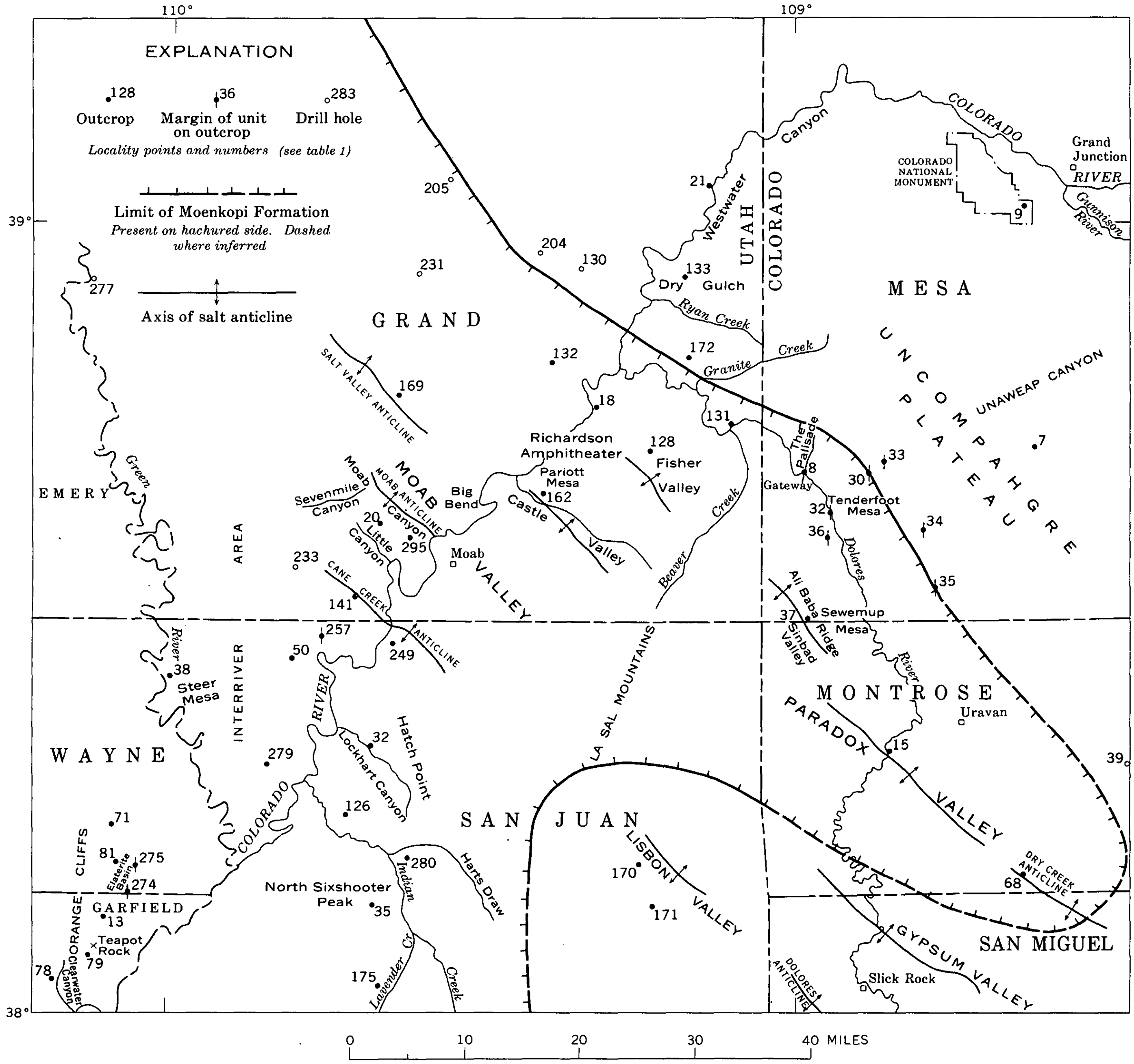

FIGURE 4.—Index map of the salt anticline region. Base from U.S. Geological Survey: Utah and Colorado, 1:500,000.

allowing subsidence to form synclines that partly encircled the intrusions. These synclines are similar to the ring synclines obtained in model experiments by Nettleton (1934, p. 1189). Deposition in the synclines produced very thick deposits. Uplifted areas across the crest of the anticlines, in contrast, received relatively thin sequences of sediment. Locally the formation is absent from the crests of the anticlines, a result both of nondeposition in the uplifted areas and of pre-Chinle erosion.

The Moenkopi Formation is not present in outcrops of Triassic rock throughout the Lisbon Valley, Gypsum Valley, and Dolores anticlines (fig. 4). Its absence on these three anticlines may be due to a regional pinchout of the formation before it reaches this southern part of the salt anticline region or may be due to the local absence of the formation across the crests of the anticlines. The formation may be present on the flanks and between these anticlines in areas where Triassic strata are now covered by younger strata. More data from drill holes should delimit the Moenkopi Formation in the southern part of the salt anticline region.

The Moenkopi Formation ranges in thickness from 350 to 450 feet in much of east-central Utah and west-central Colorado. Near the salt anticlines, however, it differs greatly in thickness from place to place. It is absent on some of the crests of structures and reaches its maximum thickness in local basins adjacent to them. Along the flank of Sinbad Valley anticline (loc. C37), its thickness is 1,264 feet (Shoemaker and Newman, 1959), and it may be 1,300 feet or more along the Colorado River near the flank of Castle Valley anticline; here, however, a complete section is not exposed (Shoemaker and Newman, 1959). On the southwest flank of the Uncompahgre Plateau, the Moenkopi thins and pinches out, owing to thinning of individual beds and to truncation at the top by erosion prior to deposition of the Chinle Formation.

Both the upper and lower contacts of the Moenkopi Formation in this region are unconformities. The formation overlies the Cutler with an angular discordance, ranging from a few degrees to 90°. Discordances in dip, however, are only rarely greater than 5°. Locally across the salt anticlines the Moenkopi rests with sedimentary contact on uplifted beds of the Paradox Member of the Hermosa Formation. Along the southwest side of Moab anticline, a southeastward erosional truncation of the Cutler and Rico Formations and of the uppermost part of the Hermosa Formation below the Moenkopi Formation was described by McKnight (1940) and Baker, Dobbin, McKnight, and Reeside (1927). At Little Canyon, 7 miles northwest of Moab, the Moenkopi overlies the Cutler; southeastward, a minimum of 1,000 feet of the Cutler and Rico Formations and the top 100 feet or so of the Hermosa Formation are cut out, and as a result, in an area 2 miles northwest of Moab, the Moenkopi overlies the Hermosa. This truncation is due to uplift of Pennsylvanian and Permian strata as the salt mass rose during pre-Triassic time, followed by erosion of these uplifted beds before deposition of the Moenkopi Formation.

The Moenkopi Formation is everywhere overlain unconformably by the Chinle Formation. In most places the unconformity is represented by a scour surface on the Moenkopi Formation that is filled with sediment of the Chinle. The scours rarely exceed 10 feet in depth. Locally an angular discordance is noticeable between the Moenkopi and Chinle Formations. Shoemaker (1955) records such a discordance, involving as much at 7°, exposed along the Dolores River southeast of Gateway where the Moenkopi Formation is cut out northeastward toward the Uncompahgre Plateau. Because erosion prior to the deposition of the Chinle Formation removed the Moenkopi across the crests of some of the salt anticlines, the discordance in such places may be sharply angular.

TENDERFOOT MEMBER

The Tenderfoot Member was named by Shoemaker and Newman (1959, p. 1838) for outcrops along the north and west sides of Tenderfoot Mesa about 4 miles southeast of Gateway, Colo. (fig. 4). The member is recognized on all outcrops of the formation in the salt anticline region except possibly along Moab anticline, where it has been only tentatively recognized (Shoemaker and Newman, 1959, p. 1845). The member is divided into four lithologic units (Shoemaker and Newman, 1959, p. 1844); the lower two are thin and discontinuous, whereas the upper two constitute most of the thickness of the member and are widely distributed.

The first or lowest unit is composed of reddish-brown, horizontally stratified and cross-stratified, medium to very coarse grained conglomerate and small amounts of reddish-brown, horizontally stratified, sandy siltstone. The conglomerate contains granules, pebbles, and cobbles of granite, gneiss, schist, and small amounts of quartz and quartzite. This unit consists mostly of arkosic material, probably reworked from the underlying Cutler Formation. It has a limited, spotty distribution and ranges in thickness from a thin edge to 20 feet.

The second unit of the Tenderfoot Member is a bed of gypsum, locally as much as 7 feet thick, which overlies the lower unit of the Tenderfoot in some parts of the region, but rests directly on the Cutler Formation in places where the lower unit is absent. The gypsum is present in less than half of the outcrops of the basal beds of the Moenkopi Formation.

The third unit of the Tenderfoot Member is composed of pale-reddish-brown micaceous siltstone containing scattered fine to very coarse quartz grains. It consists of horizontally stratified, thin to thick beds which contain indistinct wavy laminae. The unit weathers to a massive cliff in most areas. The unit is variable in thickness and locally is absent; commonly it is about 100 feet thick and constitutes more than half of the member. In Sinbad Valley (loc. C37), in west-central Colorado, it reaches a thickness of more than 200 feet.

The fourth and highest unit of the Tenderfoot Member consists of platy and slabby, pale-reddish-brown and grayish-red siltstone that has well-defined horizontal laminae and very thin to thin beds. Locally the unit contains ripple-laminae and some parts of it contain scattered medium to coarse quartz grains. The unit is somewhat similar to the underlying one, but does not contain as many scattered quartz grains and is more distinctly bedded. It is not everywhere present in the region, but in some places is more than 100 feet thick and forms as much as half of the member.

Lateral variation in lithology and thickness within the Tenderfoot Member is great, and the interrelationship of these four units is not completely understood. At the Richardson Amphitheater (loc. U18), the entire Tenderfoot consists of the third unit only, here 112 feet thick. At The Palisade (loc. C8), the first unit is 23 feet thick, the second is missing, the third is 30 feet thick, and the fourth is 68 feet. At Paradox Valley (loc. C15), the first and second units are missing, the third is 71 feet thick, and the fourth is 72 feet. Along Moab anticline, the first and second units are missing and the third is present only at the north end of the line of outcrop. The third unit is about 30 feet thick at Sevenmile Canyon, 10 miles northwest of Moab, and thins to a thin edge at Little Canyon, 7 miles northwest of Moab (fig. 4). The rest of the Tenderfoot Member along Moab anticline is not recognized with certainty, but if it is present it consists of the fourth unit only.

In some areas the upper part of the massive third unit appears to grade laterally into the well-bedded fourth unit (Shoemaker and Newman, 1959, p. 1844–1845), and this may account for some of the lateral variation in lithology within the member. The complex history of sedimentary deposition in the salt anticline region also accounts for some of the lateral variations. The salt masses at times raised the Triassic strata and caused beds to be eroded, and at the same time locally prevented deposition of additional strata. Different periods of salt movement, coupled with slightly different rates of salt movement, may have caused a particular unit to be thick in one area but thin in another.

The third unit of the Tenderfoot Member is lithologically identical to the Hoskinnini Member of the Moenkopi Formation and probably is a physical continuation of the Hoskinnini Member (fig. 3; Stewart, 1959, p. 1864). This correlation is based on the similar lithology of the Hoskinnini and the third unit of the Tenderfoot, and on their similar stratigraphic positions. The Hoskinnini, in areas southwest of Moab, rests directly on arkosic beds of the Cutler Formation. The third unit of the Tenderfoot Member either rests directly on arkosic beds of the Cutler or is separated from these beds by the thin lower two units of the Tenderfoot Member.

The fourth unit of the Tenderfoot Member lithologically resembles the Hoskinnini in some respects, but not in others. Both units are composed dominantly of reddish-brown siltstone, and both contain scattered medium to coarse quartz grains, although these grains are not as common in the fourth unit of the Tenderfoot as in the Hoskinnini Member. The fourth unit is distinctly bedded and locally contains ripple-laminated strata. This type of stratification is foreign to the Hoskinnini and characteristic of strata that overlie it in southeastern Utah. If, however, part of the fourth unit grades laterally into the third unit, as Shoemaker and Newman (1959, p. 1844–1845) suggest, then part or all of the fourth unit may grade laterally into the Hoskinnini Member. The first and second units are most likely discrete units separate from the Hoskinnini Member, but present information does not rule out the possibility that these units grade laterally into the Hoskinnini Member. Thus, although only the third unit of the Tenderfoot is lithologically identical with the Hoskinnini, possibly the entire Tenderfoot may grade laterally into the Hoskinnini Member.

The Tenderfoot Member in most places is 100–150 feet thick but locally at the margin of salt intrusions reaches greater thicknesses. The thickest measured section of this member, 292 feet, is in Sinbad Valley (loc. C37) at the margin of the salt intrusion (Shoemaker and Newman, 1959, p. 1841). The member thins in the vicinity of Gateway, Colo., toward the Uncompahgre Plateau both by thinning of individual beds and by truncation at the top by erosion prior to deposition of the Chinle Formation. The member extends farther eastward at Gateway than the other members of the Moenkopi Formation because pre-Chinle erosion cuts down through the Moenkopi Formation eastward, truncating, in descending order, the Sewemup, Ali Baba, and Tenderfoot Members (Shoemaker and Newman, 1959, p. 1845). Locally across salt intrusions, the Tenderfoot Member is cut out by an angular unconformity at the base of the Ali Baba Member. Such an erosional truncation can be observed in Sinbad (loc. C37) and Paradox (loc. C15) Valleys, Colo., and probably also in Fisher Valley (loc. U128), Utah.

The lower contact of the Tenderfoot Member is a sharp lithologic break marked by a conspicuous unconformity. The Tenderfoot Member is dominantly a reddish-brown to brown siltstone unit and is contrasted with the pale-red arkosic sandstone and conglomeratic sandstone of the Cutler Formation. Where the Tenderfoot Member rests on the Rico or Hermosa Formation, the contact is especially well marked. An angular discordance of 5° or less is common between the Tenderfoot and underlying units, but locally near the margins of salt anticlines the discordance is as great as 90°.

The contact of the Tenderfoot Member with the overlying Ali Baba Member is marked by a change from slope-forming reddish-brown siltstone of the upper part of the Tenderfoot Member to ledge-forming pale-red arkosic sandstone and conglomeratic sandstone at the base of the Ali Baba Member. The contact is marked by a scoured surface underlying the lowest sandstone or conglomeratic sandstone of the Ali Baba Member. Locally, across some of the salt intrusions the contact is an angular unconformity.

ALI BABA MEMBER

The Ali Baba Member was named by Shoemaker and Newman (1959, p. 1838) for exposures on Ali Baba Ridge in Sinbad Valley (fig. 4). The member is characterized by coarse clastic sediments derived from the ancestral Uncompahgre highland and spread into a basin containing dominantly finer grained sediments. The member is recognized on all outcrops of the Moenkopi Formation in the salt anticline region, but its correlation with rocks of the Moab anticline is uncertain.

The Ali Baba Member consists of conglomeratic sandstone and sandstone interstratified with siltstone. The conglomeratic sandstone and sandstone is pale red and grayish red, fine to very coarse grained, and arkosic. The conglomeratic parts contain granules, pebbles, and cobbles of granite, schist, gneiss, quartz, and sandstone. Granules of feldspar occur locally. The layers of sandstone and conglomeratic sandstone are mostly 1–35 feet thick and are indistinctly bedded or cross-stratified in planar or trough sets and on a small to medium scale. The lower contacts of the layers are erosion surfaces that contain many small scours. In addition, convoluted small ridges and knobs, some resembling flow casts (Pettijohn, 1957, pl. 2), occur along the lower surfaces of some of the layers and project into the underlying siltstone beds. These "flow casts" are a distinctive and diagnostic feature of the member.

Intervening siltstone units are grayish red, horizontally laminated to very thin bedded or ripple laminated, and locally are marked by mud cracks. The siltstone layers are mostly ½–30 feet thick.

The Ali Baba Member changes facies within a short distance from northeast to southwest, away from the limit of the Moenkopi Formation, along the front of the Uncompahgre Plateau. In outcrops close to the Uncompahgre Plateau, as at Gateway and nearby sections along the Dolores River, the member is composed dominantly, perhaps 80 percent, of pale-red arkosic, fine to very coarse grained sandstone and conglomeratic sandstone. The gravels are coarse; they contain many cobble-sized fragments.

Away from the Uncompahgre Plateau the amount of pale-red arkosic sandstone and conglomeratic sandstone, the size of the gravels, and the grain size of the sandstone decrease in the Ali Baba Member. The amount of reddish-brown and brown siltstone and fine to very fine grained sandstone increases progressively as the amount of arkosic sandstone and conglomeratic sandstone decreases. At the Richardson Amphitheater (loc. U18), for example, which lies about 6 miles southwest of the limit of the Moenkopi Formation, about 55 percent of the member is pale-red, arkosic, fine to very coarse grained sandstone and conglomeratic sandstone; gravel fragments rarely exceed 2 inches in diameter. In Castle Valley, about 15 miles southwest of the limit of the Moenkopi Formation less than 20 percent of the member is arkosic sandstone. In Castle Valley, the sandstone is dominantly reddish-brown and fine to medium grained, and conglomerate layers are uncommon. The remainder of the member in Castle Valley is reddish-brown and brown siltstone and very fine to fine-grained sandstone.

Along Moab anticline, which lies 26 miles southwest of the limit of the Moenkopi Formation (fig. 4), a sandy and ledgy unit of siltstone is locally present in the middle part of Moenkopi Formation. This unit has been correlated by Shoemaker and Newman (1959, p. 1845) with the Ali Baba Member. It is, however, poorly defined and lithologically is much like overlying and underlying parts of the Moenkopi Formation.

The Ali Baba Member ranges in thickness from about 290 feet to a thin edge (pl. 4). It is removed by erosion toward the Uncompahgre Plateau in the vicinity of Gateway and locally across the salt anticlines where an angular truncation is developed at the base of the Chinle Formation.

The contacts of the Ali Baba Member separate the ledgy arkosic sandstone and conglomeratic sandstone of the member from siltstone and very fine grained sandstone of the overlying and underlying members. The lower contact is a surface of erosion. Locally in Sinbad Valley (loc. C37), Paradox Valley (loc. C15), and around Fisher Valley (loc. U128), an angular unconformity separates the Ali Baba Member from underlying strata. The upper contact of the member is gradational and intertongues with the overlying Sewemup Member. This contact is located by Shoemaker and Newman (1959, p. 1846) at a color change from dark-brown beds below to light-brown beds above. It generally occurs slightly above the highest prominent ledge-forming sandstone of the Ali Baba Member. The color change reflects, in part, the presence of gypsum in beds of the Sewemup Member.

Correlation of the Ali Baba Member with rock units to the southwest of the salt anticline region is not completely understood, but probably the member grades laterally into siltstone and loses its identity within the main mass of the Moenkopi Formation in southeastern Utah (fig. 3). The member is almost inseparable from the rest of the Moenkopi Formation along the Moab anticline.

The Ali Baba Member apparently lies below the *Meekoceras* faunal zone, which occurs in the Sinbad Limestone Member across a large part of southeastern Utah. Fossils, collected by G. A. Williams and identified by J. B. Reeside, Jr., from the Moenkopi Formation of the Salt Valley anticline in T. 22 and 23 S., R. 19 and 20 E., Grand County, Utah (USGS Mesozoic loc. 23869), include ammonites that appear to be *Meekoceras*, although the specimens are too small for positive determination (Shoemaker and Newman, 1959, p. 1849). These specimens are probably from the same locality as those collected by McKnight (Dane, 1935, p. 43). The exact stratigraphic position of the fossils cannot be determined because of very poor exposures and faulting, according to Shoemaker and Newman (1959, p. 1849), but all beds of the Moenkopi Formation in the vicinity of the fossil locality can be assigned with fair certainty to the Sewemup Member.

SEWEMUP MEMBER

The Sewemup Member was named by Shoemaker and Newman (1959, p. 1838) for exposures on Sewemup Mesa, which forms the east wall of Sinbad Valley (fig. 4). The member is generally a homogeneous sequence of siltstone, exhibiting many of the characteristic features of the Moenkopi Formation as a whole.

The member is present in all outcrops of the Moenkopi Formation within the region except near the Uncompahgre Plateau and locally across the salt anticlines, where it has been cut out by erosion prior to deposition of the Chinle Formation.

The Sewemup Member is composed predominantly of pale-reddish-brown and grayish-red micaceous siltstone. In most sections, the siltstone is distinctly and evenly laminated, although some ripple-laminated strata also occur. The amount of ripple-laminated strata is related to the thickness of the member; thicker sections contain dominantly horizontally laminated strata, whereas thinner sections contain as much as 50 percent ripple-laminated strata. Locally the member contains resistant partly cross-stratified beds of sandy siltstone or very fine to fine-grained sandstone. On the northwest side of Richardson Amphitheater (loc. U18), the member contains abundant conglomeratic sandstone beds and is lithologically similar to the underlying Ali Baba Member. Gypsum is commonly present in the member as an interstitial cement or as crosscutting veinlets near the base, and as discrete nodular beds near the top.

The thickness of the Sewemup Member ranges from about 500 feet to a thin edge. The range in thickness is due to thinning of individual beds and to thinning by truncation at the top of the member. Marked changes in thickness and in type of stratification occur within short distances near salt anticlines. One such change is noticeable between Pariott Mesa at the northeast end of Castle Valley and in the cliffs on the northeast side of Richardson Amphitheater, 8 miles to the northeast. At Pariott Mesa (loc. U162), the member is 379 feet thick (Shoemaker and Newman, 1959, p. 1842) and composed dominantly of horizontally laminated siltstone; on the northeast side of Richardson Amphitheater it is about 170 feet thick and includes much ripple-laminated siltstone in addition to horizontally laminated siltstone.

The thick section at Pariott Mesa was probably deposited in a local basin on the flanks of the Castle Valley salt intrusion. The basin probably formed as the salt was squeezed out of an area peripheral to the main salt mass. In this basin, water depths may have been greater and currents weaker than elsewhere, thus accounting for the predominance of supposed quiet-water deposits such as horizontally laminated siltstone. In contrast, outside of the basin, the water may have been shallow and the currents strong, thus accounting for the predominance of supposed current-deposited strata such as ripple-laminated siltstone.

The contact of the Sewemup Member with the underlying Ali Baba Member is gradational and intertonguing. It is located at the color change from dark-brown strata below to light-brown strata above, and this color change marks approximately the highest ledge-forming sandstone of the Ali Baba Member.

In most places in the salt anticline region, the Sewemup Member is unconformably overlain by the Chinle Formation. In a few places, however, as in part of the Castle Valley–Richardson Amphitheater (loc. U18) area, in an isolated belt of outcrops at the Big Bend of the Colorado River about 3 miles west of the northern part of the Castle Valley area, and in the vicinity of Sinbad Valley (loc. C37), it is overlain by the Pariott Member, the highest member of the Moenkopi Formation.

The contact between the Sewemup Member and the Chinle Formation is placed, in most places, below a basal sandstone unit of the Chinle Formation. The sandstone unit is grayish red purple and light greenish gray and fine to very coarse grained; locally it contains granules and pebbles of quartz. It characteristically forms a prominent white band between red beds of the underlying Moenkopi Formation and the overlying part of the Chinle Formation. The unit is discontinuous and ranges in thickness from a thin edge to at least 30 feet. It locally fills small scours cut into the Moenkopi Formation.

Where the basal sandstone unit of the Chinle Formation is not present, location of the contact between the Sewemup Member and the Chinle Formation is difficult to determine and is based on subtle lithologic differences. The siltstone of the Moenkopi Formation is characteristically "chocolate brown," micaceous, and well bedded, whereas the siltstone of the Chinle Formation is "brick red," dominantly nonmicaceous, and is stratified chiefly in indistinct horizontal beds 1–20 feet thick. Locally sandstone beds form a large part of the Chinle Formation, and these are generally coarser, and more cross-stratified, than those in the top part of the Moenkopi Formation. Limestone or siltstone granule-and-pebble conglomerate is abundant in the Chinle Formation, and is sparse in most parts of the Moenkopi Formation of this region.

An angular relationship locally occurs between the Sewemup Member and the overlying Chinle Formation. The angularity is great in a few places above the crests of salt anticlines. An angular discordance of 7° along the Dolores River southeast of Gateway, an area not directly adjacent to a salt anticline, is reported by Shoemaker (1955).

The contact of the Pariott and Sewemup Members is placed at the change from distinctly bedded brown siltstone of the Sewemup to a heterogeneous assemblage of red-brown to purplish-brown sandstone and grayish-red, orange, and red siltstone of the Pariott. The basal unit of the Pariott Member is, in most places, a sandstone which fills small scours cut into the Sewemup Member (E. M. Shoemaker, oral commun., 1958).

The Sewemup Member is lithologically similar to the upper slope-forming member of the Moenkopi Formation in southeastern Utah, and part of the Sewemup may be laterally continuous with this member (fig. 3). In the Salt Valley anticline, however, small ammonites that are tentatively identified as *Meekoceras* occur in strata that are assigned, although with some uncertainty, to the Sewemup Member. If the Sewemup Member contains *Meekoceras*, then it includes strata equivalent in age to the Sinbad Limestone Member, which also contains *Meekoceras*, and to the ledge-forming and upper slope-forming members that overlie the Sinbad Limestone Member in southeastern Utah.

PARIOTT MEMBER

The Pariott Member was named by Shoemaker and Newman (1959, p. 1838) for exposures on Pariott Mesa (loc. U162) on the north side of Castle Valley (fig. 4). The member is recognized on outcrops in the Castle Valley and Richardson Amphitheater (loc. U18) area, on an isolated belt of outcrop at the Big Bend on the Colorado River 3 miles west of Castle Valley, and in the vicinity of Sinbad Valley (loc. C37) (Shoemaker and Newman, 1959, p. 1847).

The member consists of a heterogeneous sequence of red-brown to purplish-brown sandstone and chocolate-brown, orange, and red mudstone, siltstone, and shale (Shoemaker and Newman, 1959, p. 1847). Some of the sandstone beds are conglomeratic. The member is characterized by a variety of colors and by a high sandstone content. Some of the sandstone is ledge forming. The color of the member is similar to that of the overlying Chinle Formation, but the presence of ripple marks and the abundance of mica, both characteristic of the Moenkopi Formation of this area and not of the Chinle, indicate that assignment of the member to this formation is appropriate.

The member is 135 feet thick at the type section on Pariott Mesa, and thickens abruptly to the west. It is several hundred feet thick where it dips beneath the surface beyond the northeast end of Castle Valley (Shoemaker and Newman, 1959, p. 1842, 1847). It is 252 feet thick at a measured section in Sinbad Valley (Shoemaker and Newman, 1959, p. 1839).

The basal contact of the Pariott Member is placed at a change from light-brown, laminated, locally gypsiferous siltstone of the Sewemup Member to brown, red, purple, and orange sandstone and siltstone of the Pariott Member.

The contact of the Pariott Member with the overlying Chinle Formation is well defined in the southern and eastern parts of Castle Valley and in adjoining outcrops in Richardson Amphitheater (loc. U18). Here the basal unit of the Chinle Formation is a light-colored sandstone, in strong contrast with the multicolored beds of the Pariott Member. Field relationships strongly suggest the presence of a low-angle unconformity at the top of the Pariott Member. The Pariott Member thins within a short distance and pinches out below the basal sandstone of the Chinle Formation. The easternmost beds of the Pariott that are truncated can be traced westward into the base of the Pariott in areas where the member is relatively thick.

Along the Colorado River, northwest of Castle Valley and at the Big Bend of the Colorado River, no unconformity has been detected at the top of the Pariott Member, and the Pariott-Chinle contact is difficult to locate. At these localities, the Pariott Member is overlain by a lens of mottled gray silty conglomeratic sandstone which is at least 200 feet thick. This lens was assigned to the Shinarump Conglomerate by Baker (1933, p. 37–38), but to the Chinle Formation by Dane (1935, p. 56) and Shoemaker and Newman (1959, p. 1847). It is assigned by us to the Chinle Formation because similar units elsewhere in southeastern Utah are definitely assignable to the Chinle Formation. The contact of this lens and the Pariott Member appears to be conformable, although exposures of this contact are so limited that its regional significance cannot be demonstrated (Shoemaker and Newman, 1959, p. 1848).

The Pariott Member occurs in only a small part of the salt anticline region and apparently was deposited in small local areas peripheral to salt intrusions. It may represent some of the youngest strata in the formation and is preserved only in local areas around the salt intrusions. The lithologic character of the member is in some respects intermediate in type between that of the Moenkopi and that of the Chinle Formation. The member may contain deposits formed during the time of change from Moenkopi deposition to Chinle deposition and is represented on most of the Colorado Plateau by a hiatus between these formations.

NORTHEASTERN UTAH AND NORTHWESTERN COLORADO (UINTA MOUNTAINS REGION)

The Moenkopi Formation and laterally equivalent strata crop out extensively along the south flank and, to a lesser extent, along the north flank of the Uinta Mountains. The formation also crops out at Cross Mountain (loc. C121) and Vermilion Creek (loc. C122) in northwestern Colorado.

In the western Uinta Mountains, strata laterally equivalent to the Moenkopi Formation are divided into three formations. These formations, in ascending order are (a) the Woodside Formation, a red siltstone, claystone, and sandstone unit; (b) the Thaynes Formation, a gray and brown dominantly carbonate unit; and (c) the Mahogany Formation (new usage), a red siltstone, claystone, and sandstone unit. The Thaynes Formation pinches out eastward (fig. 5) in the eastern Uinta Mountains, and beyond this pinchout the name Moen-

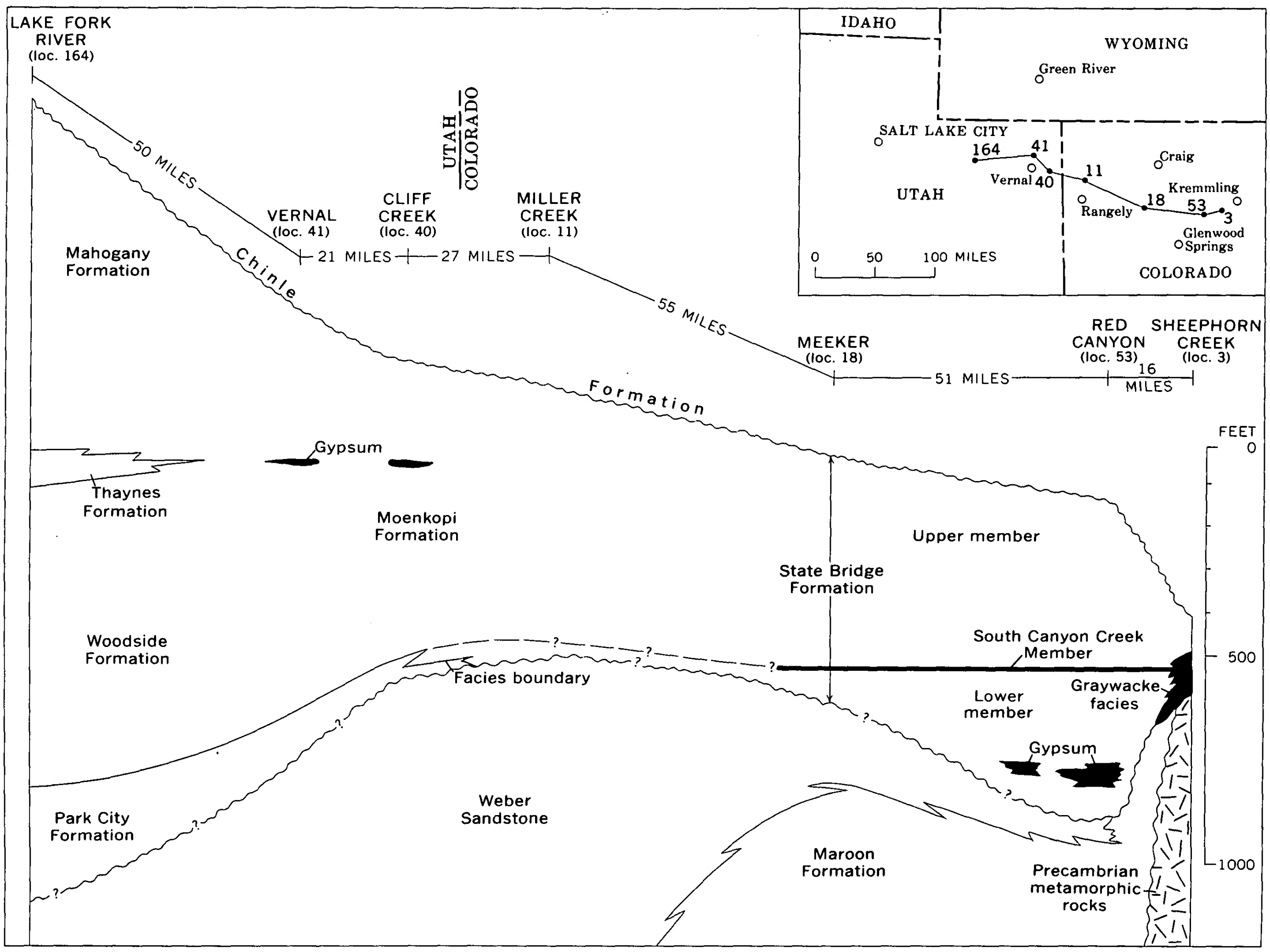

FIGURE 5.—Stratigraphic relations of Permian and Lower Triassic strata between Lake Fork River, Utah, and Sheephorn Creek, Colo.

kopi Formation is applied to the red-bed sequence that contains strata laterally continuous with both the Woodside and Mahogany Formations.

The names Woodside and Thaynes Formations were proposed by Boutwell (1907) in the Park City mining district west of the area discussed here. These names have been applied commonly in the western part of the Uinta Mountains (Mathews, 1931; Williams, 1945; Thomas and Krueger, 1946; Huddle and McCann, 1947a, b; Huddle and others, 1951).

The name Mahogany Formation is applied in this report to strata that have commonly been referred to as Ankareh Formation (restricted) in the western part of the Uinta Mountains. This change is made to overcome the dual use of the term Ankareh by restricting it to the Wasatch Range. In the Wasatch Range, the name Ankareh Formation continues to be used (Calkins and Butler, 1943; Baker, 1947) to include strata equivalent to the upper part of the Moenkopi Formation of Early Triassic age as well as to the Chinle Formation of Late Triassic age. In the Uinta Mountains, on the other hand, the name Ankareh Formation has been used (Mathews, 1931; Williams, 1945; Thomas and Krueger, 1946; Huddle and McCann, 1947b; Huddle and others, 1951) to include only the Lower Triassic part of this sequence. The name Mahogany Formation was originally defined by Kummel (1954) as the Mahogany Member of the Ankareh Formation and refers to only the Lower Triassic part of the sequence. The stratigraphic rank of the Mahogany in the western Uinta Mountains is here changed to formation, and is equivalent to the unit designed the Mahogany Member of the Ankareh Formation in the Wasatch Range.

WOODSIDE, THAYNES, AND MAHOGANY FORMATIONS

The Woodside, Thaynes, and Mahogany Formations are more than 3,000 feet thick in the Wasatch Range of north-central Utah, and they thin eastward to about 1,000 feet in the central Uinta Mountains. The east limit of the Thaynes Formation is near Whiterocks Canyon (loc. U167) in the central Uinta Mountains. These formations have not been examined in detail by us, and therefore their stratigraphic relations are only briefly described.

The Woodside Formation is composed dominantly of red siltstone, claystone, and a small amount of very fine grained sandstone. It is about 1,000 feet thick in parts of the Wasatch Range and thins to about 500 feet in the central Uinta Mountains (Thomas and Krueger, 1946). It extends over a wide area in northern Utah, western Wyoming, and southwestern Montana (Kummel, 1954, p. 170).

Some workers have reported an intertonguing relationship between the Woodside and Park City (Thomas and Krueger, 1946; McKelvey and others, 1956), whereas others have reported an unconformable contact between them (Huddle and McCann, 1947a, b; Huddle and others, 1951). The Mackentire Tongue of the Woodside Formation of Thomas (1939) is a red and gray shaly unit between limestone units of the Franson Member of the Park City Formation that has been interpreted by many geologists (Thomas and Krueger, 1946; McKelvey and others, 1956) as a tongue of the Woodside. Although we have not studied the Park City–Woodside contact in detail, we believe that the Mackentire is not unequivocally established as a tongue of the Woodside, nor is it correlated with certainty outside the type area near Lake Fork River (loc. U164). Therefore, in this report the Mackentire is considered as a unit within the Park City Formation.

Deposition may have been continuous across the Permian-Triassic boundary, for the basal part of the Woodside Formation is believed by us to be Permian in age. This possibility is supported by the presence of fossils, considered of Permian age, 200 feet above the base of the Woodside Formation in western Duchesne County, Utah (Yochelson and others, 1961).

The Thaynes Formation is a limestone unit between red beds of the Woodside and Mahogany Formations. It is composed dominantly of gray to brown, thick- to thin-bedded limestone, and small amounts of sandy limestone and calcareous sandstone (Thomas and Krueger, 1946). It is more than 1,600 feet thick in parts of the Wasatch Range and thins, probably both by lateral gradation and by restricted deposition, to a thin edge near Whiterocks Canyon (loc. U167) in the central Uinta Mountains (pl. 4). Gypsum lenses, however, are present in many places as far east as Cliff Creek (loc. U40), and possibly Miller Creek (loc. C11), and they occur at approximately the same horizon as the thin limestone beds of the Thaynes Formation (fig. 5). This formation extends across a wide area in north-central Utah, eastern Idaho, western Wyoming, and southwestern Montana.

The base of the Thaynes Formation is indicated as a continuous plane (Thomas and Krueger, 1946, fig. 5), suggesting that intertonguing along this contact is minor, if it exists at all. Intertonguing of the upper part of the Thaynes Formation and the overlying basal Mahogany Formation (Thomas and Krueger, 1946, fig. 6; Kummel, 1954, fig. 21) suggests that most of the eastward thinning of the Thaynes Formation may result from lateral gradation of limestone into siltstone at the top of this formation.

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The Thaynes Formation contains an extensive fauna, described mostly from localities outside of the Uinta Mountains (Smith, 1932; Mathews, 1929; Kummel, 1954). This fauna includes fossils from the *Meekoceras*, *Anasibirites*, *Tirolites*, and *Columbites* zones, as well as from the Prohungarian division of Spath (1934, 1951). These zones span a major part of Early Triassic time.

The lower part of the Thaynes Formation probably is physically continuous with the Sinbad Limestone Member of the Moenkopi Formation in central and south-central Utah (pl. 3). The Sinbad Limestone Member occupies a stratigraphic position similar to that of the Thaynes Formation and contains a *Meekoceras* fauna as does the Thaynes (MacLachlan, 1957). The span of deposition of the Thaynes Formation, however, is considerably greater than that of the Sinbad Limestone Member, for it includes several faunal zones in addition to the *Meekoceras* zone which is the only one that has been reported in the Sinbad Limestone Member.

The Mahogany Formation is composed dominantly of red siltstone, claystone, and some sandstone. It ranges in thickness from 450 feet in the Wasatch Range (where it is designated the Mahogany Member of the Ankareh Formation), to 1,400 feet in the western Uinta Mountains, and to 550 feet near the limit of recognition in the central Uinta Mountains (Thomas and Krueger, 1946). The Mahogany Formation intertongues and intergrades extensively with the underlying Thaynes Formation (Thomas and Krueger, 1946), and is unconformably overlain by the Chinle Formation. The Mahogany Formation is assigned to the Lower Triassic.

MOENKOPI FORMATION

East of the pinchout of the Thaynes Formation, in the central and eastern Uinta Mountains, the name Moenkopi Formation is applied to the red-bed sequence containing strata laterally continuous with the Woodside, Thaynes, and Mahogany Formations (fig. 5). The name Moenkopi is applied to these rocks as far east as Coyote basin in northwestern Colorado because their stratigraphic position, lithology, and sedimentary structures are similar to the Moenkopi Formation of central Utah. In addition, regional thickness trends and sedimentary facies of these strata in the Uinta Mountains match those of the Moenkopi of the Colorado Plateau (pls. 4, 5).

Gray and yellow strata (sometimes called tawny beds) below the Moenkopi Formation, previously included in the Moenkopi by many workers, were assigned by Schultz (1918, p. 54) and by Schell and Yochelson (1966) to the Park City Formation, and similar strata were provisionally assigned by Hansen (1955), in the Flaming Gorge quadrangle in the northeastern Uinta Mountains, to the Dinwoody (?) Formation.

Similar strata between the Weber Sandstone and Moenkopi in the easternmost Uinta Mountains in Colorado are also assigned to the Park City Formation in accord with the interpretation of Schell and Yochelson (1966). Thomas, McCann, and Raman (1945) and Thomas and Krueger (1946) have suggested the presence of Park City or Phosphoria age rocks in the easternmost Uintas.

The Moenkopi Formation is composed dominantly of red, brown, orange, yellow, and gray siltstone and minor amounts of very fine grained sandstone, mudstone, claystone, and gypsum.

In general, the Moenkopi Formation increases in coarseness eastward in the eastern Uinta Mountains (pl. 5). Between Vernal (loc. U41) and Miller Creek (loc. C11), for example, sandstone increases about 5 percent. Bedded gypsum decreases eastward from about 4 percent at Vernal to less than 1 percent at Miller Creek.

Gray and yellow zones are common in the Moenkopi Formation in the central and eastern Uinta Mountains. These zones make up about 35 percent of the Vernal section (loc. U41), 8 percent of the Cliff Creek section (loc. U40), and 57 percent of the Miller Creek (loc. C11) section. They generally are parallel or subparallel to the bedding, but in some areas they sharply transect bedding. They are present where the strata are gypsiferous, and they contain abundant petroliferous material.

The Moenkopi Formation is mostly gray at Vermilion Creek (loc. C122) and at Cross Mountain (loc. C121). The colors probably result from reduction of red pigment, presumed to be hematite, to a nonred iron mineral. This reduction may have occurred at the time of deposition, but much of it probably occurred later, being related to the presence of petroliferous material which acted as a reducing agent. The common occurrence of such material in the gray and yellow strata, as well as the somewhat erratic and variable thickness of these strata from place to place, supports the concept of a secondary reducing environment.

In the eastern Uinta Mountains, the tawny beds of the Park City Formation are somewhat different lithologically from the gray and yellow strata of the overlying Moenkopi Formation. The tawny beds of the Park City are composed mainly of silty limestone (Schell and Yochelson, 1966), whereas the gray and yellow strata in the Moenkopi generally are composed of calcareous and gypsiferous siltstone.

The Moenkopi Formation thins eastward in the Uinta Mountains from 971 feet at Vernal (loc. U41) to 616 feet at Miller Creek (loc. C11; pl. 4). It conformably overlies the redefined Park City Formation throughout the eastern Uinta Mountains, according to E. M. Schell (oral commun., 1967). Hansen (1965), however, presents regional evidence for an unconformity between the Park City and Dinwoody in the Flaming Gorge area.

The Park City Formation of Permian age in the eastern Uinta Mountains is the lateral continuation of the Franson Member of the Park City Formation in the western Uinta Mountains. The Moenkopi Formation in the eastern Uinta Mountains is the lateral continuation of the Woodside, Thaynes, and Mahogany (new usage) Formations of Early Triassic age in the western Uinta Mountains. Therefore, an Early Triassic age is assigned to the Moenkopi. Basal strata of the Woodside and Moenkopi have not yielded diagnostic fossils and may contain strata of Permian age.

CENTRAL COLORADO
STATE BRIDGE FORMATION

The unit here referred to as the State Bridge Formation (Donner, 1936, 1949) crops out along the north and west sides of the White River Plateau and in the McCoy-Eagle area. The name State Bridge Formation was given to the rock sequence about one-fourth mile north of State Bridge, Colo., the type locality where about 525 feet of red and yellow siltstone rest on the Maroon Formation of Pennsylvanian and Permian age and underlie the Chinle Formation of Late Triassic age. We follow Brill (1944, 1952), Sheridan (1950), and Murray (1958) in restricting the Maroon Formation to rocks below the Weber Sandstone or, where the Weber is absent, the State Bridge Formation. Hence, in this report we apply the name State Bridge to the rocks between the subjacent Weber or Maroon and the superjacent Chinle as far northwest as Coyote basin in northwestern Colorado. In the Rifle and Glenwood Springs areas, strata that are here called State Bridge Formation were assigned by Brill (1944) to the Dinwoody or Moenkopi Formation. In certain areas, the strata of the State Bridge were previously assigned to the Maroon Formation (Lovering and Johnson, 1933; Bass and Northrop, 1950; and Brill, 1952). In the western part of the White River Plateau area, they were assigned by Thomas, McCann, and Raman (1945) to the Moenkopi and Phosphoria Formations undifferentiated. At Main Elk Creek, they were assigned by Thomas, McCann, and Raman (1945) in part to the Phosphoria(?) Formation and in part to the Chinle Formation.

The State Bridge Formation in the White River Plateau and the McCoy-Eagle areas is composed of three lithologic units or members (fig. 5) which are, in ascending order: (a) a unit of siltstone and lesser amounts of sandstone, referred to as the lower member; (b) a thin gray dolomite and limestone unit (the South Canyon Creek Member), and (c) a unit of red siltstone and subordinate amounts of sandstone and claystone, referred to as the upper member. The South Canyon Creek Member thins south of Glenwood Springs and south and east of Eagle. Beyond this locality in the Eagle area, the State Bridge Formation forms an undifferentiated sequence that is difficult to separate from the underlying Maroon Formation. We have not made a detailed study of this contact in the Eagle area.

The State Bridge Formation thins gradually (pl. 4) to the south and east from about 600 feet in the northwestern part of the White River Plateau to a thin edge a few miles south of Glenwood Springs and along the west flank of the Gore Range.

The State Bridge Formation appears to unconformably overlie the Weber Sandstone throughout much of the region (fig. 5). Most of the evidence for an unconformity between the State Bridge Formation and older rocks in the McCoy area has been summarized by Sheridan (1950). Evidence of an angular unconformity between it and older rocks in the vicinity of McCoy and in the area northwest of McCoy is given by Murray (1949, 1950, 1958). Post-Weber warping and erosion may account for apparent similar stratigraphic relationships south of the White River Plateau.

In the central part of the Maroon depositional basin, the Weber and State Bridge are probably conformable (Murray, 1949, 1958), but along the northeast flank of the basin, toward the Front Range highland, the State Bridge lies with angular unconformity on successively older beds. Figure 5 shows a similar relationship between Red Canyon (loc. C53) and Sheephorn Creek (loc. C146) on the west side of the Gore Range. The lithologic contrast between the State Bridge Formation and the underlying Weber Sandstone or Maroon Formation in central Colorado indicates a change in depositional conditions and suggests a possible widespread unconformity.

The State Bridge Formation is unconformably overlain by the Chinle Formation throughout the central Colorado region.

The South Canyon Creek Member of the State Bridge Formation contains fossils at several localities (Brill, 1944; Bass and Northrop, 1950) that have been dated as Permian. The lower member and the South Canyon Creek Member of the State Bridge Formation are believed by us to be laterally equivalent to the Permian Park City Formation as used by Schell and Yochelson (1966) in the eastern Uinta Mountains; the upper member is here correlated with the lower part of the Moenkopi Formation of the Uinta Mountains and thus is probably, at least in part, Triassic in age.

LOWER MEMBER

The lower member of the State Bridge Formation consists dominantly of red siltstone and small amounts of claystone and very fine grained sandstone. The siltstone and sandstone are composed dominantly of moderately well sorted subrounded to well-rounded grains of quartz, minor amounts of feldspar, and sparse mica.

At South Canyon Creek (loc. C4) the lower member is 56 percent siltstone and 44 percent sandstone; both generally contain scattered medium to very coarse grains of quartz. Most of the strata weather massive and appear structureless; some parts are laminated to thick bedded. Ripple laminae, formed of ripple marks with low index (low ratio of wavelength to amplitude), and contorted laminae are common in the member.

At Oak Ridge (loc. C18), southeast of Meeker, the lower member consists entirely of laminated to thin-bedded and structureless siltstone, except that in the top 6 feet it contains sandstone.

At Red Canyon (loc. C53) near McCoy, the basal part of the lower member contains red interbedded siltstone, claystone, very fine grained sandstone, and limestone, which are chiefly laminated to thin bedded and commonly contain ripple laminae. Above this zone is an interval containing lenticular gypsum which is overlain by red siltstone and small amounts of claystone and very fine grained sandstone.

At Sheephorn Creek (loc. C3) the lower member consists of approximately 80 percent dark-greenish-gray graywacke conglomerate and sandstone and 20 percent red siltstone to fine-grained sandstone. The graywacke conglomerate and sandstone are composed of moderately to poorly sorted, angular to rounded fragments—as much as 11 inches in maximum diameter—of quartz, feldspar, mica, gneiss, schist, granite, and pegmatite in a silty and clayey matrix containing abundant chlorite and biotite. The siltstone and sandstone are composed dominantly of moderately to poorly sorted, subangular to rounded grains of quartz and feldspar and much muscovite and biotite mica. These strata are calcareous and well cemented. The graywacke conglomerate and sandstone occur in lenticular units that are laminated to very thick bedded, and locally contain both medium- and small-scale trough and planar sets of low-angle cross-strata. The red siltstone and sandstone are laminated to thin bedded and commonly contain low-index ripple marks.

The lower member is 90 feet thick at Oak Ridge (loc. C18), about 50 feet at Main Elk Creek (loc. C123), 98 feet at South Canyon Creek (loc. C4), and about 40 feet at Sheephorn Creek (loc. C3). It is 39 feet at Sylvan (loc. C55), 367 feet at Red Canyon (loc. C53), 134 feet at State Bridge (loc. C54), and 164 feet at Kent (loc. C58) (Sheridan, 1950). Thus, thickness in the lower member differs considerably in adjacent areas directly east of the White River Plateau; the thickest sections are in the McCoy-Eagle area.

The lower member seems to unconformably overlie the Weber Sandstone at Oak Ridge, Main Elk Creek, South Canyon Creek, Sylvan, Red Canyon, and Kent. The contact between the Weber and lower member of the State Bridge is placed at the top of the highest light-colored sandstone or conglomerate in the Weber Sandstone, and separates the sandstone and conglomerate of the Weber from the red siltstone of the State Bridge Formation. At State Bridge and Radium, which are east of the Weber margin, the lower member unconformably overlies the red and gray arkosic sandstone and conglomerate of the Maroon Formation (Sheridan, 1950). The contact between the Maroon and State Bridge is placed at the top of the highest arkosic sandstone or conglomerate in the Maroon Formation, and separates the sandstone and conglomerate in it from the red siltstone of the State Bridge Formation (Sheridan, 1950). At Sheephorn Creek the lower member of the State Bridge Formation unconformably overlies Precambrian metamorphic rocks. Red siltstone of the basal State Bridge fills fractures in the upper 10 feet of the Precambrian rocks.

The lower member of the State Bridge Formation grades upward into the South Canyon Creek Member. The contact between these members is placed at the top of the highest red siltstone in the lower member and separates the red siltstone in it from the light-gray dolomite and limestone of the South Canyon Creek Member.

SOUTH CANYON CREEK MEMBER

A thin carbonate unit occurs in the State Bridge Formation throughout the White River Plateau and the McCoy-Eagle area in northwestern Colorado. Along the Grand Hogback west of Glenwood Springs this unit was named the South Canyon Creek Dolomite Member of the Maroon Formation by Bass and Northrop (1950); in the McCoy-Eagle area it was named the Yarmony Limestone Member of the State Bridge Formation by Sheridan (1950), and more recently it has been referred to as the South Canyon Creek Member of the State Bridge Formation (Murray, 1958), a nomenclature adopted in the report. Although a break in outcrop occurs between these two areas, on the basis of lithology, thickness, and stratigraphic position we believe, as did Brill (1952), that the units were initially physically continuous.

The South Canyon Creek Member is 5.6 feet thick at South Canyon Creek (loc. C4) and consists of dolomite and limestone. The limestone, which is restricted to the top 1.5 feet of the unit, contains finely crystalline calcite, chert lenses, vugs and geodes commonly containing black solid hydrocarbon residue and white calcite crystals, wavy to crinkled laminae (probably stromatolite structures), and fossil shell fragments. At Main Elk Creek (loc. C123) the South Canyon Creek Member is similar to the unit at South Canyon Creek. At Oak Ridge (loc. C18) the member consists of silty and sandy limestone and a small amount of cherty limestone. The unit is vuggy and porous and the upper 1.5 feet contains brownish-gray lenses and stringers of chert and wavy to crinkled laminae. In the McCoy-Eagle area the member consists dominantly of silty and sandy limestone and a small amount of chert and glauconite, and at Sylvan (loc. C55), it consists of cherty limestone, limy shale, and limy sandstone (Sheridan, 1950).

Poorly preserved pelecypods, scaphopods, gastropods, and algallike structures occur in the South Canyon Creek Member of the State Bridge Formation at several localities in central Colorado. Pelecypods from the member at South Canyon Creek (loc. C4) were identified by N. D. Newell (in Brill, 1944) as *Pleurophorus* sp. and *Anodontophora* sp. *Anodontophora*, however, has not been reported from any subsequent collections. Pelecypod genera from the member west of Glenwood Springs were identified by S. A. Northrop (in Bass and Northrop, 1950) as *Myalina*, *Pleurophorus*, *Aviculopecten*, *Allorisma*, *Schizodus*, and *Solenomya*. The gastropod genera include *Bellerophon* and *Euomphalus*. Two species of *Plagioglypta* represent the scaphopods. Molds of algallike structures and of the pelecypod genera *Myalina*, *Pleurophorus*, and *Aviculopecten* occur in the member at State Bridge (loc. C54) (Brill, 1942, p. 1393; 1944, p. 636). Molds of *Myalina*, *Pleurophorus*, and *Aviculopecten* occur in a thin unit at Squaw Creek that probably represents the South Canyon Creek Member (Brill, 1944, p. 636, 650). Sparse fossils are reported from the member in the McCoy-Eagle area (Sheridan, 1950, p. 129).

The South Canyon Creek Member west of Glenwood Springs is considered by Bass and Northrop (1950) to be Permian and probably equivalent in age to the Phosphoria Formation. Initially, fossils from this unit had been considered by N. D. Newell (in Brill, 1944, p. 638) to be related to the fauna of the Dinwoody Formation of Early Triassic age. Fossils from the member at State Bridge, however, were considered by Newell (in Brill, 1944, p. 636) as Middle or Late Pennsylvanian or Permian. The unit west of Glenwood Springs containing fossils and the one at State Bridge are considered in this report to be correlative and to be Permian in age.

The thickness of the South Canyon Creek Member averages about 5 feet. Measured thicknesses include 5.6 feet at South Canyon Creek (loc. C4), 5 feet at Main Elk Creek (loc. C123), and 4.8 feet at Oak Ridge (loc. C18). Thicknesses ranging from 1.5 to 6.3 feet, between South Canyon Creek and Butler Creek, are reported by Bass and Northrop (1950). Thicknesses of 6 feet at Sylvan (loc. C55), 4 feet at Red Canyon (loc. C53) and Antelope Creek (loc. C46), 2 feet at Bond (loc. C47), 6 feet at State Bridge (loc. C54), 2 feet at Garden Creek (loc. C49) and Sheephorn Creek (loc. C3), 3 feet near Radium, 10 feet at Posey Creek (loc. C51), 9 feet at Eiby Creek (loc. C48), and 2 feet at Kent (loc. C58) are recorded by Sheridan (1950). The member becomes more arenaceous to the northeast in the McCoy-Eagle area, and thins rapidly east of State Bridge and Radium (Sheridan, 1950).

UPPER MEMBER

The upper member of the State Bridge Formation in the White River Plateau area is dominantly red siltstone with minor amounts of claystone and sandstone. East of the White River Plateau, the upper member contains more sandstone than claystone. The siltstone and sandstone are composed dominantly of subrounded to well-rounded, coarse silt and very fine grained quartz sand with small amounts of feldspar. The siltstone and sandstone are moderately well sorted and contain some mica.

At South Canyon Creek (loc. C4), the upper member is 42 percent siltstone, 42 percent clayey siltstone-silty claystone, and 16 percent sandstone. The siltstone and very fine grained sandstone commonly contain scattered, well-rounded, medium-sized grains of quartz and feldspar. The siltstone and sandstone are chiefly very thin to thick bedded. The beds generally are parallel and persistent; however, a few units at the base and near the top of the member are lenticular. Ripple marks with low index and ripple laminae occur locally in the siltstone and sandstone.

At Oak Ridge (loc. C18) the upper member is 50 percent siltstone, 25 percent claystone, and 25 percent very fine to coarse-grained sandstone. The siltstone units are laminated to thin bedded and contain some ripple-laminated layers; claystone units are laminated, and the sandstone units are laminated to thick bedded. Locally they contain trough and planar sets fo medium- to small-scale, low-angle cross-strata, as well as a few parallel and cusp ripple marks and mud cracks. The stratification is generally parallel.

At Sheephorn Creek (loc. C3), the upper member is 90 percent siltstone and very fine grained sandstone which are thinly laminated to thin bedded and which contain parallel ripple marks with low index. The rest of the member is fine-grained sandstone to granule conglomerate which contains abundant mica and angular to rounded fragments of quartz, feldspar, gneiss, schist, and granite and which occurs in lenticular units that are laminated to thin bedded.

A red-bed unit below the Chinle Formation at East Brush Creek (loc. C2), which is tentatively assigned to the upper member, is 55 percent very fine grained sandstone, 30 percent claystone, and 15 percent siltstone. A few of the very fine grained sandstone units contain scattered coarse grains of quartz. The siltstone and very fine grained sandstone generally are thinly laminated to very thick bedded. The siltstone appears to be structureless in some places. Many of the sandstone units contain trough and planar sets of medium- to small-scale, low-angle cross-strata. Ripple laminae also occur in some of the sandstone, siltstone, and claystone layers.

Zones of gray and yellow strata, which are common in the Moenkopi Formation in the Uinta Mountains and Colorado Plateau, also occur in the upper member of the State Bridge Formation in central Colorado. At Oak Ridge (loc. C18), such a zone is 235 feet thick; its base lies 125 feet above the top of the South Canyon Creek Member. A light-colored zone at State Bridge (loc. C54) is about 140 feet thick; its base lies 150 feet above the top of the South Canyon Creek Member (Donner, 1949). The gray and yellow strata are generally gypsiferous or petroliferous, or both.

The upper member is about 500 feet thick at Oak Ridge (loc. C18), about 70 feet at Main Elk Creek (loc. C123), about 55 feet at South Canyon Creek (loc. C4), least 265 feet at East Brush Creek (loc. C2), and at least 107 feet at Sheephorn Creek (loc. C3). It is 377 feet at Sylvan (loc. C55), 429 feet at Red Canyon (loc. C53), 376 feet at State Bridge (loc. C54), and 331 feet at Kent (loc. C58) (Sheridan, 1950). The thickest sections are present along a line extending from Meeker southeast through Burns.

The contact between the South Canyon Creek Member and upper member is marked by a sharp lithologic change and may represent a hiatus. The contact between the upper member and the overlying Chinle Formation is an erosional unconformity. The strata at the base of the Chinle Formation fill small channels cut into the underlying State Bridge Formation.

The upper member in central and northwestern Colorado is the lateral continuation of the Moenkopi Formation in the eastern Uinta Mountains. Therefore, an Early Triassic age is assigned to the upper member of the State Bridge Formation. Like the Moenkopi, its basal strata have not yielded diagnostic fossils and may contain strata of Permian age.

SEDIMENTARY FACIES

The Moenkopi Formation exhibits a marked change in facies from dominantly horizontally stratified siltstone and claystone and minor amounts of limestone or dolomite in the westernmost part of the Colorado Plateau to cross-stratified and cusp ripple-marked sandstone and siltstone along the east margin of the formation. To investigate and document this change in facies, the amounts of different lithologic types were measured and the results plotted on maps. The sedimentary facies study, in addition to providing basic factual data, led to interpretation of the environments of deposition and of the location of source areas.

Most of the control points used in the study were stratigraphic sections measured by us, but some published and unpublished sections measured by other workers were used. The location of the control points and the lithologic data at those points are shown in table 6. Seventy measured sections scattered over the Colorado Plateau were used in this facies study.

As the differentiation of lithologic types used in the sedimentary facies study depends in large part upon the types of sedimentary structures in the rocks, only information obtained from outcrops proved suitable for use. Data from well logs could not be used because features of sedimentary structure are not usually obtainable from well data. Thus, for large areas of the Colorado Plateau where the Moenkopi Formation is buried beneath younger strata, no control points are given. Where feasible, facies patterns are interpolated across these areas, but where distances are great, these areas are left blank on the facies maps.

LITHOLOGIC TYPES

For the purpose of the sedimentary facies study, the rocks of the Moenkopi Formation and equivalent strata are divided into five lithologic types, each believed to represent a specific environment of deposition. These lithologic types are: (1) cross-stratified sandstone and siltstone, (2) parallel ripple-laminated siltstone, (3) horizontally stratified siltstone and claystone, (4) primary gypsum, and (5) limestone and dolomite.

CROSS-STRATIFIED SANDSTONE AND SILTSTONE

Under the heading of cross-stratified sandstone and siltstone are grouped the coarsest grained rocks in the Moenkopi Formation including cross-stratified sandstone, coarse siltstone, and conglomerate. Some of the conglomerate consists of lenses containing siliceous pebbles; some contains clasts of claystone and limestone. Characteristic cross-stratification consists of trough sets of low- or high-angle, small- to large-scale cross-strata.

(See classification of McKee and Weir, 1953, p. 385.) Less common are tabular and wedge-shaped planar sets of small- to medium-scale cross-strata. The cross-stratified sandstone and siltstone typically weather to form cliffs and ledges (fig. 6), and occur in thin to very thick sets interstratified with horizontally stratified siltstone and claystone and, to a lesser extent, with ripple-laminated siltstone. In general, the term "cross-stratified sandstone and siltstone" corresponds to the term "thick-bedded sandstone and siltstone" as used by McKee (1954, p. 39).

Sandstone and coarse siltstone containing indistinct horizontal bedding, interference ripple marks, scour surfaces, current lineation, plant fragments, and tetrapod tracks and bones are also included under the heading of cross-stratified sandstone and siltstone. These strata generally occur in the same ledge-forming units as the cross-stratified layers. Strata containing cusp ripple marks, which consist of irregular crescent-shaped ridges and intervening irregular depressions (fig. 7), are associated with cross-stratified layers in some places, but in other places they are associated with ripple-laminated strata containing parallel ripple marks. Strata containing cusp ripple marks are classed with cross-stratified sandstone and siltstone in places where they are associated with cross-stratified rocks, and elsewhere are classed with parallel ripple-laminated siltstone. Such an assignment of ripple-marked strata of cusp type is arbitrary, but the amount of these strata is relatively small in the Moenkopi Formation, and their assignment to one or another category does not significantly change the overall facies pattern in the formation.

Locally, strata of an unusual lithologic type or with an unusual type of cross-strata are included under the heading of cross-stratified sandstone and siltstone. For example, in the Lees Ferry area, the lower massive sandstone unit of the Moenkopi Formation, which elsewhere is cross-stratified sandstone and siltstone, grades westward into gypsiferous sandstone and gypsum which is composed largely of wedge planar sets of high-angle, medium-scale cross-strata. This gypsiferous unit, as discussed later, may have formed as sand dunes whereas the typical cross-stratified sandstone probably formed

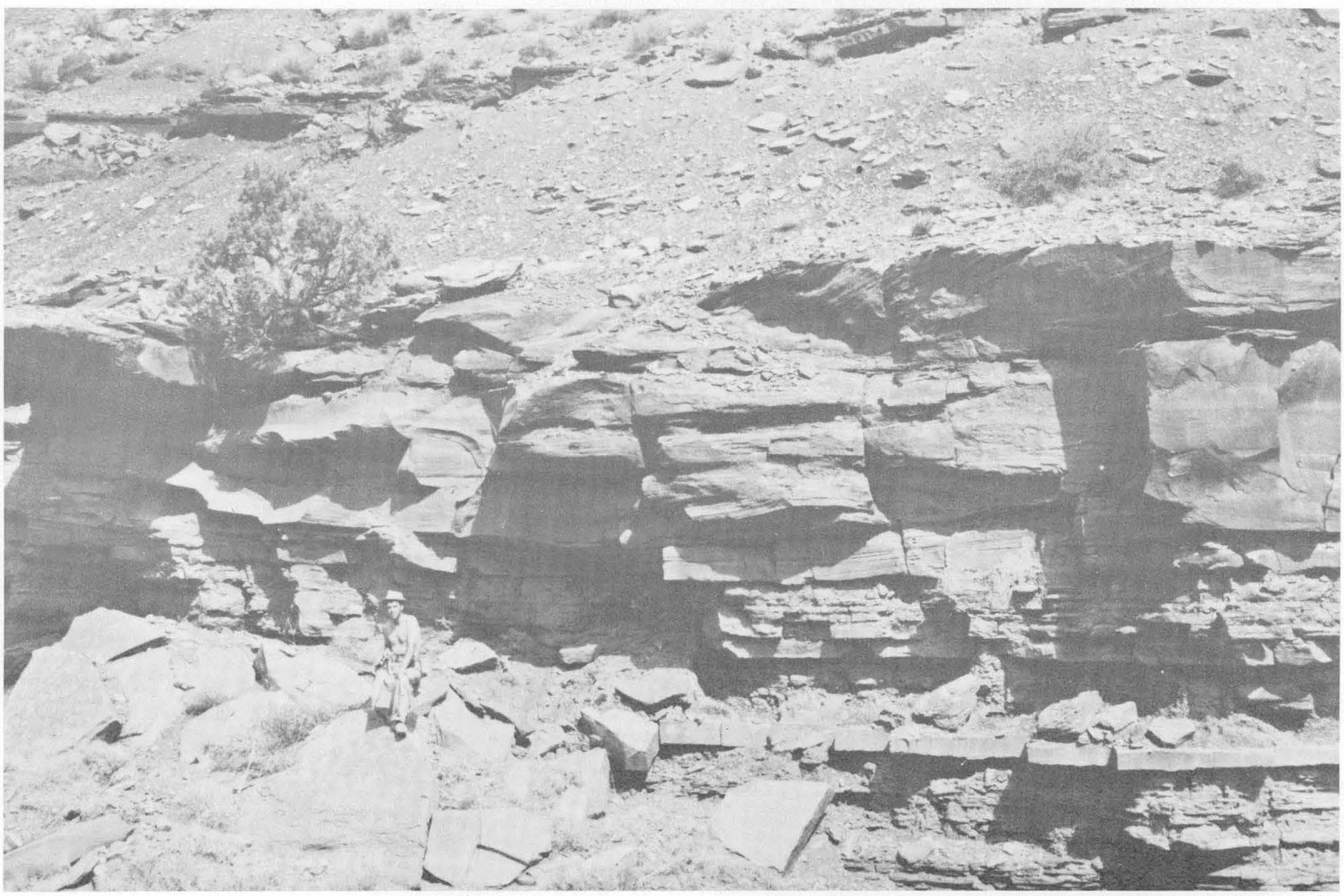

FIGURE 6.—Cross-stratified ledge-forming sandstone and siltstone and overlying and underlying horizontally stratified siltstone in ledge-forming member of Moenkopi Formation near east end of Red Canyon, Utah (near loc. U109).

TABLE 6.—*Data for sedimentary facies study of Moenkopi Formation* [1] *and related strata, arranged alphabetically by locality name*

[Explanation of symbols: Leaders (...) indicate data not calculated because unit not present; ∞, infinity; ~, approximate; question mark indicates uncertainty as to presence of unit, or it indicates percents and ratios not known because of incomplete data; plus symbol (+) standing alone indicates unit present but thickness unknown]

Locality No.	Locality	Thickness (feet)			Quiet-water deposits (percent) (A)			Confined-current deposits (percent) (B)			Unconfined-current deposits (percent) (C)			Channel-deposit ratio B/C			Current-deposit ratio (B+C)/A		
		Total	Lower part	Upper part	Total	Lower part	Upper part	Total	Lower part	Upper part	Total	Lower part	Upper part	Total	Lower part	Upper part	Total	Lower part	Upper part
U25	Bears Ears	222	27	195	50.5	84.6	46.2	40.4	11.5	44.0	9.1	3.8	9.7	4.4	3	4.5	0.98	0.18	1.2
A15	Big Canyon	308	0	308	57.3	...	57.3	17.6	...	17.6	24.9	...	24.9	.71	...	.71	.75	...	.75
A1	Black Creek	169	0	169	59.4	...	59.4	27.0	...	27.0	13.5	...	13.5	2	...	2	.68	...	.68
U2	Block Mountain	604	177	427	55.6	76.8	47.3	15.8	0	22.1	28.5	23.3	30.6	.55	0	.72	.80	.30	1.1
U26	Bridger Jack Mesa	217	37	180	43.7	55.0	40.3	28.4	0	36.9	27.9	45.0	22.9	1.02	0	1.6	1.3	.82	1.5
U9	Buckacre Point	379	93	286	48.3	35.8	51.6	30.6	38.5	28.4	21.4	25.6	20.0	1.4	1.5	1.4	1.1	1.8	.94
A79	Cameron, 12 miles NW [2]	288	0	288	57.1	...	57.1	17.8	...	17.8	25.1	...	25.1	.71	...	.71	.75	...	.75
U42	Capitol Wash	833	179	654	69.0	82.0	65.5	15.0	9.5	16.4	16.1	8.5	18.1	.93	1.1	.91	.45	.22	.53
A18	Cedar Ridge	414	0	414	62.5	...	62.5	16.7	...	16.7	20.8	...	20.8	.80	...	.80	.60	...	.60
NM1	Chavez-Prewitt	26	0	26	55.1	...	55.1	37.2	...	37.2	7.7	...	7.7	4.8	...	4.8	.82	...	.82
U43	Chimney Rock	921	249	672	65.9	82.3	60.5	16.4	0	22.0	17.7	17.7	17.6	.93	0	1.2	.52	.22	.65
U173	Clay Gulch	336	38	298	60.8	67.4	59.9	18.2	0	20.5	21.0	32.6	19.6	.87	0	1.1	.64	.48	.67
U49	Clay Hills Pass	320	44	276	57.3	70.5	55.2	22.7	0	26.3	20.0	29.5	18.4	1.1	0	1.4	.75	.42	.81
U40	Cliff Creek	685	443	242	65.0	58.5	75.0	1.5	0	4.1	33.5	40.0	21.0	.04	0	.20	.54	.68	.33
A19	Coconino Point	372	0	372	57.1	...	57.1	27.0	...	27.0	15.9	...	15.9	1.7	...	1.7	.75	...	.75
U27	Comb Wash	202±	48±	154±	55.6	56.8	55.0	24.7	17.7	26.8	19.8	25.5	18.1	1.2	.69	1.5	.80	.76	.82
A68	Concho [2]	114+	0	114+	35.0	...	35.0	65.0	...	65.0	0	...	0	∞	...	∞	1.8	...	1.0
U28	Cottonwood Creek	179	62	117	38.4	64.7	24.6	41.9	1.1	63.3	34.2	12.1	38.4	2.1	.03	5.2	1.6	.55	3.1
C2	East Brush Creek	265+	265+	0	44.0	44.0	...	26.0	26.0	...	30.0	30.0	...	.86	.86	...	1.3	1.3	...
A73, 74	East of Black Point combined with Black Falls [2]	381	0	381	69.5	...	69.5	18.5	...	18.5	12.0	...	12.0	1.5	...	1.5	.44	...	.44
A12	East Sunset Mountain	444	0	444	81.2	...	81.2	13.6	...	13.6	5.2	...	5.2	2.6	...	2.6	.23	...	.23
NM3	Fort Wingate	36	0	36	38.0	...	38.0	62.0	...	62.0	0	...	0	∞	...	∞	1.6	...	1.6
A87	Fredonia [2]	1,188±	0	1,188±	78.4	...	78.4	4.5	...	4.5	17.1	...	17.1	.26	...	.26	.27	...	.27
U29	Hite	287	6	281	49.2	0	50.1	33.0	100.0	31.5	17.8	0	18.4	1.8	∞	1.7	1.03	∞	1
A60	Holbrook [3]	158	0	158	69.0	...	69.0	27.5	...	27.5	3.5	...	3.5	7.9	...	7.9	.45	...	.45
A104	Holbrook Quarry [4]	175	0	175	67.4	...	67.4	24.0	...	24.0	8.6	...	8.6	2.8	...	2.8	.48	...	.48
U10	Horse Canyon	613	67	546	73.3	100.0	70.1	8.7	...	9.8	18.0	...	20.1	.49	...	.49	.36	0	.43
N1	Horse Spring valley	1,816	0	1,816	88.5	...	88.5	7.5	...	7.5	4.0	...	4.0	1.8	...	1.8	.13	...	.13
A5	Hunters Point	43	0	43	77.5	...	77.5	22.5	...	22.5	0	...	0	∞	...	∞	.29	...	.29
U30b	Jacobs Chair	260	20	240	48.3	86.5	45.7	34.3	13.5	35.8	17.4	0	18.6	2	∞	1.9	1.1	.16	1.2

U22	Kanarraville	1,871±	450±	1,421	86.3	78.0	89.0	7.7	22.0	3.1	6.0	0	7.9	1.6	∞	.39	.23	.28	.12
U32	Lockhart Canyon	266	113	153	54.8	533.0	56.4	10.2	8.4	11.5	35.0	38.0	32.1	.29	.22	.36	.82	.89	.77
C18	Meeker	504	504	0	47.5	47.5	----	4.0	4.0	----	48.5	48.5	----	.08	.08	----	1.1	1.1	----
NM20	Mesa Gallina	212	0	212	65.1	----	65.1	23.1	----	23.1	11.8	----	11.8	2	----	2	.54	----	.54
U48	Mexican Bend	883	234	649	61.0	64.2	60.0	12.7	3.4	16.0	26.3	32.4	24.0	.48	.10	.67	.64	.56	.67
U33	Milk Ranch Point	238	59	179	63.6	58.7	65.3	24.1	0	28.5	15.0	41.3	6.2	1.4	0	4.6	.57	.70	.53
C11	Miller Creek	616	334	282	58.5	70.4	45.0	11.5	3.0	21.2	30.0	26.6	33.8	.38	.11	.63	.71	.42	1.2
U20	Moab Canyon	323	199	124	43.3	43.6	40.0	25.2	28.4	20.0	31.5	28.4	40.0	.80	1	.50	1.3	1.3	1.5
U34	Monitor Butte	310	47	263	56.7	71.8	54.4	24.8	0	28.3	18.6	28.2	17.2	1.3	0	1.6	.77	.39	.84
U6	Muddy River	821	216	605	65.3	68.9	63.9	6.5	1.7	8.3	28.2	29.3	27.8	.23	.06	.30	.53	.45	.56
U11	Muley Twist	483	15	468	57.1	55.2	57.1	28.5	44.8	27.9	14.6	0	15.0	2	∞	1.9	.75	.81	.75
U35	North Sixshooter Peak	295	95	200	60.2	69.7	55.5	17.2	11.3	20.2	22.6	19.0	24.4	.76	.59	.83	.66	.43	.80
A21	Ott Mountain	396+	0	396+	37.1	----	37.1	40.1	----	40.1	22.8	----	22.8	1.8	----	1.8	1.7	----	1.7
A13	Owl Rock	156	31	125	51.3	51.6	51.3	32.0	38.7	30.2	16.7	9.7	18.5	1.9	4	1.6	.95	.94	.95
C15	Paradox Valley	321	199	122	47.1	29.9	69.6	32.4	55.8	2.0	20.5	14.3	28.4	1.6	3.9	.07	1.1	2.3	.44
U162	Pariott Mesa [5]	778	264	514	48.5	27.3	59.4	33.0	58.2	20.0	18.5	14.5	20.6	1.8	4	.97	1.1	2.7	.69
U36	Poncho House	114	+	+	48.0	?	?	32.8	?	?	19.2	?	?	1.7	?	~1.7	1.1	?	~1.1
U13	Range Canyon [6]	336	108	228	51.4	62.9	45.8	27.4	7.6	37.2	21.1	29.5	17.0	1.3	.26	2.2	.94	.59	1.2
U208	Red Canyon	243	39	204	50.1	71.9	46.0	31.4	15.3	34.5	18.5	12.8	19.6	1.7	1.2	1.8	1	.39	1.2
A16	Red Point	592	0	592	59.5	----	59.5	10.5	----	10.5	32.0	----	32.0	.33	----	.33	.74	----	.74
U18	Richardson Amphitheater	325	152	173	43.7	25.5	61.8	30.1	54.8	5.4	26.2	19.7	32.8	1.2	2.8	.16	1.3	2.9	.62
NM16	Riley	161	0	161	66.5	----	66.5	19.0	----	19.0	14.5	----	14.5	1.3	----	1.3	.50	----	.50
U47a	St. George	1,828	0?	1,828	92.0	----	92.0	5.0	----	5.0	3.0	----	3.0	1.7	----	1.7	.12	----	.12
A9	St. Johns	50	0	50	22.0	----	22.0	78.0	----	78.0	0	----	0	∞	----	∞	3.5	----	3.5
NM17	Sevilleta Grant	101	0	101	41.6	----	41.6	44.6	----	44.5	13.8	----	13.8	3.2	----	3.2	1.4	----	1.4
U50	Shafer Canyon	392	143	249	60.2	60.9	60.0	19.4	7.7	26.0	20.4	31.5	14.0	.95	.24	1.8	.66	.65	.67
C3	Sheephorn Creek	126	126	0	24.0	24.0	----	20.0	20.0	----	56.0	56.0	----	.36	.36	----	3.2	3.2	----
U14	Silver Falls Creek	394±	20	374±	55.3	70.0	54.5	21.6	30.0	21.2	23.1	0	24.3	.94	∞	.87	.81	.43	.83
C37	Sinbad Valley [5]	1,030	341	689	48.3	38.8	53.2	41.3	44.1	39.8	10.4	17.2	7.0	4	2.6	5.7	1.1	1.6	.88
A23	Soap Creek	559	0	559	63.2	----	63.2	7.3	----	7.3	29.5	----	29.5	.25	----	.25	.58	----	.58
C4	South Canyon Creek	56	56	0	69.0	69.0	----	0	0	----	31.0	31.0	----	0	0	----	.45	.45	----
U38	Steer Mesa	448	199	249	68.8	58.6	76.9	13.4	18.6	9.3	17.8	22.7	13.8	.75	.82	.67	.45	.70	.30
U8	Temple Mountain	614	166	448	61.0	71.2	56.7	14.9	2.6	20.0	24.1	26.2	23.3	.62	.10	.86	.64	.40	.76
A24	The Gap	233	0	233	57.0	----	57.0	24.1	----	24.1	18.9	----	18.9	1.3	----	1.3	.76	----	.76
C8	The Palisade	119	119	0	35.2	35.2	----	49.6	49.6	----	15.2	15.2	----	3.3	3.3	----	1.8	1.8	----
U37	The Rincon	64	0?	64	?	----	?	?	----	?	?	----	?	>1	----	>1	>1	----	>1
U41	Vernal	971	615	356	83.0	87.7	74.1	4.0	3.0	5.9	13.0	9.2	20.0	.31	.33	.29	.22	.14	.35
A75	West of Black Point [2]	355	0	355	68.4	----	68.4	14.0	----	14.0	17.5	----	17.5	.80	----	.80	.46	----	.46
A70	Winslow [2]	250	0	250	56.3	----	56.3	30.2	----	30.2	13.5	----	13.5	2.2	----	2.2	.78	----	.78
A69	Woodruff Butte [2]	237?	0	237?	54.1	----	54.1	41.7	----	41.7	4.2	----	4.2	9.9	----	9.9	.85	----	.85

[1] Hoskinnini Member and equivalent strata are excluded from all calculations and thickness figures.
[2] Data obtained from sections measured by McKee (1954); some sections modified by us.
[3] Data obtained from section measured by M. E. Cooley and J. P. Akers.
[4] Data obtained from section measured by Welles (1947).
[5] Data obtained from sections measured by Shoemaker and Newman (1959).
[6] Sandstone and conglomerate unit excluded from facies study at Range Canyon because this unit is probably equivalent to strata below the Hoskinnini Member. (See fig. 3.)

in stream channels. This gypsiferous unit is nonetheless assigned to the category of cross-stratified sandstone and siltstone. A second example is in the Clay Hills area and at Monitor Butte (loc. U34) in southeastern Utah, where the Moenkopi Formation commonly contains sandstone and siltstone units with some large planar sets of low to very low angle, medium- to large-scale, tangentially inclined cross-strata resembling the type of cross-stratification characterizing the upper foreshore of beaches. These strata are also included in the general heading of cross-stratified sandstone and siltstone.

Strata included under the heading of cross-stratified sandstone and siltstone are the common to dominant lithologic types in the eastern and southeastern parts of the depositional basin of the Moenkopi Formation, and are present in almost all sections of the formation examined elsewhere. This lithologic type is most abundant near what is believed to have been the source areas of the formation. It generally forms the dominant lithologic type in the Ali Baba and Holbrook Members and in the ledge-forming member of the Moenkopi. It is a common lithologic type in many other units of the formation.

PARALLEL RIPPLE-LAMINATED SILTSTONE

Siltstone containing parallel ripple marks is one of the most distinctive lithologic types in the Moenkopi Formation (fig. 8). The parallel ripple marks are defined as ripple marks that have even parallel ridges and troughs in plain view and may be symmetrical or asymmetrical in cross section (McKee, 1954, p. 57). The ripple-marked strata commonly contain, or are closely interstratified with, strata containing mud cracks, casts

FIGURE 7.—Cusp ripple marks in Moenkopi Formation near Hite, Utah.

FIGURE 8.—Parallel ripple marks on several different layers, in Moenkopi Formation in Red Canyon, Utah (near loc. U109).

of salt crystals, and raindrop prints. Cusp ripple-marked strata are commonly associated with parallel ripple-marked strata and are included with the parallel ripple-marked strata where the two are associated. Parallel ripple-laminated siltstone occurs interstratified with all other lithologic types in the Moenkopi Formation, but is most commonly interstratified with horizontally stratified siltstone and claystone. Generally the parallel ripple-laminated strata consists of siltstone. This rock is intermediate in grain size between those referred to as "cross-stratified sandstone and siltstone" and "horizontally stratified siltstone and claystone." The ripple-laminated siltstone typically occurs in sets that range in thickness from a few inches to several feet; these sets weather to form ledges or small benches. In general, the term "parallel ripple-laminated siltstone," as used in this report, corresponds to the term "shaly siltstone," as used by McKee (1954, p. 42).

Parallel ripple-laminated siltstone is conspicuous in the Moenkopi Formation at most localities. The highest percentage of ripple-laminated strata in the formation occurs in a northerly trending belt across the central part of the Colorado Plateau between areas characterized by abundance of horizontally stratified siltstone, limestone, or dolomite on the west and by cross-stratified sandstone and siltstone on the east.

HORIZONTALLY STRATIFIED SILTSTONE AND CLAYSTONE

Horizontally stratified siltstone and claystone, which is the dominant lithologic type throughout the Moenkopi Formation except at a few control points along the east and southeast margins of its depositional basin, is marked by stratification that ranges from papery laminations to very thick, seemingly structureless beds (fig. 9). The stratification commonly is persistent laterally; individual strata may be traced for considerable distances along the outcrop. However, some horizontally laminated siltstone and claystone is lenticular; individual laminae may persist for only a few inches or feet. Sedimentary features that can be observed on outcrop, other than horizontal stratification, are rare in the horizontally stratified siltstone and claystone. Horizons of "core-and-shell" structures, described by McKee (1939; 1954, p. 65) and believed by him to be due to shrinkage during the drying of uniform structureless mud, are present in some localities. In a few places, mud-cracked surfaces are preserved at the top of horizontally stratified siltstone layers and beds. The horizontally stratified siltstone and claystone contains the finest grained strata in the Moenkopi Formation and locally grades laterally westward into limy siltstone or silty limestone. It generally weathers to slopes or recesses between ledges and cliffs formed by other lithologic types. In general, the term "horizontally stratified siltstone and claystone," as used in this report, corresponds to the term "structureless mudstone" as used by McKee (1954, p. 44).

PRIMARY GYPSUM

Primary gypsum is present in the Moenkopi Formation in the form of flat nodules along bedding planes and in stratified lenses and layers ranging from laminae to thick beds. Secondary gypsum, in the form of veinlets crosscutting stratification planes, is common throughout most of the Moenkopi, but, because it does not represent primary deposition and thus is not an indication of sedimentary environment, its amount and distribution were not considered in this sedimentary facies study.

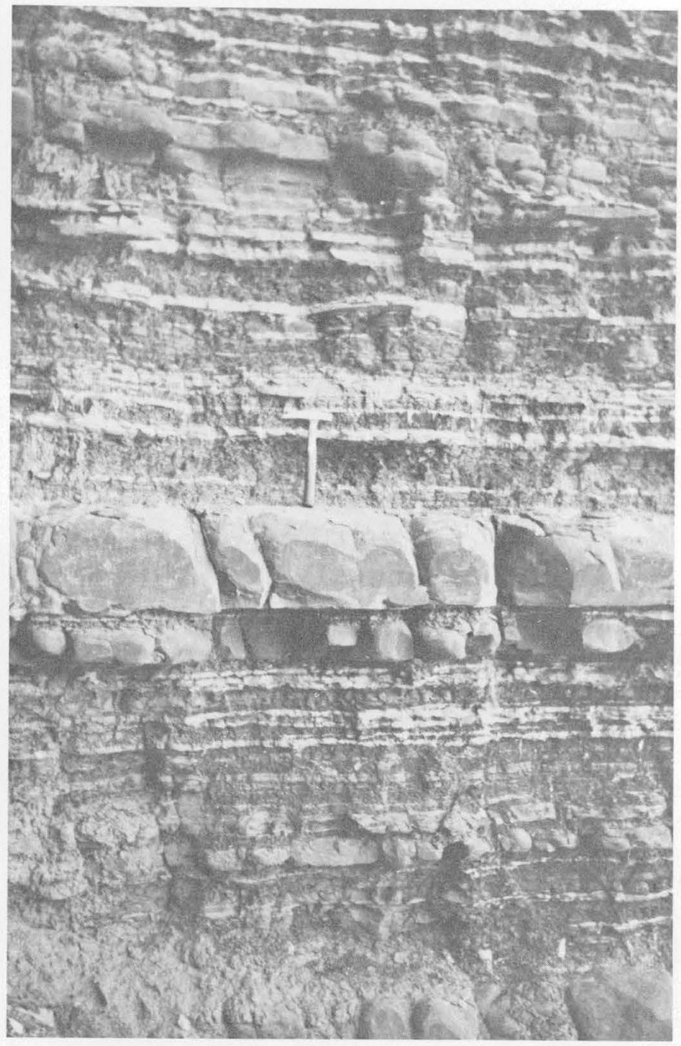

FIGURE 9.—Moenkopi Formation at Bridger Jack Mesa, Utah, (near loc. U26), showing even bedding and lamination.

Primary gypsum in the Moenkopi Formation generally is interstratified with horizontally stratified siltstone and claystone. Less commonly, it is interstratified with parallel ripple-laminated siltstone. In the southwestern part of the Colorado Plateau and in southern Nevada, laminae to thin beds of primary gypsum are interstratified with silty limestone of the Shnabkaib Member. Some primary gypsum also occurs as a cementing agent in gypsiferous siltstone of the Shnabkaib and Moqui Members.

Primary gypsum forms at least 15 percent of the Moenkopi at some localities in the western and southwestern parts of the depositional area of the formation, but is sparse or absent in much of the eastern part of the depositional area. Stratigraphically, primary gypsum in the Moenkopi Formation is common to abundant in the Shnabkaib and Moqui Members, and is common to sparse in the remaining parts of the formation.

LIMESTONE AND DOLOMITE

Limestone and dolomite in the Moenkopi Formation occur in very thin to very thick sets interstratified with horizontally stratified siltstone and claystone and locally with primary gypsum. Many of the carbonate rocks occur in widespread members such as the Sinbad Limestone Member and the Timpoweap Member. Owing to the difficulty of distinguishing between limestone and dolomite in the field, the two rock types were not separated in the sedimentary facies study.

Much of the limestone and dolomite is aphanitic; some is oolitic, and locally some is composed of organic debris. Clay, silt, and sand are commonly admixed with the carbonate minerals. The limestone and dolomite, in most places, occur as horizontal layers ranging from laminae to very thick beds. Cross-stratified units are common and many of them are oolitic. Some of the cross-strata occur in trough sets, but most form thin tabular planar sets. Marine invertebrate fossils are fairly common in some of the limestone units in the western part of the depositional basin.

Limestone and dolomite are common to dominant lithologic types in the Virgin Limestone Member and Timpoweap Member in southwestern Utah, the Shnabkaib Member in southwesternmost Utah and southern Nevada, and the Sinbad Limestone Member in southwestern Utah. The Thaynes Formation in the Uinta Mountains of northern Utah, stratigraphically equivalent to part of the Moenkopi Formation, also contains limestone and dolomite as the dominant lithologic type. A few thin lenses of limestone and silty limestone occur locally in the Moenkopi Formation in northeastern Arizona.

The limestone and dolomite in the Moenkopi Formation increase toward the west and northwest on the Colorado Plateau and form significant amounts of the formation only in the western and northwestern parts of the depositional area. Plate 5 shows the amount of marine limestone and dolomite in the formation. The marine origin of most of the limestone and dolomite is indicated by contained fossils. A few thin lenses of limestone and silty limestone, probably of fresh-water origin, occur in northeastern Arizona but are not included in the figure.

METHOD OF FACIES ANALYSIS

The facies maps were developed by grouping the strata in the Moenkopi Formation at each control point into three categories based upon lithologic types: (A) horizontally stratified siltstone and claystone plus limestone, dolomite, and primary gypsum, believed to represent dominantly quiet-water deposition; (B) cross-stratified sandstone and siltstone, believed to represent dominantly channel or confined-current deposition; and (C) parallel ripple-laminated siltstone believed to represent largely "sheet-flow" or unconfined-current deposition.

Included under the heading of "sheet-flow" or unconfined-current deposition are strata that may have formed in part by wave action. Ripple-laminated strata, consisting of superposed ripple-marked layers, are formed either by currents or by waves, and the essential factor in their formation is the introduction of an abundance of sediment into an area of ripple movement (McKee, 1965). Such conditions are commonly met on river flood plains, and thus much of the ripple-laminated strata in the Moenkopi Formation may have had this origin. On the other hand, at least some of the ripple-laminated strata could have formed by currents or waves on tidal flats or in a shallow marine environment.

The three categories of lithologic types (A, B, and C) which are interpreted to reflect process of deposition are treated as end members of a conventional triangular diagram (pl. 5). This triangular diagram is divided, on the basis of two ratios, into fields. These ratios (table 6) are:

$$\text{(1) channel-deposit ratio} = \frac{\text{percent of channel deposits (B)}}{\text{percent of "sheet-flow" deposits (C)}}$$

$$\text{(2) current-deposit ratio} = \frac{\text{percent of channel deposits (B)} + \text{"sheet-flow" deposits (C)}}{\text{percent of quiet-water deposits (A)}}$$

The method is analogous to facies differentiation based upon sand-shale and clastic ratios as used by Sloss, Krumbein, and Dapples (1949), except that differentiation of rock types is based upon depositional process in order to determine the types and amounts of current action effecting the deposition of the Moenkopi Formation. The ratios represent "indices of the relative amounts of material in the numerator of the ratio deposited per unit thickness of material in the denominator" as stated by Sloss, Krumbein, and Dapples (1949, p. 100). A channel-deposit ratio of 1.2 indicates that 1.2 feet of channel deposits (cross-stratified sandstone and siltstone) accumulated for every foot of "sheet-flow" deposits (parallel ripple-laminated siltstone). A current-deposit ratio of 1.2 indicates that 1.2 feet of current deposits (cross-stratified sandstone and siltstone plus parallel ripple-laminated siltstone) accumulated for every foot of quiet-water deposits (horizontally stratified siltstone and claystone plus limestone, dolomite, and primary gypsum).

On the basis of these ratios, the triangular diagram is divided into six fields. The horizontal lines dividing the triangle are dividing lines representing current-deposit ratios of 0.25, 0.50, and 1.0. Lines representing the channel-deposit ratio radiate outward from the apex of the triangle. Of these lines, only one, based upon a channel-deposit ratio of 1.0, is used. When plotted on the triangular diagram, all control points whose ratios plot to the left of this line would have channel deposits and quiet-water deposits as the dominant lithologic types present, while those plotting to the right of the line would have "sheet-flow" deposits and quiet-water deposits dominant.

The six fields differentiated on the triangular diagram have been assigned patterns and are used in the construction of the sedimentary facies maps. In addition, the distribution of primary gypsum in the Moenkopi Formation is shown on the facies maps by a line separating areas in the Moenkopi Formation that contain primary gypsum from areas that do not. The distribution of limestone and dolomite in the Moenkopi Formation is also presented on plate 5.

MOENKOPI FORMATION AND RELATED STRATA

Strata included in the sedimentary facies study of the Moenkopi Formation represent all units of the Moenkopi Formation exclusive of the Hoskinnini Member in southeastern Utah and northernmost Arizona and its stratigraphic equivalents in the Tenderfoot Member of the Moenkopi Formation in the salt anticline region of east-central Utah and west-central Colorado. The lowest three units of the Tenderfoot Member (section on stratigraphy) in east-central Utah and west-central Colorado are, for the purposes of the facies study, considered equivalent to the Hoskinnini Member, and only the upper unit of the Tenderfoot Member is included in the facies map. The Woodside, Thaynes, and Mahogany Formations and the upper member of the State Bridge Formation, all lateral equivalents of the Moenkopi Formation, are included in the facies study in the northern part of the Colorado Plateau.

The Hoskinnini Member and its equivalents in the Tenderfoot Member of the Moenkopi Formation were excluded from the facies study because these units are composed of a lithologic type and represent a sedimentary environment only rarely, if at all, represented in other units of the Moenkopi Formation. Because of their distinctive lithologic character, these units cannot be classified satisfactorily in any of the categories of lithologic types used for the rest of the Moenkopi Formation.

The Moenkopi Formation and related strata exhibit a gradual change in facies to the west and northwest across the Colorado Plateau (pl. 5). This change is from strata generally containing common to abundant cross-stratified sandstone and siltstone and other current-deposited strata along the east margin of the formation to those composed of almost entirely horizontally stratified siltstone, claystone, limestone (or dolomite), and gypsum in the western part of the Colorado Plateau. These facies changes follow rather closely the changes in thickness of the formation shown by the isopach map (pl. 4). Where the formation is thin, as in the eastern part of its area of distribution, coarse-grained cross-stratified sandstone and siltstone is common to abundant. To the west and northwest, where the formation is thick, horizontally stratified siltstone, claystone, limestone (or dolomite), and gypsum representing quiet-water deposition is the dominant lithologic type. In the southern part of northeastern Arizona, where the formation thickens to the southwest, the trend of maximum facies change is also to the southwest.

A facies consisting of current-deposited strata—including cross-stratified conglomerate, sandstone, and siltstone and, generally in lesser amounts, ripple-laminated siltstone—is dominant in the Moenkopi Formation and related strata in the following areas:

(1) Eastern part of northwestern Colorado. Along the east margin of the upper member of the State Bridge Formation in northwestern Colorado, ripple-laminated siltstone is the dominant type of current deposit, although cross-stratified rocks are locally common to abundant. At Sheephorn Creek (loc. C3) the upper member of the State Bridge contains 20 percent of cross-stratified sandstone and graywacke conglomerate, and at East Brush Creek (loc. C2) 26 percent of a partially exposed unit tentatively correlated with the upper member of the State Bridge is composed of cross-stratified rock.

(2) Salt anticline region. Cross-stratified sandstone and conglomerate constitutes 30–50 percent of the Moenkopi Formation, mostly in the Ali Baba Member.

(3) In a westward-extending lobe in southeastern Utah. Most of the cross-stratified rocks in this belt occur in the ledge-forming member of the Moenkopi Formation, and consist of fine-grained sandstone to coarse siltstone and little, if any, conglomerate.

(4) Eastern part of the Monument Valley area near the Arizona-Utah State line. Cross-stratified sandstone and siltstone is the dominant lithologic type at one control point (loc. U36) and this suggests a general abundance of cross-stratified strata in the area.

(5) Sycamore Canyon area (near Ott Mountain loc. A21) in north-central Arizona. Cross-stratified sandstone and siltstone are abundant, largely because a basal conglomerate unit is about 90 feet thick there. This conglomerate unit is not present northward and eastward in the area south of Cameron (loc. A75) or at East Sunset Mountain (loc. A12).

(6) Concho–St. Johns and Fort Wingate areas in east-central Arizona and west-central New Mexico. At Concho (loc. A68) and St. Johns (loc. A9) more than 50 percent of the Moenkopi Formation is composed of fine- to medium-grained, locally conglomeratic, cross-stratified sandstone. The abundant cross-stratified rock at and near Concho and St. Johns may continue northeastward into the Fort Wingate area (loc. NM3), where the Moenkopi(?) Formation contains more than 60 percent cross-stratified sandstone.

(7) Sevilleta Grant area (loc. NM13) in west-central New Mexico. Here, 45 percent of the Moenkopi(?) Formation is composed of cross-stratified sandstone and siltstone. Some conglomerate lenses are present.

Primary gypsum is absent along the east margin of the depositional area of the Moenkopi Formation, but is generally present in the central and western parts (pl. 5). Except in the salt anticline region in Utah and Colorado, Sycamore Canyon area (loc. A21) in Arizona, and Red Canyon area (loc. C53) in Colorado, primary gypsum generally is absent in areas containing common to abundant cross-stratified rocks. The east limit of primary gypsum corresponds rather closely with the west limit of the facies pattern indicating dominantly horizontally stratified and cross-stratified rocks (channel-deposit ratio greater than 1.0 and current-deposit ratio less than 1.0, but greater than 0.50).

LOWER AND UPPER PARTS OF THE MOENKOPI FORMATION AND RELATED STRATA

In order to analyze changes of depositional patterns of the Moenkopi Formation and related strata through their depositional history, the rocks have been divided into upper and lower parts (table 7). The lower part consists of strata that either (a) contain a *Meekoceras* fauna, (b) underlie strata containing a *Meekoceras* fauna, or (c) contain strata laterally equivalent to (a) and (b). The upper part consists of strata overlying the *Meekoceras* fauna or laterally equivalent strata.

TABLE 7.—*Rocks described as the lower and upper parts (Moenkopi Formation and related strata). All members listed are those of the Moenkopi Formation unless otherwise indicated.*

Area	Lower part	Upper part
Northwestern Arizona and southwestern Utah.	Timpoweap Member	Upper red member. Shnabkaib Member. Middle red member. Virgin Limestone Member. Lower red member.
Northeastern Arizona (excluding Monument Valley area).	Absent	All of the Moenkopi Formation including Holbrook, Moqui, and Wupatki Members.
West-central New Mexico	Absent	All of the Moenkopi(?) Formation.
Southeastern Utah	Sinbad Limestone Member. Lower slope-forming member. Conglomerate and sandstone units.	Cliff-forming member. Upper slope-forming member. Ledge-forming member.
East-central Utah and west-central Colorado (salt anticline region).	Ali Baba Member Upper unit of Tenderfoot Member.	Pariott Member. Sewemup Member.
Northeastern Utah and northwestern Colorado (Uinta Mountains region).	Thaynes Formation Woodside Formation. (Part of Moenkopi Formation. east of Thaynes pinchout).	Mahogany Formation (where Thaynes present). Part of Moenkopi Formation (east of Thaynes pinchout).
Central Colorado	Upper member of State Bridge Formation.	Probably absent.

A *Meekoceras* fauna occurs in the Timpoweap Member of the Moenkopi Formation in southwestern Utah and part of northwestern Arizona, the Sinbad Limestone Member of the Moenkopi Formation in southeastern and central Utah, and the Thaynes Formation in northern Utah. The contact between the upper and lower parts of the Moenkopi and related formations is placed at the top of these limestone units (table 7).

In southeastern Utah beyond the limit of the Sinbad Limestone Member, the contact between the lower slope-forming and the ledge-forming members is used as the contact between the upper and lower parts of the Moenkopi. The contact between these members marks the projected position of the Sinbad Limestone Member (fig. 3). At Lockhart Canyon (loc. U32) the Moenkopi Formation is not separated into members; here, the contact between the upper and lower parts is placed arbitrarily at a position 113 feet above the top of the Hoskinnini Member of the Moenkopi Formation. This location marks the approximate position of the Sinbad Limestone Member, or the contact between the ledge-forming and upper slope-forming members, as projected from the nearby sections. As in the study of the entire Moenkopi Formation, the Hoskinnini Member is not included in the lithofacies study of the lower part of the Moenkopi and related formations.

In northeastern Utah beyond the limit of the Thaynes Formation, the contact between the upper and lower parts of the Moenkopi and related formations is placed at the top of a prominent gypsiferous unit in the Moenkopi Formation. This gypsiferous unit occupies the same stratigraphic position as the Thaynes Formation, and is believed by Kinney (1955, p. 56) to be equivalent to it. This unit has been noted as far east as Cliff Creek, Utah (loc. U40). East of Cliff Creek, at Miller Creek, Colo. (loc. C11), the contact between the upper and lower parts of the Moenkopi is placed arbitrarily at the top of bedded gypsum deposits.

Near Meeker (loc. C18) and sections farther east and south in northwestern and central Colorado, all the beds assigned to the upper member of the State Bridge Formation are considered by us to be stratigraphically below the *Meekoceras* fauna and thus probably represent the equivalents of the lower part of the Moenkopi Formation.

In east-central Utah and west-central Colorado, the top of the Ali Baba Member is selected arbitrarily as the approximate horizon of the *Meekoceras* fauna and is recognized as the contact between the upper and lower parts of the Moenkopi. The occurrence of *Meekoceras* (?) is recorded in beds in Salt Valley, Utah (loc. U169), which probably are in and near the base of the Sewemup Member of the Moenkopi Formation (Shoemaker and Newman, 1959, p. 1849). Inasmuch as the Sewemup Member overlies the Ali Baba Member of the Moenkopi Formation, and the *Meekoceras* (?) occurs near the base of the Sewemup, the top of the Ali Baba Member is a convenient position at which to place the contact between the upper and lower parts of the Moenkopi. In the Moab area (loc. U20), where the Sewemup and Ali Baba Members cannot be differentiated easily, the *Meekoceras* horizon has been arbitrarily placed at the top of the highest massive cross-stratified sandstone in the Moenkopi Formation. As in the study of the entire Moenkopi Formation, only the upper unit of the Tenderfoot Member is included in the lithofacies study of the lower part of the Moenkopi and related formations.

LOWER PART

The lower part of the Moenkopi Formation and related strata extend over most of eastern Utah and into adjacent parts of Colorado and Arizona. It covers a much smaller area than does the upper part of the Moenkopi Formation and related strata. It thickens generally to the northwest or north across the Colorado Plateau (pl. 5) and is less than 200 feet thick in much of southeastern Utah. It thickens to more than 1,300 feet in north-central Utah.

In central Utah, a northeast-trending line approximately along the position of the 500-foot isopach marks the position northwest of which the lower part of the Moenkopi Formation thickens greatly in a short distance westward. This line marks the approximate position of the northwest limit of the shelf area during deposition of the lower part of the formation. Northwest of this line the slope of the depositional area steepens, probably toward a marine basin or geosyncline, to the northwest.

The lower part of the Moenkopi Formation exhibits the same overall distribution of facies (pl. 5) as does the Moenkopi Formation as a whole; the lower part of the formation contains common to abundant cross-stratified sandstone and siltstone along its east margin and grades to the northwest into dominantly horizontally stratified siltstone, claystone, limestone (or dolomite), and gypsum. In detail, however, the facies patterns are more complex in the lower part of the formation and, as mentioned previously, the lower part covers a much smaller area than the upper part.

Current-deposited strata are dominant in the lower part of the Moenkopi and related formations in the following areas:

(1) Eastern part of northwestern Colorado. Ripple-laminated siltstone of the upper member of the State Bridge Formation is the dominant lithologic type in this area, although cross-stratified sandstone is abundant at East Brush Creek (loc. C2) and Sheephorn Creek (loc. C3). Graywacke conglomerate occurs at Sheephorn Creek.

(2) Salt anticline region. The conglomeratic Ali Baba Member of the Moenkopi Formation is included in the lower part of the formation and accounts for the dominance of cross-stratified sandstone in this region.

(3) Eastern part of Monument Valley area near the Arizona-Utah State line. The Moenkopi Formation in this area contains as much as 40 percent cross-stratified sandstone and siltstone and is coarser than the lower part of the formation to the north, where it contains practically no cross-stratified rocks.

(4) Along the Colorado River near Hite, Utah. The abundance of current-deposited strata in this area is due largely to a thin sandstone and conglomerate unit that constitutes most or all of the lower part of the formation. The conglomeratic portion of the unit contains granules and pebbles composed largely of chert. The sandstone and conglomerate unit is 6 feet thick at Hite, Utah (loc. U29) and 30 feet at Buckacre Point (loc. U9) on Dirty Devil River.

No facies patterns are shown on plate 5 for the south edge of the lower part of the Moenkopi Formation in southwestern Utah. In this area, the lower part of the Moenkopi Formation is represented by the Timpoweap Member. This member is highly variable in lithology, grading laterally and vertically from conglomerate to horizontally stratified limestone and siltstone. Because of the abrupt lateral variation in lithology of the member, a much more detailed study than has been made would be needed to obtain meaningful facies patterns.

Primary gypsum occurs in the lower part of the Moenkopi Formation and related strata throughout the northwestern part of its depositional basin, including the areas where primary gypsum crops out in the northern part of Circle Cliffs, in the San Rafael Swell, and throughout the Uinta Mountains. Primary gypsum also occurs in isolated patches in the southern part of the Clay Hills area and in the northwestern part of Monument Valley area in southeastern Utah, in the central part of the salt anticline region, and near the east margin of the upper member of the State Bridge in northwestern Colorado (loc. C53).

UPPER PART

The upper part of the Moenkopi Formation and related strata covers nearly the same area as the Moenkopi Formation as a whole. It extends far beyond the limits of the lower part and covers most of northern Arizona and parts of east-central New Mexico. The only area in which strata equivalent to the lower part extends appreciably beyond the limit of the upper part is in northwestern and central Colorado, where the east limit of the upper part is tentatively placed to the west of Meeker (loc. C18). This restriction of the upper part may result from a limitation of the depositional area of the Moenkopi and State Bridge Formations, and it may also be due to removal of the upper part of the Moenkopi and State Bridge in this area during a period of pre-Chinle uplift and erosion.

The extent of the upper part of the Moenkopi Formation in the salt anticline region of east-central Utah and west-central Colorado is slightly less than that of the lower part. This relationship probably is the result of pre-Chinle erosion.

The upper part of the Moenkopi Formation thickens gradually to the west across most of the Colorado Plateau and attains a thickness of 2,100 feet or more in southwestern Utah along the west margin of the Plateau (pl. 5). The westerly trend of the direction of maximum thickening in the upper part of the formation contrasts with the northwest-to-north trend in the lower part.

The upper part of the formation exhibits the same general trends of facies changes (pl. 5) as the Moenkopi Formation as a whole. Cross-stratified sandstone and siltstone is common to abundant along the east margin. Facies gradually change westward, and horizontally stratified siltstone, claystone, limestone (or dolomite), and gypsum are dominant along the west edge of the Colorado Plateau.

Current-deposited strata are dominant in the upper part of the Moenkopi and related formations in the following areas:

(1) Eastern Uinta Mountains of Colorado. The east margin of the upper part of the Moenkopi in northwestern Colorado is characterized by abundant parallel ripple-laminated siltstone. Coarse sandstone and graywacke conglomerate occur in the upper member of the State Bridge Formation east of McCoy, Colo., near the east margin of the State Bridge Formation, but do not occur in the Moenkopi west of Meeker, Colo. Stream-channel deposits constitute about 20 percent of the upper part of the Moenkopi Formation at Miller Creek (loc. C11) in northwestern Colorado, but these deposits are dominantly fine-grained sandstone and siltstone.

(2) Near Moab, Utah. Abundant ripple-laminated siltstone occurs near Moab (loc. U20). This abundance may, however, be local and related to uplift of the salt structures during the time of Moenkopi deposition. Such uplift may have produced shallow-water conditions in which current- or wave-formed ripple-laminated strata could form.

(3) Central part of the San Rafael Swell. In comparison with areas at the northwest and southwest ends of the San Rafael Swell, the upper part of the Moenkopi Formation in the central part of the Swell is relatively thin and contains a high proportion of current deposits, particularly ripple-laminated siltstone. This high proportion probably indicates deposition of the strata in shallower water here than elsewhere in the Swell and may indicate that the present-day Swell had its beginning in the Triassic.

(4) In a westward-extending lobe in southeastern Utah. Abundant cross-stratified sandstone and siltstone occurs in southeastern Utah as far west as the eastern part of Circle Cliffs (loc. U11) and in parts of Capitol Reef National Monument (loc. U43). This cross-stratified sandstone and siltstone occurs mostly in the ledge-forming member.

(5) Eastern part of the Monument Valley area near the Arizona-Utah State line. Abundant cross-stratified sandstone and siltstone occurs at one control point (loc. U36) in this area.

(6) Sycamore Canyon (near Ott Mountain, loc. A21), (7) Concho (loc. A68)–St. Johns (loc. A9) and Fort Wingate (loc. NM3), and (8) Sevilleta Grant (loc. NM17) areas. In these areas, only the upper part of the Moenkopi Formation occurs, and the current

deposits in these areas have been treated in the discussion of the sedimentary facies of the Moenkopi Formation as a whole (p. 56).

The distribution of current-deposited strata in the upper part of the Moenkopi in southeastern Utah and adjoining parts of Colorado is different from that in the lower part. In the salt anticline region, coarse conglomeratic sandstone (mostly in the Ali Baba Member) is common in the lower part of the Moenkopi Formation, but largely absent in the upper part. In southeastern Utah, the upper part contains abundant cross-stratified sandstone and siltstone forming a westward-extending lobe. This area did not receive sediments during deposition of the lower part of the formation. Finally, near Hite, sandstone and conglomerate is abundant in the lower part of the formation, but not in the upper.

Primary gypsum distribution in the upper part of the Moenkopi Formation is similar to that in the formation as a whole. One difference, however, is the absence of gypsum in the upper part of the formation in the central part of San Rafael Swell.

In this study, the upper part of the formation in northeastern Arizona and west-central New Mexico has been divided into a lower unit, which contains strata below the top of the lower massive sandstone, and an upper unit, which contains strata above the top of the lower massive sandstone. The lower massive sandstone is a persistent sandstone unit extending throughout much of northeastern, and possibly northwestern, Arizona (p. 23).

The pattern of deposition of the upper part of the Moenkopi Formation below the top of the lower massive sandstone (pl. 5; table 8) follows the general regional pattern of deposition found in the Moenkopi Formation as a whole. This part of the formation thickens generally northwestward (pl. 5), and its facies changes from coarse stream-channel deposits in the southeast to fine-

TABLE 8—*Thickness of upper part of Moenkopi Formation below, or above, top of lower massive sandstone in Arizona and New Mexico, together with percentages and ratios of quiet-water, confined-current, and unconfined-current deposits*

[Basic data for pl. 5. Leaders (----) indicate data not calculated because unit not present. ∞, infinity]

Locality No.	Locality	Upper part of Moenkopi Fm. (thickness, ft)		Quiet-water deposits (percent) (A)		Confined-current deposits (percent) (B)		Unconfined-current deposits (percent) (C)		Channel-deposit ratio B/C		Current-deposit ratio (B+C)/A	
		Below, or above, top of lower massive sandstone											
		Below	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below	Above
A15	Big Canyon	207	101	52.7	67.2	18.9	15.0	28.4	17.8	0.67	0.84	0.90	0.49
A1	Black Creek	0	169	------	59.4	------	27.0	------	13.5	------	2	------	.68
A79	Cameron, 12 miles NW[1]	149	139	51.2	63.6	30.8	3.6	18.0	32.8	1.7	.11	.95	.57
A18	Cedar Ridge	328	86	65.5	51.9	11.7	35.4	22.8	12.7	.51	2.8	.53	.93
NM1	Chavez-Prewitt	0	26	------	55.1	------	37.2	------	7.7	------	4.8	------	.82
A19	Coconino Point	147	225	44.2	65.7	37.4	20.1	18.4	14.2	2	1.4	1.3	.52
A68	Concho [1]	0	114+	------	35.0	------	65.0	------	0	------	∞	------	1.8
A73, 74	East of Black Point combined with Black Falls[1]	121	260	44.5	80.8	37.8	10.0	17.7	9.2	2.2	1.1	1.2	.24
A12	East Sunset Mountain	11	433	36.7	82.4	63.3	12.3	0	5.3	∞	2.3	1.7	.21
NM3	Fort Wingate	0	36	------	38.0	------	62.0	------	0	------	∞	------	1.6
A60	Holbrook [2]	25	133	0	81.9	78.0	18.1	22.0	0	3.5	∞	∞	.22
A104	Holbrook Quarry [3]	33	142	9.1	81.0	63.6	14.8	28.3	4.2	2.2	3.5	10	.23
A5	Hunters Point	0	43	------	77.5	------	22.5	------	0	------	∞	------	.29
A35	Klagetoh	0	124	------	------	------	------	------	------	------	------	------	------
NM20	Mesa Gallina	0	212	------	65.1	------	23.1	------	11.8	------	2	------	.54
A39	Oak Springs	0	196	------	------	------	------	------	------	------	------	------	------
A21	Ott Mountain	171	225+	3.8	62.6	84.5	6.2	11.7	31.2	7.2	.2025		.60
A16	Red Point	502	90	56.1	64.3	8.8	20.1	35.1	15.6	.25	1.3	.78	.56
NM16	Riley	0	161	------	66.5	------	19.0	------	14.5	------	1.3	------	.50
A9	St. Johns	0	50	------	22.0	------	78.0	------	0	------	------	------	3.5
NM17	Sevilleta Grant	0	101	------	41.6	------	44.6	------	13.8	------	3.2	------	1.4
A81	Shinumo Altar	269	147	------	------	------	------	------	------	------	------	------	------
A23	Soap Creek	492	67	61.7	74.7	6.8	10.4	31.5	14.9	.22	.70	.62	.34
A24	The Gap	187	47	54.3	67.8	22.1	32.2	23.6	0	.94	∞	.84	.47
A86	Vermilion Cliffs	------	152	------	------	------	------	------	------	------	------	------	------
A75	West of Black Point [1]	79	276	57.6	71.4	15.8	13.4	26.6	15.2	.59	.88	.73	.40
A70	Winslow [1]	16	233	15.0	59.2	85.0	26.4	0	14.4	∞	1.8	5.7	.69
A69	Woodruff Butte [1]	25	212?	35.3	56.4	43.1	41.5	21.6	2.1	2	20	1.8	.77

[1] Data obtained from section measured by McKee (1954); some sections modified by us.
[2] Data obtained from section measured by M. E. Cooley and J. P. Akers.
[3] Data obtained from section measured by Welles (1947).

grained, quiet-water, and "sheet-flow" deposits in the northeast. The stream-channel deposits occur in a broad platform area extending from near St. Johns (loc. A9) northwestward as far as Cameron (loc. A17). Bedded gypsum occurs only in the northwestern part of the area studied, where this part of the formation is relatively thick.

The unit from the top of the lower massive sandstone to the base of the Moenkopi Formation thins to the southeast and is only about 25 feet thick in the Holbrook area of Arizona (loc. A60). This part of the formation is interpreted to pinch out west of St. Johns, Ariz., and therefore the Moenkopi Formation farther east in Arizona and the Moenkopi(?) Formation of New Mexico is regarded as a deposit formed later than the lower massive sandstone.

The depositional pattern of the upper part of the Moenkopi Formation above the lower massive sandstone, including the entire Moenkopi Formation in easternmost Arizona and the Moenkopi(?) Formation in New Mexico (pl. 5; table 8), is markedly different from that below the top of the lower massive sandstone. The Moenkopi Formation above the lower massive sandstone in northeastern Arizona shows a general southwestward and westward thickening and a change of facies from current-deposited strata in the northeast to relatively fine-grained, quiet-water-deposited layers in the south and southwest. Bedded gypsum occurs in sections in the southwestern part of the area, but not in sections in the northeastern part (pl. 5). These thickness and facies trends are almost at right angles to the trends in the Moenkopi Formation below the top of the lower massive sandstone.

SEDIMENTARY PETROLOGY

By R. A. Cadigan

The Moenkopi Formation and related strata contain a variety of lithologic types. These include sandstone and coarse siltstone in the orthoquartzite and arkose series, fine-textured rocks which, owing to chlorite and mica clay content, are classified dominantly as graywackes and carbonate rocks, dominantly limestone. The results of a study of the texture and composition of these rocks are briefly described here. Some results of this study have already been presented (Cadigan, 1957, 1971; R. A. Cadigan in Stewart and others, 1959).

SANDSTONE AND COARSE SILTSTONE

The most common types of sandstone and coarse siltstone in the Moenkopi Formation are feldspathic orthoquartzite, calcareous orthoquartzite, arenaceous-chert orthoquartzite, and sodic and potassic arkose. These rocks consist chiefly of various proportions of quartz, feldspar, and detrital tuffaceous and heavy-mineral grains, set in a clay matrix and having a dominantly calcareous cement. Descriptions of the mineral components of these rocks follow.

QUARTZ AND SILICEOUS MATERIAL

The dominant mineral in the Moenkopi Formation is quartz, occurring as detrital monomineralic grains. Most single grains show unstrained extinction and many have inclusions of tourmaline; most aggregated quartz grains within quartzite fragments show strain extinction. Grains are angular to subrounded. Coarse sand grains in the Hoskinnini Member are rounded or subrounded, and very fine sand grains in other members tend to be subangular or subrounded. Coarse silt grains in some strata are so angular and nonspherical that they resemble microbreccia. Detrital quartz also occurs in several forms of microcrystalline aggregates, including: homogeneous grains of chert; heterogeneous-looking silicified-rock fragments with inclusions of microlites of mica calcite, and partially isotropic interstitial silica; and poorly crystallized microcrystalline quartz aggregates which contain much isotropic material and which could be either fragments of silicified limestone or devitrified, silicified glass.

FELDSPAR

Feldspar mineral grains constitute a small percentage to more than 25 percent of the rock and include the potassic varieties orthoclase and microline, and possibly sanidine, and the sodic varieties albite and oligoclase. Detrital grains include angular euhedral particles and angular to rounded fracture fragments. Overgrowths are common in some strata; orthoclase overgrowths occur on orthoclase and albite grains, and albite overgrowths occur on oligoclase grains. The albite-oligoclase grains appear to be the most weathered and apparently are readily susceptible to alteration and replacement. Albite, where abundant, shows at least some alteration to chlorite.

TUFFACEOUS DETRITUS

Tuffaceous detritus consisting of altered silicic tuff fragments and ash is recognized in significant amounts (5–15 percent) in some strata of the Ali Baba Member in west-central Colorado and in the Holbrook Member in east-central Arizona. Most of the Moenkopi Formation contains, on the average, less than 1 percent recognizable tuffaceous detritus, but a few samples from strata possibly equivalent to the tuff-bearing members contain 1–5 percent.

The tuff fragments were derived from potassic and sodic varieties of crystal and lithic tuff. The fragments have been devitrified, but in many of the crystal tuff fragments the matrix appears isotropic, although the indices of refraction of the fragments are estimated to be in the range 1.51 to 1.54. The crystal tuff fragments contain phenocrysts of potassic or sodic feldspar. The lithic tuff fragments contain anhedral crystal forms that have flamboyant extinction which suggests lithification by radial crystallization of potassic or sodic (albitization?) feldspars from the matrices before, after, or during devitrification. The tuff matrices seem to consist of quartz and sanidine in the potassic tuff, and quartz and albite in the sodic tuff. Tuff fragments show, in addition to devitrification and silicification, alteration to montmorillonite and, in sodic tuff, to chlorite clay minerals. Crystal and lithic tuff fragments that contain anhedral quartz crystals grade into those that are classified as silicified-rock fragments of unknown origin.

Silicic ash has been altered to montmorillonitic and chloritic clays and interstitial microcrystalline silica and is replaced locally by carbonate or iron oxide cements. Much altered ash is practically indistinguishable from other altered detrital components in the matrix.

HEAVY MINERALS

Detrital heavy-mineral grains comprise less than 50 percent of the sandstone and coarse siltstone. The most plentiful heavy-mineral grains are those of the iron oxide group. Magnetite, magnetite-ilmenite, and ilmenite occur as black to brown, rounded to subangular, opaque grains. Leucoxene occurs as white, opaque, well-rounded, spherical grains, or, where it is associated with anatase, it occurs as rims, halos, or seams on ilmenite and ilmenite-magnetite grains. Anatase occurs as pale-golden-yellow rounded cloudy, translucent grains, as aggregates of cubic crystals, as rounded grains with euhedral overgrowths, and as grains with various irregular forms. The anatase is probably authigenic and derived by alteration of detrital ilmenite and leucoxene.

Zircon is present in several varieties. The most common zircon is the rounded clear, colorless variety; other types are colorless euhedral zircon in elongated dipyramidal prisms, rounded pale-pink zircon, and rounded clouded or metamict zircon. Some of the euhedral zircon crystals show zoning and crystal intergrowths. All zircon grains contain various kinds of inclusions.

Tourmaline occurs as rounded grains that have many pleochroic color combinations, predominantly green, brown, and yellow. Garnet, variety grossularite(?), occurs as clear, colorless to pink grains. Some grains have uneven building-block forms (irregular arrangement of cubes) which suggest etching by interstratal solutions; other grains are angular and show only fracture surfaces; many grains are rounded to subrounded.

Staurolite occurs sparsely as pale-golden angular to subangular splintery-looking grains. Epidote occurs as subrounded lemon-yellow to greenish-yellow grains. Rutile occurs in reddish-brown or golden-brown rounded grains. Brookite occurs in brown rounded to euhedral grains with striated crystal faces. Apatite occurs in rounded colorless oval-shaped grains.

Both biotite and muscovite are present in the sandstone and siltstone. Biotite occurs in dark-brown and green flakes or, rarely, in bundles. Some flakes are almost colorless, probably as a result of loss of iron. Muscovite occurs in colorless to pale-green flakes and is common in thin sections of siltstone, where it appears in longitudinal sections as a threadlike, fibrous highly birefringent mineral, curved or slightly contorted in some places. Some of the mica flakes are altered to chlorite and some are altered less commonly to or replaced by iron oxide in ghosts of mica-bundle shapes.

A green detrital amphibole mineral, hornblende(?), was found in samples from limy strata of the lower red member, Virgin, and Shnabkaib Members in the St. George, Utah, area. Some of the rounded grass-green particles have pale-green overgrowths.

Authigenic heavy minerals that occur with the concentrates of detrital heavy minerals include interstitial ragged-looking or subangular particles of colorless barite and similarly shaped dark-red semiopaque to opaque particles of microcrystalline hematite.

CLAY MINERALS

Mica clays, which are moderately to lightly impregnated with red iron oxide and microlites of calcite and dolomite, are the dominant interstitial clay minerals in the sandstone and coarse siltstone of the Moenkopi. These clays occur as red, moderately to poorly crystallized, interstitial aggregates or platelets of low birefringence, or as highly crystallized (probably recrystallized), high-birefringent, red rims on the detrital grains. Chlorite clay, the dominant clay in many of the strata, is present as bright colorless crystalline scales on altered grains, as sand-sized aggregates of dull colorless parallel fibrous crystals of clinochlore(?), and as dull pale-green low-birefringent anhedral crystalline material which occurs interstitially or is included in altered albite and sodic tuffaceous detritus. Chlorite also occurs in some strata as a poorly crystallized mixed-layer clay with montmorillonite or mica clay. The green chlorite clay mineral is identified as pennine(?). Kaolinite occurs as a colorless, usually well-crystallized, interstitial clay mineral of high relief, and is relatively abundant in some strata. Montmorillonite is sparse and occurs as a brown poorly crystallized, interstitial crystalline clay mineral. Locally it shows a "swirling" pattern of oriented platelets, but in most places it occurs in poorly crystallized physical or mineralogical clay mixtures with mica clay. Montmorillonite-mica clays are also alteration products of tuffaceous fragments and other glassy detritus, and have in many place completely replaced tuff fragments, while preserving their physical forms and inclusions. In the red or reddish-brown sandstone and siltstone strata, which are typical of the formation, the mica and montmorillonite-mica clays are impregnated to various degrees with microscopic dustlike crystals of iron oxide and very finely crystalline carbonate cement, predominantly calcite, to yield a matrix which is semiopaque in thin section.

The different clay minerals tend to be associated with sand- and silt-sized detritus of possibly related composition. Montmorillonite and montmorillonite-mica clays are commonly associated with coarse detritus of potassic or potassic-sodic volcanic materials. Kaolinite is common in strata containing high proportions of potassic feldspar. Chloritic clays are abundant in strata containing relatively high proportions of sodic or sodic-potassic feldspars and volcanic detritus.

Kaolinite and chlorite, as determined by Schultz (1963, p. C24), commonly constitute a notably higher proportion of the clay minerals in the coarse-grained rocks than in the fine-grained ones. This finding is in general agreement with the findings presented here. Montmorillonite and montmorillonite-mica clays also seem to be more abundant in some coarse-textured rocks than in fine-textured ones.

CEMENT AND ACID-SOLUBLE MINERALS

Calcite is the second most abundant mineral in the Moenkopi Formation; detrital quartz is the most abundant. Calcite impregnates the red clayey matrix of some siltstone strata and occurs as an interstitial cement in the sandstone and coarse-grained siltstone. In some strata it forms discontinuous coarsely crystalline anhedral octopuslike patches; in other strata, possibly where dolomitic, it forms isolated fine-grained sand-sized rhombs; in still others, it forms a continuous cement. The partially destroyed or skeletal feldspar, tuff, and quartz grains in contact with or surrounded by calcite and the optically anomalous detrital-grain-shaped ghosts in the calcite are good evidence that calcite has replaced detrital sand grains. The late-crystallizing relationship of interstitial calcite to matrix and the microlites and relatively coarse euhedral rhombs suspended in the clay matrix suggest that calcite, and possibly dolomite also, replaced the clay minerals and ground-up quartz, feldspar, and precipitated silica which make up the interstitial matrix of some sandstone and coarse siltstone strata. Calcite crystals range in size from microlites to megascopic "sand crystals."

Dolomite in every place is associated with and surrounded by calcite and forms sand- and coarse-silt-sized rhombs, many of which are zoned. In a few places, dolomite replaces rounded quartz grains to yield conspicuous ghosts of relatively high relief surrounded by calcite. In most places, dolomite rhombs seem to replace calcite or to have been precipitated on microcrystals of calcite. The rhombs commonly contain tiny inclusions which give them a dusty appearance.

Red and brown iron oxide minerals, presumably mixtures of hematite and limonite, are present in nearly all strata of the Moenkopi Formation and are responsible for its typically deep red color. As dustlike microlites, iron oxide materials impregnate the clay and fine silt matrices and are also present in some of the coarsely crystalline calcareous interstitial cements.

Gypsum is a primary component of the Shnabkaib Member and is a significant cementing mineral at many localities. Interstitial gypsum forms bladed, fibrous crystal aggregates which tend to saturate the rock in the manner of a late-crystallizing, invading mineral. Detrital grains of quartz and other minerals are corroded where they are in contact with the gypsum cement. The absence of clay minerals in a gypsum-cemented sandstone suggests complete replacement of the clay by the gypsum.

Quartz occurs commonly as an authigenic cement, both as optically continuous overgrowths on detrital quartz grains and as poorly crystallized microcrystalline interstitial silica cement.

REGIONAL VARIATIONS IN ROCK COMPOSITION

Conspicuous regional gross variations in the proportions of detrital rock-forming mineral components were observed in the feldspars, tuff fragments, chloritic clays, and silicified-rock fragments. Total feldspar content is highest in southeastern Utah. Regional trends of sodic and potassic feldspar are parallel, which suggests that they had common source areas.

Tuff fragments are present in higher than average proportions in southeastern Utah and in east-central Arizona and adjoining west-central New Mexico. Proportions of chloritic clays are highest in southeastern Utah.

Proportions of silicified-rock fragments are highest in the southern part of the region, specifically in east-central Arizona and adjoining west-central New Mexico.

Details of regional variations of mineral components are presented in a report on the petrology of the formation (Cadigan, 1971).

FINE-TEXTURED ROCKS

Fine- and medium-grained siltstone strata of the Moenkopi Formation include rocks of the graywacke series. This classification is based mostly on their large content of clay minerals. The strata are typically composed of mica clay, mica-montmorillonite and chlorite clay minerals impregnated with calcite, and iron oxide minerals. The rocks also contain silt-sized grains of quartz and feldspar, flakes of muscovite and biotite, and sparse crystal aggregates of kaolinite.

The dominant clay mineral, as determined by Schultz (1963), in the fine-textured rocks of the Moenkopi Formation is illite (referred to above as mica clay). The illite occurs with minor amounts of mixed-layer illite in which expandable montmorillonite layers comprise a third or less of the total clay. Either chlorite or kaolinite generally occurs in accessory amounts with the illite and mixed-layer illite, but chlorite and kaolinite rarely occur in the same rock. Mixed-layer illite-montmorillonite, in which montmorillonite layers are estimated to constitute from one-third to about half of the total, occurs in places along with illite and chlorite.

In the northern part of the Colorado Plateau, in eastern Utah and western Colorado, the clays in the Moenkopi Formation (Schultz, 1963) contain minor amounts of chlorite on the east and minor amounts of kaolinite on the west. In New Mexico, the clays contain minor amounts of kaolinite. In northeastern Arizona, the clays in the lower massive sandstone and the underlying part of the Moenkopi Formation contain minor amounts of kaolinite, and the clays above the lower massive sandstone contain minor amounts of chlorite. In northwestern Arizona and southwestern Utah, the clays contain minor amounts of chlorite.

In a few samples studied by Schultz (1963), notably from the Comb Ridge area in southeastern Utah, chloritic strata of the Moenkopi Formation contain mixed-layer montmorillonite in which montmorillonite layers exceed illite (mica) layers.

CARBONATE ROCKS

The carbonate rocks of the Moenkopi are predominantly limestone and constitute the primary strata of the Sinbad Limestone Member, the Virgin Limestone Member, and the Timpoweap Member. The varieties of limestone present include coarsely crystalline unfossiliferous limestone, coquinite composed of fossil shell debris and coarsely crystalline calcite, oolitic limestone, and fossiliferous limestone. Many of the reddish-brown detrital strata contain high proportions of $CaCO_3$ (25–75 percent).

SEDIMENTARY STRUCTURE STUDIES

Current directions have been determined by several studies of the orientation of cross-strata and ripple marks in rocks of the Moenkopi Formation. Parts of these results have been reported previously by Poole (1961).

A study of cross-strata consists of measuring the direction and amount of dip on many individual cross-strata sets in a single stratigraphic unit of similar rock type and probably of similar genesis. At each locality the number of measurements necessary for adequate sampling depends on the diversity in dip directions of the cross-strata, but in general 50–150 individual measurements were considered sufficient in each study of the Moenkopi. If each dip direction reading is considered a vector, a resultant of the readings can be obtained by mathematical or graphical methods. This resultant is the downcurrent direction from which a transportation direction and a source direction can be inferred.

The resultant dip directions of cross-strata in the Moenkopi Formation are dominantly west to northwest and a few are in other directions (fig. 11). Studies in the Holbrook Member in east-central Arizona indicate dominantly west and northwest resultant dip directions.

In the area from near Cameron to Lees Ferry, in north-central Arizona, two studies in the lower massive sandstone show westerly to northwesterly directions and two show southeasterly directions. Near Lees Ferry where a southeasterly direction was determined from one study, the lower massive sandstone is a gypsiferous sandstone composed, in part, of gypsum grains. The cross-strata in the gypsiferous lower massive sandstone are of small to medium scale and in planar and, to a lesser extent, in trough sets. This type of cross-strata is suggestive of eolian deposition; such an origin for this gypsiferous part of the lower massive sandstone has also been proposed by McKee (1954, p. 51). The anomalous southeasterly resultant dip direction, therefore, may be due to deposition by southeast-blowing winds, whereas the fluvial parts of the Moenkopi Formation were deposited by generally west- to northwest-flowing streams. A southeasterly direction of wind transportation is consistent with wind directions as determined for Permian strata and also younger Triassic and Jurassic strata on the Colorado Plateau (Poole, 1962, 1964). At the second locality, where a southeasterly direction was measured, the lower massive sandstone also contains planar sets of small- to medium-scale cross-strata and may likewise be of eolian origin. In contrast, at the localities where westerly to northwesterly directions were determined the lower massive sandstone probably is of fluvial origin; these directions are consistent with stream directions in other units of the Moenkopi Formation.

In southeastern Utah, cross-strata studies were made in sandstone of the ledge-forming member or laterally equivalent strata, units considered fluvial in origin, and resultant dip directions are dominantly westerly to northerly. In extreme east-central Utah and west-central Colorado, studies also were made in sandstone probably also of fluvial origin of the Ali Baba Member, and directions are consistently northwest.

Four studies of the orientation of ripple marks were made by us, and 13 such studies were made previously by McKee (1954, fig. 18). The strike of the symmetrical and asymmetrical ripples was measured on generally 10–30 individual bedding planes within a single lithologic unit, and the steep side of the asymmetrical ripples recorded. Trends of the cuspate ripples are more difficult to determine, but a trend comparable to the strike of the symmetrical and asymmetrical ripples can generally be approximated and the steep side recorded. In the studies made, the strike of the ripples was fairly constant at any one locality. The orientation of the steep sides of the ripples, however, was not consistent. In some studies there were about as many ripples with steep sides in one direction as ripples with steep sides in the other direction.

Three ripple studies in the northern part of southeastern Utah indicate consistently northeast-striking ripples, but no consistent current direction. A fourth study indicates a similar strike and also a dominant southeast current direction. Studies by McKee (1954, fig. 18) in the Wupatki and Holbrook Members and in age-equivalent strata in north-central Arizona indicate north-striking ripples and a dominantly east current direction in the Wupatki Member and a dominantly west current direction in the Holbrook Member.

PALEONTOLOGY OF THE MOENKOPI FORMATION AND EQUIVALENT STRATA

Remains of invertebrate and vertebrate animals and scattered remains of plants are present in various parts of the Moenkopi Formation. Invertebrates, consisting of worms, brachiopods, molluscs, echinoderms, and arthropods, are largely confined to the marine or coastal parts of the formation, particularly the marine limestone units. Vertebrate remains, consisting of fish, amphibians, and reptiles, seem to be confined to rocks deposited in continental environments. Various parts of the Moenkopi fauna, particularly the invertebrates, from various localities have been described by a considerable number of authors. The Moenkopi fauna and flora as a whole has been summarized by McKee (1954, p. 67–75).

The following summary of the Moenkopi paleontology includes both material presented in the literature and new data obtained by us and other workers during the course of the present investigation.

WORMS

Worm borings and trails have been noted in the Moenkopi Formation by several authors. *Spirorbis* sp. has been reported from what is now considered to be Timpoweap Member in southwestern Utah (Reeside and Bassler, 1922, p. 67). Worm tubes possibly representing *Spirorbis* have been noted by Poborski (1953, p. 79) in the Virgin Limestone Member in the St. George area, Utah.

Various worm trails and borings have been reported by Gregory and Williams (1947, p. 225) in the lower red member in Zion National Monument, and by McKee (1954, p. 72–73) at various localities in the Moenkopi of Arizona.

BRACHIOPODS

The brachiopod fauna of the Moenkopi Formation consists of both inarticulate and articulate forms. Inarticulate brachiopods consist mostly of the genus *Lingula* and have been reported in the literature by Gregory (1950a, p. 63) in the Moenkopi of the Zion National Park region, by Walcott (1880, p. 223) above the base of the Virgin Limestone Member in the Kanab area, Utah, by McKnight (1940, p. 58) in the Sinbad Limestone Member along the Green River, Utah, and by Smith, Huff, Hinrichs, and Luedke (1963, p. 13) 10–51 feet above the Sinbad Limestone Member in the Capitol Reef area. *Discina* sp. has been noted by Reeside and Bassler (1922, p. 67) in the Timpoweap Member, and by Walcott (1880, p. 223) in the upper part of the Moenkopi of southwestern Utah. *Lingula* sp. has been identified by J. B. Reeside, Jr. (written commun., 1957), in three lots of fossils from various localities in southeastern Utah. The first lot (USGS Mesozoic loc. 24344) was collected by us 51 feet above the top of the Sinbad Limestone Member of the Moenkopi at the Chimney Rock section, Capitol Reef, Utah (loc. U43). The second lot (USGS Mesozoic loc. 25255) was collected by E. S. Davidson in the Sinbad(?) Limestone Member in Circle Cliffs (approximate locality, sec. 33, T. 34 S., R. 7 E.), and consists of *Lingula* associated with *Aviculopecten* and *Myalina*. The third lot (USGS Mesozoic loc. 24778) was collected by us from the Sinbad Limestone Member along the Muddy River in the San Rafael Swell, and consists of *Lingula* associated with *Monotis* aff. *M. thaynesiana* Girty.

Articulate brachiopods, mainly terebratuloid and triplesioid types, have been reported in the Moenkopi Formation of southwestern Utah by various authors

(Lee, 1907, p. 362; Poborski, 1954; Reeside and Bassler, 1922, p. 67; Thomas and Taylor, 1946, p. 19; Gregory and Williams, 1947, p. 226; Walcott, 1880, p. 223; Gregory, 1950a, p. 63; Shimer, 1919, p. 463). Most of the reported collections are from the Timpoweap and Virgin Limestone Members of the Moenkopi and contain *Pugnax*, *Pugnoides*, and *Terebratula* as the most common identifiable genera.

PELECYPODS

Pelecypods and gastropods are the most abundant fossils in the Moenkopi Formation, both in number of described genera and in total population. Most of the pelecypods occur in units of marine limestone and siltstone (Virgin Limestone, Sinbad Limestone, and Timpoweap Members), but pelecypods also have been identified in other units of the formation, such as the Shnabkaib Member and various red-bed members. In the literature, at least 27 different pelecypod genera have been noted from the Moenkopi, of which at least 20 are also present in rocks of Permian age (Branson, 1948). Of the described genera, *Aviculopecten*, *Myalina*, *Pseudomonotis*, *Monotis*, *Bakewellia*, *Pleurophorus*, and *Myophoria* seem to be the most common. Except for *Myophoria*, all of these genera are also present in the Permian. Published faunal lists containing pelecypods include those of Walcott (1880, p. 223), Lee (1907, p. 362), Shimer (1919), Reeside and Bassler (1922, p. 67–68), Butler (1913, p. 38), Gregory and Williams (1947, p. 226), Gregory (1950a, p. 63; 1950b, p. 33), and Poborski (1953, 1954) from the Moenkopi, and beds here assigned to the Moenkopi, in southwestern Utah; Longwell (1928, p. 45) and Hewett (1931, p. 33) in the Moenkopi Formation in southern Nevada; and Gregory and Moore (1931, p. 52), Gilluly and Reeside (1928, p. 66), McKnight (1940, p. 58), and Smith, Huff, Hinrichs, and Luedke (1963, p. 13) in the Sinbad Limestone Member of the Moenkopi in southeastern Utah.

Several pelecypod localities found in recent years in the Moenkopi Formation are as yet unpublished. Three of these, from which collections were made by us and identified by N. J. Silberling (written commun., 1957), follow:

"*Aviculopecten*" sp. and other indeterminate pelecypods from the Shnabkaib Member 148 feet above its base, at the Horse Spring valley section (loc. N1) in eastern Clark County, Nev.

"*Aviculopecten*"? sp. from the Timpoweap Member 169 feet above its base at the Kanarraville section (loc. U22), Iron County, Utah.

A collection of pelecypods that contains *Myalina* sp., *Bakewellia*(?) sp., *Pleurophorus*(?) sp., *Myophoria*(?) sp., and "*Aviculopecten*" sp. from the Virgin Limestone Member at a roadcut on the north side of U.S. 89 about 3.5 miles east of Fredonia, Ariz. (T. 41 N., R. 2 W., sec. 26).

Several recent collections containing pelecypods have been obtained from the Moenkopi Formation in southeastern Utah. One lot, obtained by us from the top of the ledge-forming member of the Moenkopi in the Circle Cliffs area (approximate location, long 111°5′21″ W., lat 37°45′ N.), has been identified by Bernhard Kummel (written commun., 1957), who states in an unpublished report:

> One large and three small slabs comprising this lot contain poorly preserved specimens of *Myalina* cf. *spathi* Newell and Kummel. This species is common in the Dinwoody formation of western Wyoming. Myalinids of this type are common in shallow water, near shore, generally calcareous clastic strata of Early Triassic age in Wyoming, East Greenland, Spitzbergen, and Siberia.

Two collections from the Sinbad Limestone Member of the Moenkopi in Circle Cliffs were obtained by E. S. Davidson and identified by J. B. Reeside, Jr. One lot (USGS Mesozoic loc. 25254; unsurveyed location, approximately sec. 28, T. 34 S., R. 7 E.) was described by Reeside in an unpublished report as follows:

> This lot is the widespread porous limestone with a fauna of still unstudied gastropods and a few pelecypods that at places are accompanied by *Meckoceras*. I consider it Moenkopi and Triassic. The present lot contains a pelecypod that has been called *Myalina* sp.

Regarding the other lot (USGS Mesozoic loc. 25255, approximate location sec. 33, T. 34 S., R. 7 E.), Reeside wrote (unpub. report): "This lot is like 25254 but contains, besides the gastropods, *Myalina*, *Aviculopecten*, and *Lingula*. I would call it Triassic." *Aviculopecten*(?) has also been identified by Reeside in a collection (USGS Mesozoic loc. 25250) obtained by E. S. Davidson in the Sinbad Limestone Member northwest of Wagon Box Mesa in Circle Cliffs (approximate location, long 111°6′15″ W., lat 37°50′15″ N.).

Three collections containing pelecypods from the Sinbad Limestone Member, obtained by us along the Muddy River at the south end of the San Rafael Swell, have been identified by J. B. Reeside, Jr. (written commun., 1957) as follows: USGS Mesozoic loc. 24777, *Monotis* aff. *M. bregeri* Girty, *Monotis* aff. *M. thaynesiana* Girty, indeterminable ammonites; USGS Mesozoic loc. 24778, *Lingula* sp., *Monotis* aff. *M. bregeri* Girty; USGS Mesozoic loc. 24779, *Myalina postcarbonica* Girty, *Monotis* aff. *M. thaynesiana* Girty associated with the gastropod genera *Worthenia*(?) sp., *Solariella*(?) sp., *Neritaria*(?) sp., and *Eucyclus*(?) sp. Concerning these collections, Reeside stated:

> These three collections include a number of species of pelecypods and gastropods and several indeterminable specimens of small ammonites. They are useful in that the general assemblage is

like that widespread in the Lower Triassic marine beds. However, the fauna of the Lower Triassic, except for the ammonites described by J. P. Smith and a few pelecypods described by G. H. Girty, is largely unstudied. Until someone makes a general description of the pelecypods and gastropods, only tentative names can be assigned and only the general age designation of Early Triassic can be given.

GASTROPODS

Gastropods, generally represented by poorly preserved molds, are abundant in the marine limestone units of the Moenkopi, but they have not been studied in detail and many of the generic names assigned to them are tentative and some may be inaccurate. Some 20 different generic names have been listed in the literature. At least 15 of these genera represent forms found in Permian (Branson, 1948) as well as Triassic rocks.

Of the described gastropod genera, *Pleurotomaria* and *Naticopsis* seem to be the most common; both are found in the Permian as well as the Triassic rocks. Gastropods in the Moenkopi Formation from southwestern Utah and northwestern Arizona are listed by Walcott (1880, p. 223), Shimer (1919, p. 486), Reeside and Bassler (1922, p. 67–68), Gregory (1950a, p. 63), and Poborski (1953, 1954); in southern Nevada by Longwell (1928, p. 45) and Hewett (1931, p. 33); and in the Sinbad Limestone Member in southeastern Utah by Gregory and Moore (1931, p. 52), Gilluly and Reeside (1928, p. 66), and McKnight (1940, p. 58).

A few new gastropod localities were discovered, and a few new, but questionable, generic designations were listed as a result of the present study. Bellerophontid gastropods associated with indeterminate pelecypods were identified by N. J. Silberling in a collection made by us 17 feet above the base of the Moenkopi Formation at St. George, southwestern Utah (loc. U47a). A generalized naticoid gastropod was identified by J. B. Reeside, Jr., in a collection made by the authors from a limestone bed, probably the equivalent of the Sinbad Limestone Member, 200 feet above the base of the Moenkopi Formation on the west side of the Colorado River in Grand County, Utah (sec. 13, T. 26 S., R. 20 E.). As noted in the preceding section on pelecypods, J. B. Reeside, Jr., has tentatively identified the gastropod genera *Worthenia*(?), *Solariella*(?), *Neritaria*(?), and *Eucyclus*(?) in a collection (USGS Mesozoic loc. 24779) from the Sinbad Limestone Member along the Muddy River at the south end of the San Rafael Swell, Utah.

CEPHALOPODS

Both nautiloids and ammonoids are present in the Moenkopi Formation. Because of the value of ammonites in the correlation and age determination of Lower Triassic strata, their occurrences in the formation are discussed in some detail.

The ammonite faunas of Early Triassic age were divided into five zones by Smith (1932). In ascending order these zones were: *Otoceras*, *Genodiscus*, *Meekoceras*, *Tirolites*, and *Columbites*. The *Meekoceras* zone was subdivided into three subzones by Smith (1932), in ascending order: *Pseudosageceras multilobatum*, *Owenites*, and *Anasibirites*. As noted by Kummel (1954, p. 182), Spath (1934, 1951) revised Smith's classification and divided the Lower Triassic into six faunal divisions, in ascending order: Otoceratan, Gyronitan, Flemingitan, Owenitan, Columbitan, and Prohungaritan. Kummel (1954, p. 182) stated that "the Gyronitan is equivalent to the *Genodiscus* zone of Smith (1932), the Flemingitan and Owenitan to the *Meekoceras* zone of Smith, and the Columbitan includes the *Tirolites* and *Columbites* zones of Smith." The Prohungaritan division represents a new division younger than any of Smith's zones. It has been recognized in the *Prohungarites* zone in the upper part of the Thaynes Formation in Idaho (Kummel, 1954, p. 184, 187). A further modification of Smith's original classification is noted by Kummel (1954, p. 185), who considers that the *Anasibirites* subzone of the *Meekoceras* zone of Smith, on the basis of recent work by several authors, is an independent zone immediately overlying the restricted *Meekoceras* zone.

Most of the ammonites described from the Moenkopi Formation belong either to the *Meekoceras* or to the *Anasibirites* zones of the Early Triassic as used by Kummel (1954). They occur in the Timpoweap Member of the Moenkopi Formation in southwestern Utah and in its stratigraphic equivalent, the Sinbad Limestone Member of southeastern and south-central Utah. In beds now considered to be the Timpoweap Member, *Meekoceras* aff. *M. muschbachanum* has been reported from the Zion National Park region (Reeside and Bassler, 1922, p. 67), *Meekoceras* sp. from the Iron County region north of Zion Park (Gregory, 1950b, p. 33), and *Meekoceras* in the form of molds from Kaibab Gulch in central Kane County, Utah (Gregory, 1948, p. 227). *Meekoceras gracilitatis*(?) and *Meekoceras*(?) sp. have been reported from the Sinbad Limestone Member in the San Rafael Swell (Gilluly and Reeside, 1928, p. 66), and *Meekoceras*(?) sp. from the Sinbad(?) Limestone Member on the Green River (McKnight, 1940, p. 57–58). *Meekoceras* occurs in a limestone unit, believed by us to represent the Sinbad Limestone Member, near Marysvale, Utah (Kerr and others, 1957, p. 64). It also occurs in the basal Moenkopi east of Minersville, Utah (McKee, 1938a, p. 214). *Meekoceras*(?), possibly from near the base of the Sewemup Member in Salt Valley, Utah, has been reported by Shoemaker and Newman (1959, p. 1849).

The ammonite *Wasatchites* cf. *W. seerleyi* (Mathews) has been reported in the Moenkopi Formation in the Zion Park region (Gregory, 1950a, p. 63), but unfortunately neither the location nor the stratigraphic position of this fossil is given. *W. seerleyi* is listed (Kummel, 1954, p. 186) as belonging to the *Anasibirites* zone. If the form reported by Gregory really is *W. seerleyi*, it presumably came from the Timpoweap Member, for the next overlying fossiliferous unit in the Moenkopi Formation in this region is the Virgin Limestone Member, which contains a younger fauna belonging to the *Tirolites* zone.

A collection of ammonites from the Sinbad Limestone Member in the Capitol Reef area of southeastern Utah was obtained by us 8 feet above the base of the member at Chimney Rock section A (loc. U43). Bernhard Kummel stated, in an unpublished report:

> Any name placed on this specimen would be largely guesswork; however, on that basis the specimen suggests a *Paranannites* sp., a common ammonoid in the *Meekoceras* zone of northern Utah and Idaho. This identification is made on the involute, rather plump shape of the fragment and the shape and nature of the two lateral lobes.

Another collection from the Sinbad Member in the Capitol Reef area contains *Pseudomonotis* sp., *Hemiprionites* sp., *Anasibirites* spp., and *Xenocelites* sp.; the ammonites "are very characteristic genera of the *Anasibirites* zone, upper Owenitan (=Meekoceratan)" according to Kummel (in Smith and others, 1963, p. 13).

Of the ammonites identified in the Timpoweap and Sinbad Limestone Members of the Moenkopi Formation, *Meekoceras gracilitatis*(?), *Meekoceras* (now called *Submeekoceras*) aff. *M. mushbachanum*, and *Paranannites*(?) are characteristic forms of the *Meekoceras* zone (Kummel, 1954, p. 185). *Anasibirites*, *Hemiprionites*, *Xenoceltites*, and *Wasatchites* are characteristic genera of the *Anasibirites* zone (Kummel, 1954, p. 185–186).

The *Tirolites* zone has been recognized in the Virgin Limestone Member of the Moenkopi in the St. George area, Utah (Poborski, 1953, 1954). In a collection made by Poborski, 10 feet below the top of the Virgin Limestone Member, and identified by S. W. Muller, *Tirolites spinosus* Mojsisovics s.l.,(?) *Cordillerites*, and possibly(?) *Hungarites* are present (Poborski, 1954). *Tirolites spinosus* is a characteristic species of the *Tirolites* zone (Smith, 1932, p. 18) and has previously been known from the Tyrolian Alps.

In his report on the Zion National Park region, Gregory (1950a, p. 63) listed "*Meekoceras*" *micromphalus* Smith as one of the fossils present in the Moenkopi of this region. The locality and stratigraphic position of "*M.*" *micromphalus* are not given, but Gregory stated that in the list with which it is included are fossils from the Timpoweap, Virgin Limestone, and Shnabkaib Members of the Moenkopi Formation. According to Kummel (1954, p. 187) "*Meekoceras*" *micromphalus* is a form found in the *Columbites* zone in Idaho. This indicates that the *Columbites* zone may be present in the Moenkopi Formation of southwestern Utah, and, if so, is probably represented by the Shnabkaib Member inasmuch as the other fossiliferous horizons included in Gregory's list (1950a, p. 63)—the Timpoweap and Virgin Limestone Members—contain faunas referable to older Early Triassic zones, *Meekoceras*, *Anasibirites*, and *Tirolites*.

Apart from ammonites, other cephalopods reported from the Moenkopi Formation include orthoceratid nautiloids in the Virgin Limestone Member in the St. George area in southwestern Utah (Poborski, 1954).

SCAPHOPODS

A scaphopod, *Laevidentalium*(?) sp., has been reported from the Moenkopi Formation in the Goodsprings area of southern Nevada (Hewett, 1931, p. 33) and in the Sinbad Limestone Member of the Moenkopi in the San Rafael Swell, Utah (Gilluly and Reeside, 1928, p. 66). Another scaphopod, *Plagioglypta*, is listed from the Moenkopi in northwestern Arizona (Shimer, 1919, p. 486).

ARTHROPODS

Arthropod remains and tracks are sparsely represented in the Moenkopi Formation, but have been reported from several localities in Arizona and Utah.

The most significant arthropod discovery thus far in the Moenkopi Formation was made by Pobroski (1954), who found the crustacean genus *Halicyne* in the Virgin Limestone Member in the St. George area, Utah. The only other arthropod remains reported from the Moenkopi consist of unidentified ostracods. Ostracods have been noted in southwestern Utah in the Virgin Limestone Member (Poborski, 1954) and near the top of the Timpoweap Member (Reeside and Bassler, 1922, p. 67); in the Sinbad Limestone Member of the San Rafael Swell (Gilluly and Reeside, 1928, p. 66); and questionably in sandy limestone beds (probably Sinbad Limestone Member) in the Capitol Reef area, Utah (Gregory and Moore, 1931, p. 52).

Occurrences of arthropod tracks and trails in the Moenkopi Formation were described by McKee (1954, p. 73). Two types of tracks were reported from the fossil quarry in the Wupatki Member at Meteor Crater; one is similar to *Isopodicnus* sp., an isopod described from the German Bunter. Two other types of arthropod tracks were reported from a quarry in the basal Moenkopi east of Flagstaff, Ariz. (McKee, 1954, p. 73). One is interpreted as being similar to tracks made by a scorpionlike animal, and the other type as possibly representing "swim" tracks made by small crustaceans. Tracks of a horseshoe crab near the top of a limestone unit (possibly Shnabkaib (?) Member) in the Moenkopi Formation in the Muddy Mountains in southern Nevada were noted by Peabody (1956, p. 737).

ECHINODERMS

Fragments of crinoid stems are the most abundant echinoderm remains in the Moenkopi Formation, and, in places, make up entire units of crinoidal limestone. *Pentacrinus* has been recognized in southwestern Utah, probably in the Virgin Limestone Member (Walcott, 1880, p. 223; Shimer, 1919, p. 483), and was collected in the Moenkopi Formation in the Goodsprings area, southern Nevada (Hewett, 1931, p. 33). *Isocrinus* sp. has been recognized in the Virgin Limestone Member in southwestern Utah (Reeside and Bassler, 1922, p. 67) and has been recognized questionably in beds believed to be the Virgin Limestone Member near the base of the Kolob Plateau south of Cedar City, Utah (Thomas and Taylor, 1946, p. 19).

Starfish impressions have been noted in limestone of the Moenkopi Formation in the Muddy Mountains, southern Nevada (Longwell, 1928, p. 45).

Echinoid spines are reported in the Sinbad Limestone Member in the San Rafael Swell, southeastern Utah (Gilluly and Reeside, 1928, p. 66), and an echinoid was associated with *Pseudomonotis* sp. in this member in the Capitol Reef area (Smith and others, 1963, p. 13).

FISH

Fish remains consisting of scattered bones and scales have been reported from several horizons and localities in the Moenkopi Formation.

Remains of two types of fish associated with amphibian and reptilian remains in the Holbrook Member of the Moenkopi Formation near Holbrook, Ariz., have been identified by Welles (1947). Fossils of the first fish type consist of selachian ichthyodorulites, referred by Welles to the genus *Leiacanthus*. Fossils of the other fish type consist of a patch of ganoid scales questionably referred by Welles to the palaeoniscoid genus *Boreosomus*, a marine fish known from Greenland, Spitzbergen, and Madagascar. Coelacanth remains collected by Welles from the Holbrook locality have subsequently been identified as a new genus and species, *Moenkopia wellesi* (Schaeffer and Gregory, 1961, p. 3–7).

Fish scales identical to those recognized by Welles as ?*Boreosomus* have recently been found in two localities in Utah. The first of these, discovered by E. S. Davidson, is in the ledge-forming member 70 feet above the base of the Moenkopi Formation near Muley Twist (loc. U11) in the Circle Cliffs. The scales were identified by D. H. Dunkle (written commun., 1957).

The second locality, discovered by M. L. Millgate, is 25 feet below the top of the Moenkopi Formation at the head of Fry Canyon, a tributary to White Canyon in San Juan County, Utah (sec. 11, T. 37 S., R. 16 E.). D. H. Dunkle (written commun., 1957) stated:

> In 1947, S. P. Welles reported on a collection of upper Moenkopi vertebrates from Northern Arizona which he dated as Early Triassic in age. Included among his materials were some paleoniscoid fish scales determined as ?*Boreosomus* sp. It is not clear to me on what basis of either gross features or of detailed histology Welles arrived at this generic assignment. However, regardless of true scientific identity, there are seemingly identical scales from the present Moenkopi occurrence from the Colorado Plateau of southeastern Utah.
>
> In addition, this same matrix from Utah contains two other types of remains suggestive of Lower Triassic faunal elements in other parts of the world. First, the battery of pavement teeth display a histology comparable in every respect with that of the subholostean Perleididae. Two members of this family restricted to the Lower Triassic are already known from the Western Hemisphere: *Perleidus* and *Dollopterus*. And second, the hollow, ringlike structures seem best interpreted as vertebral centra. Although conceivable from an immature amphibian or reptile, vertebra of this same general structure have been described in the Lower Triassic pholidopleurid *Australosomus* from Greenland, Spitzbergen, and the Swiss Tessin Formation.

In addition to the occurrences described above, other fish remains reported in the Moenkopi Formation consist of ganoid fish in the Wupatki Member at Meteor Crater (Camp and others, 1947, p. 7), fish bones in the Holbrook Member near Cameron (Camp and others, 1947, p. 7), fish remains in the Wupatki Member near Leupp, Ariz. (McKee, 1954, p. 68), and fish remains in what is either the top of the ledge-forming member or the base of the upper slope-forming member of the Moenkopi at the Bears Ears (loc. U25) in southeastern Utah (McKee, 1954, p. 69). Fish remains, including small fragments of bone, scales, and small teeth, are present about 200 feet above the base of the Woodside Formation in the Uinta Mountains (Yochelson and others, 1961). The teeth are considered (D. H. Dunkle and Dianne Van Sickle, in Yochelson and others, 1961) to be elements of the crushing dentition of a paleoniscoid fish. They are considered by Dunkle and Van Sickle to be of Permian age, and as yet are unknown from beds established as either Pennsylvanian or Triassic age.

AMPHIBIANS

Both skeletal remains and trackways of amphibians have been reported from the Moenkopi Formation; skeletal remains are the most abundant. Almost all of the described amphibian remains were discovered in the Wupatki and Holbrook Members of the Moenkopi Formation in the Little Colorado River valley in northeastern Arizona. All of the amphibian remains thus far generically identified consist of stereospondylid labyrinthodonts belonging dominantly to the family Capitosauridae.

The capitosaurs are represented in the Moenkopi by at least four described types and by trackways. The first capitosaur found was *Stanocephalosaurus birdi*, discovered by R. T. Bird and described by Brown (1933). The *Stanocephalosaurus* locality is about 7 miles southwest of Winsolw, Ariz., and according to Welles (1947, p. 272) is in the lower part of the formation, or Wupatki Member. Subsequently, Welles (1947) described a new species of *Cyclotosaurus*, *C. randalli*, and a new genus, *Rhadalognathus boweni*, of capitosaur from the Holbrook Member of the Moenkopi near Holbrook, Ariz. Additional capitosaurid remains resembling *Parotosaurus* were noted by E. H. Colbert and J. T. Gregory (in Reeside and others, 1957, p. 1457) in the Wupatki Member near Meteor Crater, Ariz. Amphibian trackways believed to be capitosaurid in origin were noted by Peabody (1948, p. 308) in the Wupatki Member in Moqui Wash, Ariz. The most common impressions in the Moenkopi are "swim" tracks of tetrapods of the size of large capitosaurids; they probably were formed mainly by sterospondylid labyrinthodonts, according to Peabody (1956, p. 737–738).

Other labyrinthodont amphibians reported from the Moenkopi Formation are a trematosaurid ?*Amphaneramma* (Camp and others, 1947, p. 7) in the Wupatki Member near Meteor Crater, a brachyopid amphibian in the Holbrook Member near Cameron (E. H. Colbert and J. T. Gregory, in Reeside and others, 1957, p. 1457), and a new genus of plagiosaurid, *Taphrognathus bradyi* (Welles, 1947), in the Holbrook Member near Holbrook, Ariz. As the name *Taphrognathus* was preoccupied, the name *Hadrokkosaurus bradyi* was subsequently given this genus (Welles, 1957).

Other undescribed amphibian remains in the Moenkopi are an amphibian skull in the Holbrook Member east of Holbrook (Camp and others, 1947, p. 6), amphibian skulls and interclavicles found by Welles in the Holbrook Member west of Concho, Ariz. (loc. A68) (McKee, 1954, p. 69), amphibian bones in what is probably the ledge-forming member of the Moenkopi at Bears Ears, Utah (loc. U25) (McKee, 1954, p. 69), and amphibian tracks from what may be the Shnabkaib(?) Member in the Muddy Mountains in southern Nevada (Peabody, 1956, p. 737).

REPTILES

Reptilian remains in the Moenkopi Formation consist of both skeletal elements and trackways, of which trackways are by far the most abundant. Four reptilian genera have been described to date: two are based upon skeletal elements; two are based entirely upon trackways.

The two reptilian genera described from skeletal elements were found in the Holbrook Member of the Moenkopi Formation near Holbrook, Ariz. (Welles, 1947). They consist of a pseudosuchian reptile, *Arizonasaurus babbitti* Welles, and a form whose classification is uncertain, *Anisodontosaurus greeri* Welles. Both these forms represent new genera and species.

Trackways and isolated tracks of reptilian origin have been reported from many horizons in the Moenkopi Formation. Although tracks have been reported as far north as Vernal, Utah, most of those described occur in the Little Colorado River valley in northeastern Arizona, and are of pseudosuchian origin. Two distinct pseudosuchian genera based upon trackways are recognized by Peabody (1948), who has been the principal worker on Moenkopi tracks and trackways. One of these, the genus *Chirotherium*, had been previously reported from Europe and eastern North America. The other genus, *Rotodactylus*, is a new form found only in the Moenkopi. Three species of *Rotodactylus* have been recognized by Peabody (1948). These are *R. cursorius* from the Wupatki Member at Meteor Crater, Ariz. *R. mckeei* from the upper red member west of Hurricane, Utah, and *R. bradyi* from the Holbrook Member southwest of Cameron, Ariz. Subsequently, tracks of *Rotodactylus* resembling *R. mckeei* were reported in the upper part of the Moenkopi Formation at Capitol Reef, Utah (Peabody, 1956, p. 735).

Tracks and trackways of *Chirotherium* are the most common and well known of the recognizable tetrapod trackways in the Moenkopi and have been reported from many localities in the formation. Eight species of *Chirotherium*, six of which are new, have been recognized by Peabody (1948). Four of these species occur in the Wupatki Member and four occur in the Holbrook Member of the Moenkopi Formation in the Little Colorado River area in northeastern Arizona. One of these species, *C. moquinense*, described from the Wupatki Member in Moqui Wash near Winslow, Ariz., has been subsequently described by Peabody (1956, p. 732–733) in the upper red member east of Kanab, Utah, and a form closely resembling it has also been described (Peabody, 1948, p. 378) from the upper red member of the Moenkopi near Rockville, Utah. Reptilian tracks possibly representing *Chirotherium* have been reported from the Moenkopi near Vernal, Utah (Kinney, 1955, p. 60) and in the Dinosaur National Monument, Utah and Colorado (Untermann and Untermann, 1949, table 1).

Chirotherium tracks discovered by P. P. Orkild, and identified by J. B. Reeside, Jr., are located 40 feet below the top of the Moenkopi Formation in the Orange Cliffs area, Garfield County, Utah.

Another type of reptilian trackway in the Moenkopi Formation is the type referred to as lacertoid, or lizard-like by Peabody (1948, p. 318). Lacertoid trackways have been found in the Holbrook Member northwest of Cameron, Ariz., in the Wupatki Member near Meteor Crater, and in the lower part of the Moenkopi 3 miles southwest of Paria, Utah (Peabody, 1948, 1956). Both the Cameron (Peabody, 1948, p. 319) and the Paria (Peabody, 1956, p. 735) localities contain a possible protorosaurian lacertoid trackway which according to Peabody, is similar to *Akropus* of the German Bunter. The Cameron locality also contains lacertoid trackways that were possibly formed by rhynchocephalians (Peabody, 1948, p. 322).

PLANTS

Plant fossils have been reported from some localities in the Moenkopi Formation and consist mainly of impressions, although petrified wood has been noted at a few places. The distribution of plants in the Moenkopi has been summarized by McKee (1954, p. 73–74), who stated that "reeds and *Equiseta* are the principal plants recognized." Most of the plants in this formation are in the Little Colorado River valley in northern Arizona, where they occur in the Holbrook and Wupatki Members (Ward, 1905, p. 29; Gregory, 1917, p. 24–27; McKee, 1954, p. 73–74). A species resembling *Walchia gracilis* has been found in the type section of the Moenkopi on the Little Colorado River (Gregory, 1917, p. 25).

AGE OF THE MOENKOPI FORMATION AND EQUIVALENT STRATA

The Moenkopi Formation is regarded to be of Early and Middle(?) Triassic age. The Hoskinnini Member in southeastern Utah and equivalent strata in the Tenderfoot Member in east-central Utah and west-central Colorado are undated but considered to be questionable Triassic. The formation in the eastern Uinta Mountains is assigned an Early Triassic age, although the lowermost part of the formation may be Permian. The lower part of the Woodside Formation in the western Uinta Mountains, which is laterally equivalent to the lower part of the Moenkopi Formation, may also contain some Permian strata. The basal strata of the upper member of the State Bridge Formation in Colorado may be Permian in age. The evidence for the age designation of the Moenkopi Formation and equivalent strata is based both upon marine invertebrate fossils obtained largely from limestone units and upon continental vertebrate fossils obtained from various redbed units. Some of the evidence for the age designation of the Moenkopi Formation has been summarized by McKee (1954, p. 10–11).

Evidence that the Moenkopi Formation is largely of Early Triassic age is based on the Early Triassic ammonite zones, *Meekoceras*, *Anasibirites*, *Tirolites*, and possibly *Columbites*, in the various marine units of the formation. The medial Early Triassic *Meekoceras* and *Anasibirites* zones are present in the Timpoweap Member and Sinbad Limestone Member. The *Tirolites* zone is believed to occur in the Virgin Limestone Member. Possibly the late Early Triassic *Columbites* zone is present in the Shnabkaib Member in southwestern Utah. As indicated in the preceding discussions of the paleontology of the Moenkopi, certain of the pelecypod and gastropod assemblages in the Moenkopi also suggest an Early Triassic age.

Evidence of the age of the Moenkopi derived from vertebrate remains is somewhat ambiguous. Most of the vertebrates, many undescribed, in the Moenkopi are from the Wupatki and Holbrook Members in the Little Colorado River valley in Arizona. The formation in this area is probably entirely younger than the Virgin Limestone Member (and hence the *Tirolites* zone) and equivalent only to the upper part of the Moenkopi of southwestern Utah as shown by McKee (1954, p. 22). Thus, only the youngest part of the Early Triassic may be represented in the Moenkopi of northeastern Arizona. The evidence from vertebrates tends to support this possibility. The age of a collection of fish, amphibians, and reptiles from the Holbrook Member near Holbrook, Ariz., is recorded by Welles (1947, p. 286) as follows:

> In short, the fish, the amphibians *Taphrognathus* and *Rhadalognathus*, and the reptiles are Lower Triassic, while the amphibian *Cyclotosaurus* is a Keuper [Late Triassic] form. In view of this and the general stratigraphic relations of the Moenkopi formation, it seems best that we refer it to the Lower Triassic, bearing in mind the possibility that the Moenkopi may extend at least into the Middle Triassic.

The concept that part of the Moenkopi may be of Middle Triassic age is also supported by Peabody (1956, p. 738–739). Reptile trackways in the upper red member of the Moenkopi in southwestern Utah are shown to be closely related to those in the Wupatki Member in Arizona, and are more primitive than those in the Holbrook Member. He concluded (1956, p. 739):

> On a comparative basis, it appears that the age of the chirotheriid fauna of the type Moenkopi is relatively late rather than early Lower Triassic, and probably is in part, at least, Middle Triassic.

The basal part of the Woodside Formation in the western Uinta Mountains and the equivalent basal part of the Moenkopi Formation in the eastern Uinta Mountains may be Permian. The upper part of the Park City Formation is believed to be Guadalupe and possibly Ochoa age (R. P. Sheldon, E. R. Cressman, T. M. Cheney, and V. E. McKelvey, in McKee, Oriel, and others, 1967) and may not represent the youngest Permian. Therefore, if the contact of the Park City Formation and overlying Woodside or Moenkopi Formation is conformable, the uppermost Permian may be represented in the red beds of the lower part of Woodside and Moenkopi Formations in the Uinta Mountains. Fossils described by Yochelson, Cheney, Van Sickle, and Dunkle (1961) from 200 feet above the base of the Woodside Formation in western Duchesne County in the Uinta Mountains indicate a Permian age, and thus support the view that the basal part of the Woodside and laterally equivalent strata in the Moenkopi Formation may be of Permian age.

Much of the State Bridge Formation in central Colorado is considered, on the basis of fauna that occurs in the South Canyon Creek Member, to be of Permian age. This fauna has been studied by Bass and Northrop (1950, p. 1550) and considered by them to be Permian. The lower member and South Canyon Creek Member of the State Bridge Formation were assigned a Leonard and Guadalupe, and a Guadalupe and Ochoa(?) age, respectively, by W. E. Hallgarth (in McKee, Oriel, and others, 1967). How much of the upper member of the State Bridge Formation above the South Canyon Creek Member may be of Permian age is not known.

In summary, most of the Moenkopi Formation and equivalent strata are of Early Triassic age, based upon evidence established by marine invertebrate faunas. The upper part of the Moenkopi (Holbrook Member) in Arizona is here provisionally assigned to the Early and Middle(?) Triassic, based upon evidence from vertebrates. All authorities concur that the advanced amphibian *Cyclotosaurus* described by Welles (1947) from the Holbrook Member may be of Middle Triassic age, thus suggesting that the upper part of the Moenkopi in some places is as young as Middle Triassic. The Moenkopi(?) Formation in New Mexico, the upper red member in southwestern Utah, and the cliff-forming member in south-central Utah are, at least in part, correlative with the Holbrook Member of Arizona (pl. 3) and, hence, they also are provisionally assigned an Early and Middle(?) Triassic age. Northward and northeastward across Utah, the base of the Moenkopi is believed to become progressively older and, in the Uinta Mountains, may contain beds of Permian age. The lower part of the upper member of the State Bridge Formation in central Colorado may also be Permian.

INTERPRETATIONS

The Moenkopi Formation is believed to have been deposited in a shallow epicontinental sea and on bordering land areas. The sea lay mostly in western Utah and in Nevada, but at times spread eastward and southward across a large part of the Colordo Plateau. At times, large deltaic deposits were built westward from the land area. The formation thus exhibits repeated changes from continental to marine deposition along what was once the margin of the sea.

The source areas for the sediment in the Moenkopi Formation lay east and to a lesser extent south of the basin of deposition. Locally, conglomeratic sediments were contributed to the formation from bordering highlands, but the presence of siltstone, claystone, and limestone indicates source areas of low relief drained by sluggish streams.

This discussion of interpretations is divided into two parts, one describing the environments of deposition and the other describing the location and terrane of source areas. A summary of interpretations and a history of deposition is at the end.

ENVIRONMENTS OF DEPOSITION

The environments of deposition represented in the Moenkopi Formation are indicated partly by the types of fossils and partly by the texture, composition, sedimentary structures, and intertonguing relationships of the rock types. A general discussion of the evidence afforded by fossils is followed by a specific discussion of the environment of deposition of the major rock types.

FOSSIL EVIDENCE

Fossils in the Moenkopi Formation clearly indicate both marine and continental environments of deposition. Many of the marine fossils suggest shallow-water, tidal-flat, or littoral environments; much of the formation probably was deposited near shore.

Limestone (or dolomite) units such as the Timpoweap, Sinbad, or Virgin Members of the Moenkopi Formation or the Thaynes Formation contain an extensive fauna of brachiopods, pelecypods, gastropods, cephalopods, scaphopods, and echinoderms. Most of these units contain exclusively marine animals, and the types of molluscs present are considered marine. *Lingula* is a particularly abundant brachiopod in limestone of the Moenkopi Formation, associated with pelecypods such as *Aviculopecten*, *Myalina*, and *Monotis*. It ranges from early Paleozoic to the present, and today it lives in the littoral region extending from the strand line to a depth of about 60 feet (Schuchert, 1911; Cooper, 1957). *Discina*, which also occurs in the Moenkopi Formation, lives today in the same habitat as *Lingula; Myalina*, which is common in the Moenkopi, is considered to be a shallow-water, nearshore form (Bernhard Kummel, written commun., 1957).

Remains of amphibians and reptiles and their trackways have been found in the Moenkopi Formation almost exclusively in east-central Arizona (Welles, 1947; Peabody, 1948, 1956). Fragments of bones of amphibians are more numerous than those of reptiles, and occur mostly in cross-stratified sandstone and conglomerate layers, apparently representing stream deposits. Trackways of the reptiles, on the other hand, are much more numerous than those of amphibians, and occur mostly in flat-bedded deposits lateral to the cross-stratified layers containing bones. The reptiles apparently lived, and left their footprints, along the banks of streams and in the areas between streams, but rarely are their preserved bones found.

Plant remains are sparse in the Moenkopi Formation, but their presence is suggestive of a continental environment of deposition. Reeds and *Equiseta* (McKee, 1954, p. 73) are the main types and these suggest a swampy area.

ORIGIN OF CROSS-STRATIFIED SANDSTONE AND SILTSTONE

Cross-stratified sandstone and siltstone, along with conglomeratic lenses containing siliceous pebbles and with beds of intraformational conglomerate containing claystone and limestone pebbles, constitutes the coarsest grained strata in the Moenkopi Formation. The sedimentary features present are cross-stratification, which is predominant, cusp ripple marks, interference ripple marks, scour surfaces, current lineation, plant fragments, and tetrapod tracks and bones. Cross-stratified sandstone and siltstone is dominant in the eastern and southeastern part of the depositional basin, but is present, at least as a minor constituent, in almost all sections of the Moenkopi.

Cross-stratified sandstone and siltstone and associated conglomeratic strata are considered to be dominantly stream-channel deposits. This interpretation is based on the textures and sedimentary structures of the rock types and on the types of fossils. Trackways and a few bones of reptiles, bones, probable "swim" marks, and some trackways of amphibians occur in or near the cross-stratified layers. These fossil remains indicate an environment that contained water areas. The presence of plant fragments is suggestive of continental deposition. Cross-strata, scour surfaces, current lineations, and intraformational conglomerate are features characteristic of stream deposits.

Cusp ripple marks are commonly associated with cross-stratified sandstone and siltstone in the Moenkopi. The formation of cusp ripple marks in modern streams and rivers is attributed to strong fluctuating currents such as confined currents in stream channels (McKee, 1954, p. 60). Cusp ripple marks are also formed on tidal flats (Kindle, 1917, pl. 17A; McKee, 1957, pl. 8*B*), and possibly at least some of the cusp ripple marks in the Moenkopi formed in this environment.

Although most of the cross-stratified sandstone and siltstone in the Moenkopi Formation probably was formed by stream channel deposition, in a few areas cross-strata are different and probably did not have a fluvial origin.

The basal part of the ledge-forming member of the Moenkopi Formation in the Clay Hills area and at Monitor Butte (loc. U34) in southeastern Utah commonly contains some large planar sets of low to very low angle medium- to large-scale tangentially inclined cross-strata. These cross-strata resemble the type that characterizes the upper foreshore of beaches (Thompson, 1937; McKee, 1957), and these strata in the Moenkopi Formation may, therefore, be beach deposits. However, they might also represent delta foreset deposits. The foreset beds of the Fraser River Delta, for example, have a low angle of dip (1°–10°) (Johnston, 1922, p. 119; Mathews and Shepard, 1962, p. 1434), and thus might be similar to this type of cross-strata in the Moenkopi Formation.

Along the south margin of the Vermilion Cliffs in northern Arizona, the lower massive sandstone unit of the Moenkopi Formation, which elsewhere has all the characteristics of a stream-deposited unit, grades westward into gypsiferous sandstone and gypsum that is composed largely of wedge planar sets of high-angle, medium-scale cross-strata. This type of cross-stratification is identical, except in scale, to that found in the Navajo Sandstone and other supposedly wind-deposited units on the Colorado Plateau and in modern dunes (McKee, 1957). Because of the type of cross-stratification, the gypsiferous part of the lower massive sandstone is interpreted to be a deposit laid down as sand dunes, as was first proposed by McKee (1954, p. 51). These dunes may have formed in a manner analogous to that in which the gypsum dunes formed in the vicinity of the Great Salt Lake Desert in Utah, described by Jones (1953). In that area the sand is derived from gypsum originally deposited in the salt flats of ancient Lake Bonneville. Perhaps the gypsum dunes in the Moenkopi Formation were similarly derived from the reworking by wind of gypsum deposits. These deposits may have formed by evaporation of marginal marine lagoons or lakes and ponds on tidal flats after a regression of the sea.

ORIGIN OF PARALLEL RIPPLE-LAMINATED SILTSTONE

Ripple-laminated siltstone containing parallel ripple marks comprises a large percentage of the Moenkopi Formation at most localities, and is one of its most distinctive and well-known features. Generally this siltstone is medium- to coarse-grained silt and occurs in sets a few inches to several feet thick interstratified with other lithologic types. Parallel ripple marks in the formation are both symmetrical and asymmetrical, and they are commonly associated with cusp ripple marks, interference ripple marks, mud cracks, casts of salt crystals, and raindrop imprints.

The average ripple index (ratio of wavelength to amplitude of the parallel ripple marks in the Moenkopi Formation is less than 15 (McKee, 1954, p. 58), and as shown by Kindle and Bucher (1926) indices of this size are characteristic of water deposition. The presence of mud cracks, raindrop imprints, and, to some extent, casts of salt crystals associated with the ripple laminae in the siltstone indicates periods of exposure of the ripple-laminated strata to subaerial conditions and evaporation. Thus, the ripple-laminated strata accumulated in an environment that was alternately subaqueous and subaerial.

Ripple marks are commonly observed in marine environments (Vause, 1959, fig. 10), on tidal flats (Kindle, 1917, p. 19; McKee, 1957, p. 1742; 1965, p. 81), and on the flood plains of rivers or deltas (McKee, 1938b, p. 79–80; 1939; 1965, p. 81). They can form by either current or wave action. The essential factor in the development of ripple-laminated strata that consist of superposed ripple-marked layers is the introduction of sediment into an area of ripple movement (McKee, 1965). Such conditions most commonly occur on flood plains where sediment is continually being added by river currents. Although ripple marks are common on the surfaces of tidal flats, superposed ripple laminae rarely occur in the sediments (McKee, 1965). In places, however, isolated ripple laminae do occur in tidal-flat sediments (Reineck, 1960, p. 153, fig. 3; 1962, p. 155, figs. 1, 2; Straaten, 1959, p. 212, fig. 4).

On the basis of modern occurrences, therefore, much of the ripple-laminated strata in the Moenkopi Formation may have formed by current action on flood plains. However, in many places in the Moenkopi, ripple-laminated strata are not associated with deposits that are considered to be stream deposits. Because of the lack of associated stream deposits, and until more is known of modern environments, the possibility cannot be ruled out that some of these ripple-marked strata formed on tidal flats or in a marine environment. Some ripple marks are asymmetrical to the west, others to the east (see p. 64). This suggests the back and forth motion of tidal currents, rather than the more uniformly directed currents of streams.

ORIGIN OF HORIZONTALLY STRATIFIED SILTSTONE AND CLAYSTONE

Horizontally stratified siltstone and claystone constitute the dominant type of lithology in the Moenkopi Formation throughout most of its area of deposition. The horizontal stratification ranges from paper-thin lamination to very thick stratification.

Most of the horizontally stratified siltstone and claystone in the Moenkopi Formation probably represents quiet-water deposition through the settling of suspended load in standing bodies of water with little or no current action. Both marine and nonmarine environment of deposition probably are represented. Much of the horizontally stratified siltstone and claystone in the western part of the depositional basin of the Moenkopi is associated with fossiliferous marine limestone units, and probably was deposited in a shallow sea. Much of the horizontally stratified siltstone and claystone in the eastern part of the depositional basin, where deposition is considered mainly fluvial, probably accumulated in lakes and ponds on river flood plains.

ORIGIN OF PRIMARY GYPSUM

Primary gypsum in the Moenkopi Formation occurs as nodules oriented along bedding planes and as stratified lenses and layers. It forms at least 15 percent of the formation at some localities in the western and southwestern part of the area, but is sparse or absent in much of the eastern part.

The primary gypsum in the Moenkopi Formation as postulated by McKee (1954, p. 51) was formed by the evaporation of marine water. This interpretation is supported by the absence of gypsum in almost all of the eastern part of the depositional basin, where the depositional environment is thought to have been nonmarine, and by the westward increase in amount of gypsum to more than 15 percent of the formation in southwestern Utah and southern Nevada, where the depositional environment is thought to have been largely marine or mixed marine and nonmarine. The gypsum may have formed in estuaries and other restricted arms of the sea (Scruton, 1953), or in shallow epeiric seas where circulation was restricted, or eliminated, by the great width of the shelf, low slopes, and extreme shallowness of the water (Irwin, 1965).

The conditions under which evaporites form in estuaries and other restricted arms of the sea are outlined by Scruton (1953). A characteristic circulation pattern exists in these restricted arms. In areas where evaporation exceeds precipitation, surface currents flow toward the upper ends of estuaries because of the hydrostatic head created by the lowering of sea level through evaporation in the estuary. This current is accompanied at depth by an opposing current flowing from high- to low-salinity regions. Precipitation of salts occurs in basins where the outflow into the ocean of the lower current is limited by a restricted channel outlet. A recycling of dense salt-rich waters at the boundary between the surface current and the deep current also helps concentrate saline water. The type of salt deposited may change toward the head of the estuary owing to an increase of salinity in that direction. Thus, calcium carbonate may be deposited at the mouth of the estuary, calcium sulfate in a middle region, and sodium chloride at the head. Such a lateral change in the salts was noted by Morris and Dickey (1957) in a modern estuary in Peru. Evaporation may not go to completion, and calcium sulfate, for example, may be the precipitate of the most saline waters; sodium chloride and other highly soluble salts may be returned to the sea in the seaward-flowing current at depth.

If the gypsum in the Moenkopi Formation were deposited by the evaporation of normal sea water, each gypsum bed should be underlain by a bed of limestone, for the solubility of calcium carbonate is less than that of calcium sulfate, and the carbonate should precipitate out of solution first (McKee, 1954, p. 51). Gypsum deposits in the Shnabkaib Member in southwestern Utah and southern Nevada are associated with thin beds of limestone, and the association probably represents a normal sequence of the evaporation of sea water. Elsewhere, however, the gypsum is interstratified with siltstone; no beds of limestone occur. Possibly, the carbonate was deposited from sea water at the same time that the associated siltstone layers were being deposited, for many of the siltstone layers are limy. On the other hand, the deposition of gypum beds without the presence of an underlying bed of limestone may be accounted for by a progressive increase in salinity of sea water landward in a restricted basin. Under these conditions, as outlined by Scruton (1953), calcium carbonate is deposited on the ocean side of the area, and calcium sulfate and even more soluble salts on the landward side of the basin. In this manner, gypsum deposits can form without an underlying bed of limestone.

The Shnabkaib Member may illustrate a change from deposition of limestone in the seaward part of a basin to deposition of gypsum in the landward part. As outlined in the stratigraphy part of this report, the Shnabkaib Member illustrates a change in facies from limestone, gypsum, and siltstone on the west to gypsum and siltstone on the east. The east margin of the member is marked by the lensing out of the gypsum beds into a siltstone sequence. Such a change in facies can be explained as the result of progressive increase of the salinity of sea water landward in a restricted basin. Limestone was deposited in the seaward part of the area, and gypsum in the landward part, where salts were highly concentrated by evaporation. The highly soluble salts, such as sodium chloride, were apparently returned to the sea by a seaward-flowing current at depth.

The Moenkopi Formation in parts of the salt anticline region in east-central Utah and west-central Colorado may contain some gypsum derived from the evaporation in lakes formed from sulfate-rich stream waters. In this area, the Moenkopi Formation overlaps the salt- and gypsum-bearing Paradox Member of the Hermosa Formation across the crests of some of the salt structures, and a local source of sulfate was available during at least part of the deposition of the Moenkopi Formation.

ORIGIN OF LIMESTONE AND DOLOMITE

Limestone and dolomite form significant amounts of the Moenkopi Formation in the western and northwestern parts of the depositional area of the formation. Limestone and dolomite are common to dominant lithologic types in the Virgin Limestone and Timpoweap Members in southwesternmost Utah and southern Nevada, and in the Sinbad Limestone Member of southeastern Utah. The Thaynes Formation, which is stratigraphically equivalent to part of the Moenkopi Formation, contains limestone and dolomite as the dominant lithologic types in the western Unita Mountains of northern Utah.

Limestone and dolomite in the Moenkopi Formation occur in very thin to very thick sets interstratified with horizontally stratified siltstone and claystone and with primary gypsum. Most of the limestone and dolomite ranges from horizontally laminated to very thick bedded. Some units contain tabular planar sets of cross-strata and locally, trough sets of cross-strata. Marine invertebrate fossils are present in most of the limestone units.

Because of the horizontal stratification, most of the limestone and dolomite in the Moenkopi Formation probably represents quiet-water sedimentation. The presence of marine fossils in some limestone units and the general increase of limestone and dolomite in the Moenkopi toward the geosyncline to the northwest indicate that most of these rocks are of marine origin. Thin lenses of limestone and silty limestone in the Moenkopi of northeastern Arizona may represent strata of freshwater origin deposited in the lakes of river flood plains.

How much of the limestone and dolomite in the Moenkopi represents chemical precipitation, organic precipitation, or mechanical deposition is not known. The thin lenticular limestone beds of probable fresh-water origin in northeastern Arizona may have been chemical precipitates resulting from evaporation and concentration of calcium carbonate in lake waters (McKee, 1954, p. 53). Likewise, the thin laminae and beds of limestone associated with primary gypsum in the Shnabkaib Member in southwesternmost Utah and southern Nevada may represent chemical precipitation through the evaporation of sea water. Oolitic structures in some limestone beds in the Virgin Limestone Member (Poborski, 1954, p. 984), Shnabkaib Member, and Sinbad Limestone Member of the Moenkopi Formation probably represent the chemical precipitation of carbonate around nuclei in agitated waters (Dunbar and Rodgers, 1957, p. 234). Parts of some limestone beds in the Virgin Limestone Member also are thought to represent chemical precipitation (Poborski, 1954, p. 985).

Some limestone beds in the Moenkopi Formation are composed of organic debris, and represent the clastic deposition of organic remains. Crinoidal limestone composed of well-sorted fragments of crinoid stems and plates and fragments of pelecypod shells represents such mechanically deposited organic material (Poborski, 1954, p. 984).

Many limestone beds in the Moenkopi Formation contain large amounts of insoluble clay, silt, and sand. Terrigenous mud or sand evidently was mixed with the lime muds and sand in the sea.

Some of the limestone and dolomite contains evidence of current deposition and reworking. In places the Timpoweap Member is cross-stratified on a small to large scale. Some of the cross-strata are of the trough type and imply deposition in channels. Other cross-strata are of the simple type (McKee, 1954, pl. 5A) and represent deposition with no preceding channeling or erosion. In places, limestone beds in the Virgin Limestone (Poborski, 1954, p. 988) and Sinbad Limestone Members are composed of tabular planar sets of small- to medium-scale cross-laminae that may indicate reworking and deposition by marine bottom currents. Tabular planar sets of cross-strata may develop in subaqueous "bores" like those in the Bahamas (Newell and Rigby, 1957, pl. 10). Asymmetric and symmetric ripple marks that occur in some of the silty limestone of the Virgin Limestone Member (Poborski, 1954, p. 988–989) represent wave or current action. Mud-cracked surfaces on the tops of some limestone beds in the Virgin Limestone Member indicate that at times the calcareous sediments were exposed to subaerial conditions.

BROAD ASPECTS OF ENVIRONMENTS OF DEPOSITION

The Moenkopi Formation exhibits a change from dominantly continental environments on the east to dominantly marine on the west. This change is clearly shown by the distribution and types of fossils in the formation, as well as by the distribution of lithologic types.

Fossils along the east margin of the formation consist largely of bones of amphibians and some reptiles, and of many trackways of reptiles. The amphibians apparently lived in and near streams where their remains were readily covered and preserved by stream deposits; the reptiles, on the other hand, lived along the banks of the streams and in interstream areas, leaving abundant footprints but rarely having their bones preserved. These fossil vertebrates clearly indicate continental environments of deposition along the east margin of the formation.

In contrast to the continental vertebrate remains in eastern Utah and Arizona, fossils in western Utah and Arizona consist mostly of marine invertebrates. Here most of the fossils occur in limestone and dolomite layers and consist of brachiopods, pelecypods, gastropods, cephalopods, and crinoids. Of particular importance in interpretation of environment are the brachiopod *Lingula* and the pelecypod *Myalina* which indicate a shallow-water, nearshore, marine environment. These invertebrate remains leave little doubt that marine environments of deposition were dominant in the Moenkopi Formation in the western part of the Colorado Plateau.

The distribution of lithologic types and the character of sedimentary structures in the formation support and clarify the concepts of environment as suggested by the fossils. Cross-stratified sandstone is prominent in the Moenkopi Formation in the eastern part of the Colorado Plateau, whereas limestone, dolomite, gypsum, and even-bedded siltstone are prominent in the western part. The cross-stratified layers probably are fluvial deposits. The limestone, dolomite, gypsum, and even-bedded siltstone probably were deposited in quiet water, perhaps in a shallow sea and perhaps partly in restricted basins bordering the sea. In the region between the dominantly marine deposits on the west and the dominantly continental deposits on the east, abundant ripple-laminated layers occur. These may have formed on river or delta flood plains, or possibly in part on tidal flats or on the floor of shallow seas.

The Moenkopi Formation probably was deposited during several cycles of transgression and regression. The deposits that formed during times of transgressive

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seas consist mostly of limestone, dolomite, gypsum, and fine-grained clastic sediments. These sediments formed partly in marine and partly in coastal environments. The deposits that formed during times of regressive seas consist mostly of clastic sediments, including cross-stratified sandstone and conglomerate. The members representative of different times of transgression and regression are shown in figure 10. Although this figure provides a general outline of events in the Moenkopi and related strata, the classification of units is difficult in some areas. The upper slope-forming member in southeastern Utah, for example, apparently spans the time of two transgressions and an intervening time of regression.

During the oldest transgressive episode (Permian) for the strata described in this report, the carbonate rock of the South Canyon Creek Member of the State Bridge was deposited. During the next younger transgression, a questionable one, the clastic strata of the Hoskinnini and Tenderfoot Members of the Moenkopi were deposited. Three well-defined transgressive episodes are recognized in higher strata of the Moenkopi Formation. During the first of these, carbonate sediments of the Timpoweap and Sinbad Limestone members of the Moenkopi Formation and the Thaynes Formation (the *Meekoceras* zone of medial Early Triassic age) were deposited. During this episode, carbonate deposition extended over a far greater area of the Colorado Plateau than during any other time of Moenkopi carbonate deposition (pl. 5). The second, next younger, well-defined transgressive episode is represented by the Virgin Limestone Member (*Tirolites* zone of late Early Triassic age). Marine limestone deposited during this time occupies a relatively small area in southwestern Utah and northwestern Arizona. During the third, and youngest, well-defined episode the Shnabkaib Member was deposited; it may be latest Early Triassic.

Deposits formed during times that the sea had largely withdrawn from the Colorado Plateau consist of cross-stratified sandstone and conglomerate, ripple-laminated siltstone, and some horizontally stratified siltstone. These sediments probably formed largely in fluvial and deltaic environments. The lower red member, middle red member, upper red member, lower slope-forming member, ledge-forming member, and cliff-forming member all mark times of regressive seas.

The ledge-forming member of southeastern Utah is one of the most conspicuous units deposited during a time of regressive seas. It is a westward-extending fan-shaped lobe of abundant cross-stratified sandstone and siltstone. Strata interpreted as stream-channel-type deposits are common in this member and are dominant over types considered "sheet-flow," as far west as Circle Cliffs and Capitol Reef National Mounment. The upper part of the Moenkopi Formation in southeastern Utah, including the ledge-forming member, may have been

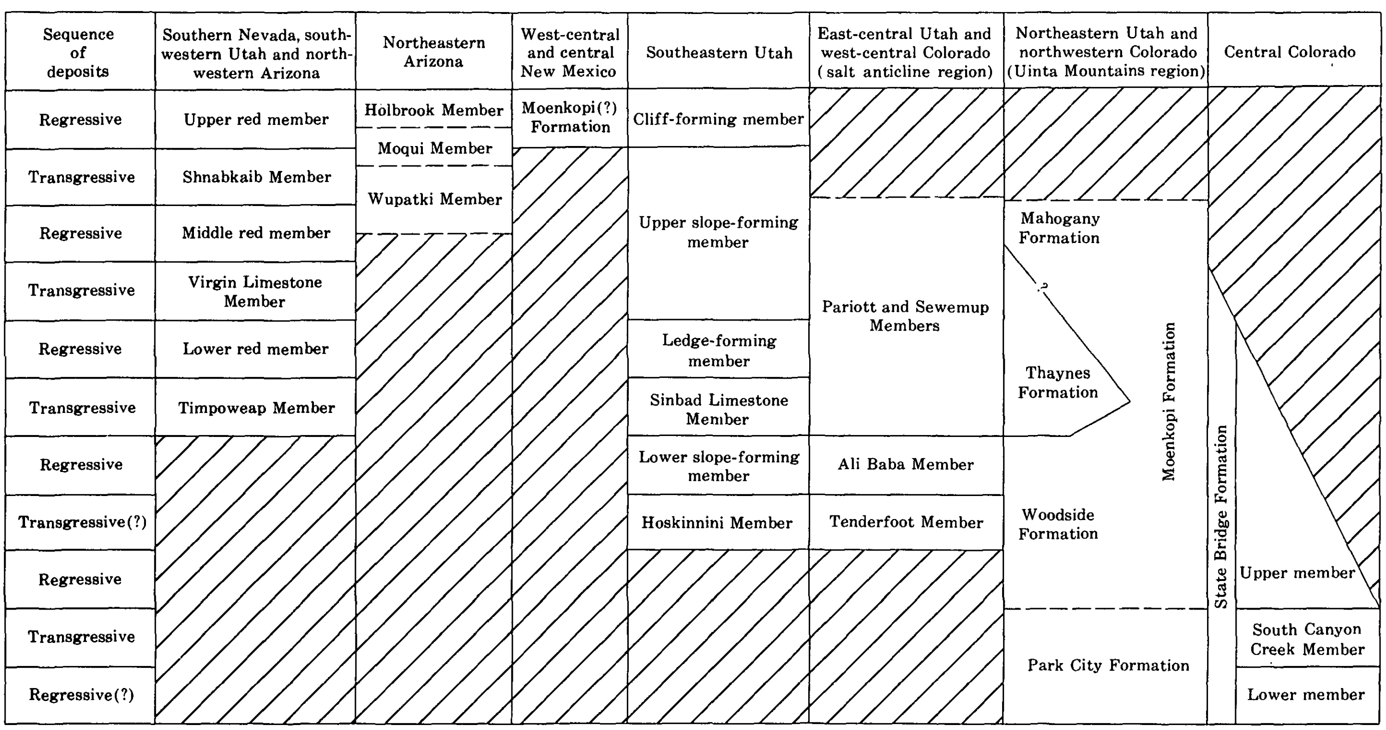

FIGURE 10.—Generalized sequence of deposits formed during times of transgressive and regressive seas in Moenkopi Formation and related strata. Except for central Colorado, members are all part of Moenkopi Formation.

deposited principally in or near stream channels on a delta.

Evidence that the lobe of abundant cross-stratified sandstone of the ledge-forming member was a fluvial deltaic deposit is provided by the close association of these deposits with sediments believed to have been laid down in coastal areas. The east limit of the distribution of primary gypsum in the upper part of the Moenkopi bends westward around the lobe of stream channel deposits. If the primary gypsum indicates the approximate limit of coastal areas, then the western part of the lobe of abundant stream channel deposits would have been surrounded on three sides by the sea. The ledge-forming member at Clay Hills Pass (loc. U49) and Monitor Butte (loc. U34) contains some cross-lamination of the type characteristic of the upper foreshore of beaches (see description of cross-stratified sandstone and siltstone under "Sedimentary Facies") and may, in part, represent beach deposits along the subaerial margin of the delta.

As the depositional slope of the Moenkopi Formation was probably extremely low, on the order of 1 foot per mile, a very slight rise in sea level, or downwarping of the depositional area, would cause extensive transgression of the sea eastward. Transgression could also be produced by a decrease in sediment supply with constant sinking. In addition, deposits built to the west, many in the form of deltas, could cause the sea to retreat great distances. Turbid waters derived from streams entering the shallow sea, particularly during times of flood, probably were carried well out into the ocean and dispersed by tidal and ocean currents. The uniform silt-sized detrital particles in much of the Moenkopi attest to the power of such currents to transport debris over wide areas.

The type of deposit in the Moenkopi Formation may be similar to the deposits on the delta of the Hwang Ho (Yellow River) of northern China. The subaerial part of the delta of the Hwang Ho forms a great triangular flat extending at least 250 miles inland and sloping on the average of 1⅓ feet per mile to the sea (Dunbar and Rodgers, 1957). The river at present empties into the Gulf of Pechili, but at times in the past it emptied into the Yellow Sea. The delta forms the floor of the Gulf of Pechili and most of the Yellow Sea. Both these water bodies are extremely shallow; water depths of 30 feet occur 80–90 miles offshore. The slope of the subaqueous part of the delta, 50 miles from the shore, is approximately 1 foot per mile. Broad tidal flats occur along the margins of the sea, and tides move in and out for many miles across the low slopes. The shores consist of a flat expanse of relatively firm sandy silt with no distinguishing features; sandy beaches and barrier islands are absent, probably because of the fineness of the sediment and the absence of breakers. Waves are dissipated in their long travel across the shallow sea and never break on shore (Keulegan and Krumbein, 1949).

The delta of the Hwang Ho is, therefore, a large deposit consisting mostly of silt being built into an extremely shallow sea, a type of deposition similar to that envisioned for the Moenkopi Formation. Tides sweep across large parts of the Hwang Ho delta as they must also have done when the Moenkopi Formation was laid down. A 100-foot rise in sea level, or lowering of the land, would cause the sea to transgress nearly 100 miles inland across the delta of the Hwang Ho, or a lowering of sea level 100 feet would transform the whole of the Gulf of Pechili and much of the Yellow Sea into land. Such transgressions and regressions of the sea appear to have taken place repeatedly during the deposition of the Moenkopi Formation.

LOCATION OF SOURCE AREAS

The location of the source areas of the Moenkopi Formation is indicated by the direction of sediment transport and by the distribution of coarse detrital material. The direction of sediment transport has been determined from studies of the direction of dip of cross-strata and from studies of the orientation of ripple marks. The distribution of coarse detrital material is shown by lithofacies studies of the formation.

Stream directions, as determined from the orientation of cross-strata, are dominantly west to northwest, indicating streams heading to the east and southeast of the area of deposition (fig. 11). The crests of ripple marks in the formation have north and northeast trends consistent with the concept of west and northwest currents.

The distribution of coarse clastic strata in the Moenkopi Formation indicates multiple source areas for the detrital material. These areas, clearly indicated by the distribution of facies, are the Front Range highland of Colorado, the Uncompahgre highland of Colorado and Utah, and the Mogollon highland of Arizona and New Mexico. In addition, sediment may have been supplied to the formation from other less well defined areas or regions along the east margin of the formation.

The east margin of the upper member of the State Bridge Formation in central Colorado is dominated by current-deposited strata. Although ripple-laminated siltstone is the dominant type of current deposit, cross-stratified rocks are also common to abundant, and a local graywacke conglomerate is present at Sheephorn Creek (loc. C3) at the east margin of the formation. These cross-stratified sandstone and conglomerate units near the east margin of the State Bridge Formation in central Colorado indicate the presence of a source area di-

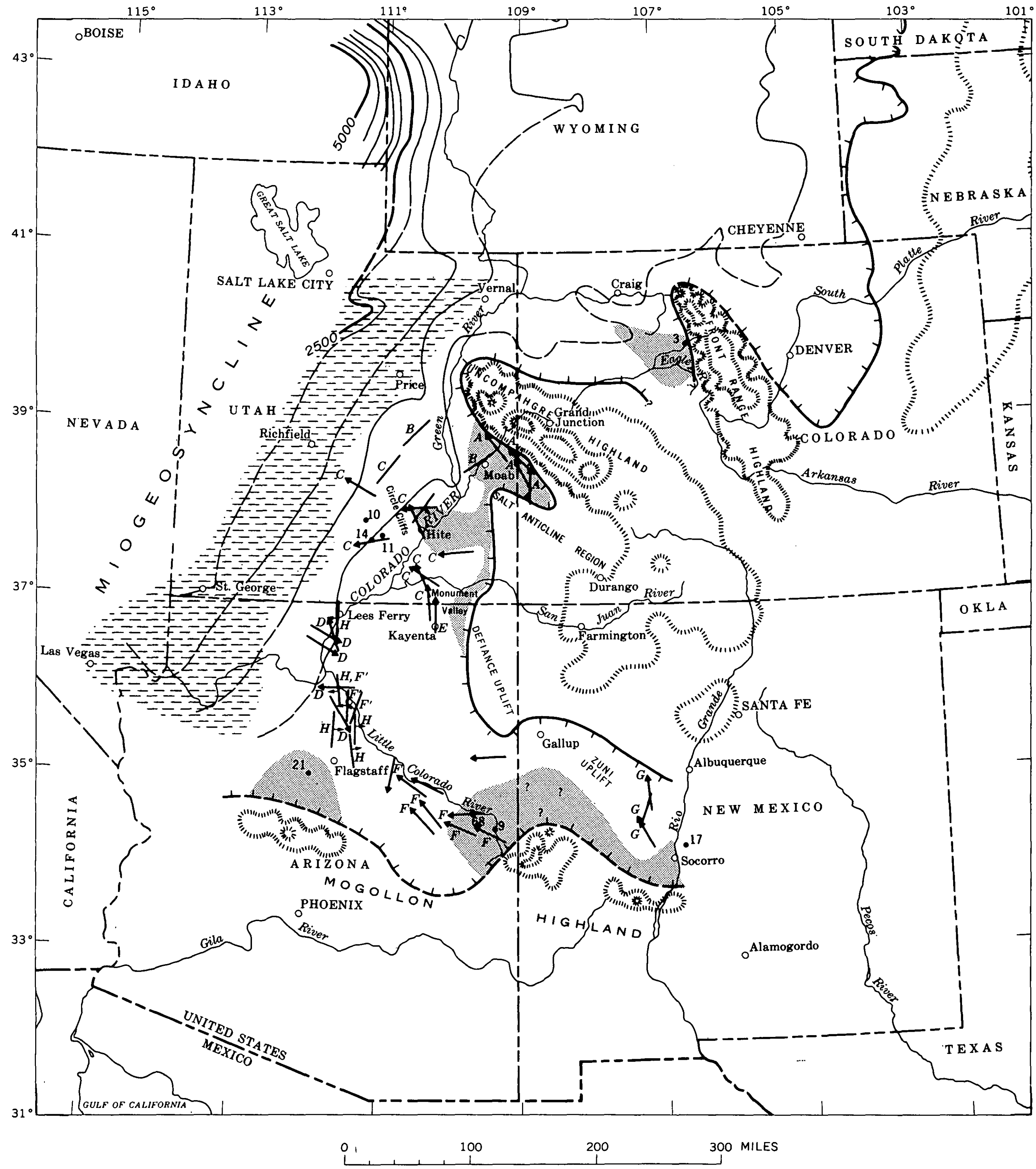

FIGURE 11.—Distribution, thickness, sedimentary facies, generalized stream directions, and source areas of Moenkopi Formation and equivalent strata. *A*, Ali Baba Member; *B*, undifferentiated siltstone; *C*, ledge-forming member; *D*, lower massive sandstone; *E*, undifferentiated sandstone; *F*, Holbrook Member (*F'*, data from McKee, 1954); *G*, undifferentiated conglomerate; *H*, Wupatki Member (data from McKee, 1954). Black dots are localities referred to in text: A9, St. Johns; A21, Sycamore Canyon; A68, Concho; C3, Sheephorn Creek; NM17, Sevilleta Grant; U10, Horse Canyon; U11, Muley Twist; and U14, Silver Falls Creek.

EXPLANATION

Cross-laminated or ripple-laminated sandstone or siltstone constitutes 50 percent of Moenkopi Formation or related strata
Shown only in Colorado Plateaus region

Horizontally laminated to very thick bedded siltstone, claystone, limestone, dolomite, or gypsum constitutes 80 percent of Moenkopi Formation or related strata
Shown only in Colorado Plateaus region

Approximate limit of deposition of Moenkopi Formation and related strata
Present on hachured side. Dashed where inferred

5000

Isopachs
Dashed where inferred. Interval is 500 feet. Thickness data outside Colorado Plateau from McKee and others (1959)

Current direction
Determined from orientation of cross-strata

Generalized strike of symmetrical ripple marks

Generalized strike and steep dip direction of asymmetrical ripple marks

Land areas and highlands

rectly east in the ancestral Front Range highland, where Precambrian rocks were exposed during deposition of the State Bridge (pl. 2).

The salt anticline region of east-central Utah and west-central Colorado provides evidence of another source area of the Moenkopi Formation. Across most of this region strata deposited by currents are the dominant lithologic type. Cross-stratified sandstone and siltstone is common and locally constitutes nearly 50 percent of the formation. In many places, particularly in the lower part of the formation (Ali Baba Member), along the east margin of the salt anticline region, the cross-stratified sandstone and siltstone includes common to abundant beds and lenses of arkosic conglomerate containing granule- to cobble-size granitic, metamorphic, and sedimentary rock. Conglomerate in the Moenkopi Formation decreases in amount westward and is absent at Moab. The source of these conglomerate beds, and probably much of the formation in the salt anticline region, as pointed out by Dane (1935, p. 52) and by Shoemaker and Newman (1959), was the ancestral Uncompahgre highland, an element of the ancestral Rocky Mountains, which lies immediately to the east and north of the salt anticline region (fig. 11). Precambrian granitic and metamorphic rocks were exposed on this uplift during the deposition of the Moenkopi Formation (pl. 2) and served as source rocks for much of the formation in the area.

The westward-extending fan-shaped lobe of abundant cross-stratified sandstone and siltstone in southeastern Utah indicates an influx of material from a significant source area (pl. 5; fig. 11). The material in this lobe is mostly siltstone and fine-grained sandstone and, as described previously, probably represents a deltaic deposit. Conglomerate is sparse and is largely of the intraformational variety, composed of siltstone and claystone pebbles. The fan-shaped lobe of sandstone and siltstone may mark the location of the entrance of a major river or group of rivers into the depositional area of the Moenkopi Formation. The river or rivers probably headed in the ancestral Uncompahgre highland to the east. The manner in which the lobe of cross-stratified rocks distort the regional trend of facies changes westward in southeastern Utah indicates that this source area was probably one that supplied a major amount of clastic sediment to the Moenkopi in southeastern Utah.

A local source, probably the northern part of the Defiance uplift, is indicated by a thin belt of abundant cross-stratified rocks in the Moenkopi Formation concentrated along the east margin of the formation in the eastern part of Monument Valley near the Arizona-Utah State line. However, most of the Defiance uplift, although a positive area during the deposition of the Moenkopi Formation (pl. 5; McKee, 1963), supplied little sediment to the Moenkopi basin. Deposits along the south margin of the uplift are fine-grained and represent predominantly quiet-water deposition as compared to deposits farther south consisting of relatively coarse grained sandstone and siltstone that represent stream-channel deposition (pl. 5). The Moenkopi Formation along the west margin of the Defiance uplift is covered by younger strata, but available well data indicate a predominance of fine-grained siltstone.

In the south a local source for part of the Moenkopi Formation is indicated by the basal conglomeratic unit in the Sycamore Canyon area (loc. A21) of north-central Arizona. This conglomeratic unit is about 90 feet thick and contains pebbles of chert, quartz, siltstone, limestone, and some quartzite. The conglomerate represents a local deposit probably derived from an uplift to the south (fig. 11). The Moenkopi Formation in Sycamore Canyon is underlain by the Kaibab Limestone (pl. 2), which probably was the source rock for chert and limestone pebbles in the conglomerate.

The proximity of an important source, possibly the principal source, of the Moenkopi Formation in eastern Arizona and western New Mexico is indicated by the abundance of cross-stratified sandstone and siltstone in the Concho (loc. A68)–St. Johns (loc. A9) area in east-central Arizona and in the Zuni uplift and Sevilleta Grant areas in west-central New Mexico (loc. NM17) (pl. 5). Locally in these areas, cross-stratified sandstone and siltstone constitute more than 50 percent of the Moenkopi. Locally the sandstone is conglomeratic. The amount of cross-stratified sandstone and siltstone decreases to the north and west away from the Concho–St. Johns area, indicating that the source of these coarse rocks lay to the south or southeast, probably in southeastern Arizona or southwestern New Mexico. A northwest direction of stream flow in the Concho–St. Johns area also supports the concept of a source to the south or southeast of this area.

The source area to the south of the south margin of the Colorado Plateau that supplied detritus to the Moenkopi Formation in the Sycamore Canyon area, Concho–St. Johns area, and in west-central New Mexico, is referred to here as the Mogollon highland. This highland is believed to have been a prominent source area during Late Triassic and Jurassic time on the Colorado Plateau, and was originally named by Harshbarger, Repenning, and Irwin (1957) who recognized its importance as a source area for rocks of Triassic age. This highland apparently first developed during Moenkopi time, although the amount of coarse detrital material supplied then was much less than during Chinle time (Late Triassic) or during part of Jurassic time.

Another source area may have existed to the west of the Colorado Plateau, in southern and central Nevada during Moenkopi time. A highland in this area was originally proposed by Nolan (1943, p. 171) and has been advocated more recently by Clark (1957). Although it is likely that an emergent area existed in southern and central Nevada during Early Triassic time, the extent of this area seems to have been much less than originally envisioned by Nolan (1943) or even as modified by Clark (1957). Strata of Early Triassic age occur at several localities in southeastern California, suggesting a continuous seaway from the Colorado Plateau across southernmost Nevada and southeastern California (McKee and others, 1959). Strata of Early Triassic age also occur in western and northeastern Nevada, indicating that if an emergent area existed in Nevada in Early Triassic time, it most likely was an island in a sea.

Nonetheless, some evidence suggests that an emergent area was present in southern and central Nevada during part of Moenkopi time. The most direct evidence is a marked unconformity at the base of the Moenkopi in some areas of southern Nevada (Longwell, 1925; Glock, 1929). In the southern Spring Mountains, evidence of pre-Moenkopi erosion ranges from a small valley cut 75 feet into the underlying Kaibab Limestone (Permian) to the removal of the entire Kaibab Limestone (Glock, 1929, p. 333). In southern Lincoln County, the Kaibab Limestone and Toroweap Formation, the topmost formations of Permian age, pinch out to the west, perhaps by pre-Moenkopi erosion (C. M. Tschanz, written commun., 1958). Westward beyond the limit of the Kaibab Limestone and Toroweap Formation, the Moenkopi Formation rests with an angular relationship on red beds of Permian age. The evidence for a marked depositional break and a time of erosion before deposition of the Moenkopi supports the supposition that an emergent area existed in southern Nevada. The areas of marked unconformity may have been along the southeast flank of this emergent area.

Further evidence of an emergent area in southern Nevada is afforded by chert pebble conglomerate at the base of the Moenkopi Formation in many parts of southern Nevada, southwestern Utah, and northwestern Arizona. The conglomerate in places is at least 100 feet thick. The chert was probably derived from the Kaibab Limestone and Toroweap Formation, and the source area could very well have been to the west in the area where these formations are known to have been eroded.

The source areas that contributed sediment to the lower part of the Moenkopi Formation and related strata are different, in some places, from those of the upper part. The most conspicuous source areas during deposition of the lower part, based on the abundance of cross-stratified sandstone and siltstone (pl. 5) and of conglomeratic strata, were the Uncompahgre highland and a northeast-trending positive area in southeastern Utah and Arizona. In addition, although not shown on plate 5, the presence of conglomerate along the east margin of the upper member of the State Bridge Formation in central Colorado, in strata laterally continuous with the lower part of the Moenkopi Formation, indicates a source in the Front Range highland. Conglomerate in the lower part of the Moenkopi in southwestern Utah indicates a possible source in southern or central Nevada.

One of the most prominent features along the south margin of the lower part of the Moenkopi Formation is a northeast-trending positive area extending approximately along the course of the present-day Colorado River from the south border of Utah northward to the vicinity of Hite, Utah. Strata of the lower part of the formation appear to be entirely missing from this area, which was probably an area of nondeposition. This positive area apparently was the source area for the conglomerate in the lower part of the formation in the Hite and Dirty Devil River areas. In addition, the southeastward increase in quantity of stream-channel deposits in the lower part of the Moenkopi across Circle Cliffs (locs. U10, U11, U14) is apparently related to the west edge of the positive element.

The most conspicuous source areas during deposition of the upper part of the Moenkopi Formation, based on the abundance of cross-stratified sandstone and siltstone, were (1) an indefinite area in southwestern Colorado, (2) an indefinite area to the east or southeast of the Monument Valley area in Utah and Arizona, and (3) the Mogollon highland along the south margin of the Colorado Plateau. Strata in the upper part of the formation were deposited across the positive area along the Colorado River that had contributed sediment to the lower part of the formation. In addition, the Uncompahgre highland, a conspicuous source area for coarse material during deposition of the lower part of the formation, contributed only a minor amount of coarse material to the upper part of the formation.

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STRATIGRAPHIC SECTIONS

Stratigraphic sections are presented alphabetically by State and county and by the locality numbers used in table 1 and on plate 1.

Most stratigraphic sections were measured with an Abney hand level. Some were measured by planetable methods. The described colors are those recommended by the National Research Council (Goddard and others, 1948). Description of stratification largely follows that recommended by McKee and Weir (1953).

In the locality data given in the headnote, meridians are abbreviated as follows:

GSRM --- Gila and Salt River Meridian.
MDM ---- Mount Diablo Meridian.
NMPM --- New Mexico Principal Meridian.
SLM ----- Salt Lake Meridian.
6th PM--- 6th Principal Meridian.

ARIZONA

A1. BLACK CREEK

[Measured, by J. H. Stewart and R. F. Wilson, April 1956, on west side of Black Creek, 2¾ miles north of U.S. Highway 66 and about same distance north-northwest of Houck, long 109°13'35" W., lat 35°19'40" N. Apache County]

Top of section; top of exposure. Top of section about 2,000 ft northwest of prominent bend in Black Creek and at southeasternmost tip of mesa capped by Shinarump.

Chinle Formation (incomplete):

Shinarump Member (incomplete): *Feet*

7. Sandstone, yellowish-gray (5*Y* 8/1) coarse to very coarse grained, fair- to well-sorted; weathers same color; composed of subangular clear and milky quartz; firmly to poorly cemented, calcareous; composed of thin to thick trough sets of low-angle medium-scale cross-strata; weathers to form ledge and mesa cap. Unit contains common disseminated granules and pebbles, about 3 in. in maximum diameter, of chert and minor quartzite and quartz. One igneous pebble (possibly a porphyritic rhyolite) was found. Silicified tree logs are common. One log 2 ft in diameter seen ---------- 18+

Total incomplete Shinarump Member ---- 18+

Total incomplete Chinle Formation ------ 18+

Unconformity. Scours as deep as 0.5 ft are cut into the Moenkopi. Contact between Moenkopi and Shinarump placed at change from siltstone of Moenkopi to coarse sandstone of Shinarump.

Moenkopi Formation:

Holbrook(?) Member:

6. Siltstone (70 percent) and sandstone (30 percent). Siltstone is dark reddish brown (10*R* 3/4) and grayish red (10*R* 4/2), weathers pale reddish brown (10*R* 5/4), common fine-grained accessory white mica; firmly cemented, slightly calcareous in parts; structureless. Sandstone is grayish red (5*R* 4/2); weathers same color; very fine to fine grained, fair sorted; composition masked; horizontally laminated, cross-stratified or structureless. Sandstone is present as thin to thick sets interstratified with sandstone. Unit as whole weathers to form steep slope. Top foot, or possibly more, is mottled purple and gray ---------- 31.0

A1. BLACK CREEK—Continued

Moenkopi Formation—Continued

Holbrook(?) Member—Continued *Feet*

5. Sandstone, grayish-red (5*R* 4/2), very fine grained, fair- to well-sorted; weathers same color; composition masked, common dark-green accessory mica; firmly cemented, calcareous; composed of trough and wedge and tabular planar sets of small- to medium-scale, low-angle cross-laminae; weathers to form most prominent ledge in exposure of Moenkopi Formation. Base of unit is erosion surface, and scours as much as 1 ft deep are present ---------- 14.2
4. Siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers same colors; fine-grained accessory white mica common in parts; firmly cemented, calcareous; structureless; weathers to form steep slope. Thin horizontal bed of grayish-red (5*R* 4/2) silty very fine grained silty sandstone is present about 5 ft below top of unit and forms small ledge ---------- 57.0
3. Sandstone, pale-red (5*R* 6/2), very fine grained, silty, fair-sorted; weathers same color; composed of subangular clear and milky quartz and 10 percent black grains (possibly biotite); poorly to firmly cemented, calcareous; horizontally laminated to very thick bedded and common trough and planar sets of medium-scale low-angle cross-laminae; weathers to form steep ledgy slope ---------- 22.4
2. Siltstone, pale-reddish-brown (10*R* 5/4) and sparse grayish-orange (10*YR* 7/4); weathers same colors; abundant fine-grained accessory white mica in some parts; firmly cemented, calcareous; stratification concealed in many places but appears to consist dominantly of horizontal laminae; weathers to form gentle slope. At 33–34 ft and 27–28 ft, unit contains grayish-orange (10*YR* 7/4) coarse siltstone ledges that are ripple laminated with ripples of both the cusp and parallel types. Basal 2 ft of unit is pale-reddish-brown (10*R* 5/4) silty sandstone which probably derived dètritus from the underlying De Chelly Sandstone ---------- 44.8

Total Moenkopi Formation, Holbrook(?) Member ---------- 169.4

A1. BLACK CREEK—Continued

Contact of Moenkopi and De Chelly sharp and probably unconformable. Base of Monekopi truncates cross-strata of De Chelly, and in places seems to scour possibly as much as 1 ft into the De Chelly.

De Chelly Sandstone (unmeasured):

1. Sandstone, very pale orange (10*YR* 8/2), fine- to medium-grained, fair- to well-sorted; weathers same color; composed of subangular to subrounded clear quartz and sparse black and orange accessory mineral; firmly cemented, calcareous; cross-stratified on a large scale, type of cross-strata not determined; forms outcrop at base of wash. Unit weathers to form vertical cliff along Black Creek.

Base of section; base of exposure. Base of section in small tributary wash of Black Creek about 1,000 ft west of Black Creek.

A5. HUNTERS POINT

[Measured, by J. H. Stewart and R. F. Wilson, April 1956, about 1 mile northwest of Hunters Point and 1.9 miles southwest of Hunters Point Day School, long 109°07'50" W., lat 35°34'10" N. Apache County]

Top of section; top of exposure.

Chinle Formation:

Shinarump Member (unmeasured): *Feet*

7. Sandstone, very pale orange (10*YR* 8/2) and grayish-orange (10*YR* 7/4), medium- to coarse-grained, fair-sorted; weathers same colors; composed of subangular clear quartz; poorly to firmly cemented, calcareous; composed of thin trough sets of low-angle small-scale cross-laminae, much of stratification obscure; weathers to form a ledge. Sandstone contains a few disseminated granules and pebbles as large as 3 in. in diameter of quartz, quartzite, and chert. Silicified tree logs present as float. About 13 ft above base of unit, orange sandstone is overlain by about 10 ft of pale-red-purple, fine- to medium-grained sandstone that is probably also part of Shinarump Member.

Moenkopi Formation:

Holbrook(?) Member:

6. Siltstone, grayish-red (10*R* 4/2); in top 5 ft grades upward to very pale orange (10*YR* 8/2), light bluish gray (5*B* 7/1), and pale yellowish orange (10*YR* 8/6); fine silt; common fine-grained accessory white mica; poorly cemented, clay binding, calcareous; structureless and horizontally laminated; weathers to form steep slope. Top 2 ft of unit contains some clayey very fine grained sandstone that possibly belongs in Chinle Formation. Exposures are not complete enough to determine definitely if this sandstone is Chinle ---------- 22.4

5. Sandstone and minor siltstone, grayish-red (10*R* 4/2), pale-red (10*R* 6/2), minor grayish-orange (10*YR* 7/4); thin pale-blue (5*PB* 7/2) band at base. Unit weathers mostly grayish red (10*R* 4/2). Grades from coarse siltstone to fine-grained sandstone; well sorted; composed of clear and red-stained quartz, common fine-grained accessory white mica; well cemented, calcareous; horizontally laminated and thin trough and tabular planar sets of low-angle small-scale cross-laminae; weathers to form a ledge ---------- 6.0

A5. HUNTERS POINT—Continued

Moenkopi Formation—Continued

Holbrook(?) Member—Continued *Feet*

4. Mostly covered. Top 2 ft is exposed and is composed of siltstone. Nature of outcrops suggests entire unit may be same type of siltstone. Siltstone is grayish red (10*R* 4/2), weathers same color; fine silt, sparse accessory white mica; horizontally laminated. Unit as whole weathers to form slope ---------- 5.4

3. Siltstone, moderate-brown (5*YR* 4/4); weathers same color; coarse silt, abundant fine-grained accessory white mica; well cemented, calcareous; composed of wavy laminae (possible ripple laminae) and thin cosets composed of thin trough sets of low-angle small-scale cross-laminae; weathers to form small ledge ---------- 3.7

2. Covered; forms slope ---------- 5.6

Total Moenkopi Formation, Holbrook(?) Member ---------- 43.1

De Chelly Sandstone (unmeasured):

1. Sandstone, grayish-yellow (5*Y* 8/4) and yellowish-gray (5*Y* 7/2); weathers yellowish gray (5*Y* 7/2); fine to medium grained, fair sorted; composed of subangular to subrounded clear quartz and abundant black accessory mineral; cross-stratified on large scale; weathers to form dip slope. Only top few feet exposed.

Base of section; base of exposure.

A9. ST. JOHNS

[Measured, by J. H. Stewart and R. F. Wilson, August 1955, 5½ miles south of St. Johns and ¾ mile up side canyon from Little Colorado River. Long 109°21'40" W., lat 34°25'40" N. Section begins at creek level, at a point N. 47° E. from northwest promontory of basalt-capped mesa about a mile south of section, and continues in a northeast direction. Apache County]

Top of section; top of exposure.

Chinle Formation (incomplete):

Shinarump Member: *Feet*

7. Sandstone to conglomeratic sandstone, very pale orange (10*YR* 8/2); weathers pale yellowish brown (1*YR* 6/2); medium to coarse grained; composed of subangular clear quartz and sparse black accessory minerals, abundant "limonite" spots; poorly cemented, calcareous, composed of thin to thick trough sets of medium-scale cross-strata; weathers to form ledge at or near top of an extensive local mesa. Unit contains about 20 percent conglomeratic sandstone which contains granules and pebbles of chert and quartzite as large as 4 in. in maximum diameter ---------- 4.5

A9. ST. JOHNS—Continued

Chinle Formation—Continued

Shinarump Member—Continued | *Feet*

6. Covered. Poor lateral exposure indicates that this unit is mostly red (minor green) siltstone and claystone. Fossil plants occur in this unit about 2,000 ft east of section line, at long 109°21'15" W., lat 34°25'25" N. Unit 5 pinches out immediately west of the plant locality ---------- 14.8
5. Conglomerate (60 percent) and sandstone (40 percent). Conglomerate is light greenish gray (5*GY* 8/1); weathers very pale orange (10*YR* 8/2). Gravel: composed of granules to cobbles of quartzite, chert, and minor quartz. Cobbles reach maximum diameter of 6 in. Matrix: medium- to coarse-grained fair-sorted; composed of subangular clear quartz and common black accessory mineral. Sandstone has same colors as conglomerate, and same texture and composition as the matrix of the conglomerate. Both sandstone and conglomerate are firmly cemented, calcareous, and are composed of thin to thick, poorly defined horizontal beds. Unit as whole weathers to form ledge. Granules to cobbles comprise 60–70 percent of conglomerate ---------- 11.7

Total Shinarump Member ---------- 31.0

Mottled strata:

4. Siltstone to claystone, poorly exposed. Grayish red (10*R* 4/2) and sparse dusky yellow (5*Y* 6/4) in basal 5 ft and pale yellowish green (10*GY* 7/2) in top 5 ft; weathers grayish red (10*R* 4/2); cementing character and stratification concealed; weathers to form slope covered by gravels from overlying unit. One thin bed of brownish-gray (5*YR* 4/1) very fine grained sandstone in middle of unit. In a large outcrop about 1,000 ft west of section line the unit is mostly grayish-purple (5*P* 4/2) silstone with dusky-yellow (5*Y* 6/4) mottling. This siltstone contains about 5 percent rounded fine to medium grains of clear quartz; it is well cemented, noncalcareous, fractures in angular fragments, and is structureless ---------- 17.8

Total mottled strata ---------- 17.8

Total incomplete Chinle Formation ---------- 48.8

Moenkopi Formation:

Holbrook Member:

3. Sandstone, yellowish-gray (5*Y* 8/1) and minor light-greenish-gray (5*GY* 8/1); weathers very pale orange (10*YR* 8/2); medium grained, fair sorted, composed of subangular clear quartz and abundant black accessory minerals; firmly cemented, calcareous; composed of thin to thick trough and planar sets of medium and minor large-scale cross-strata; weathers to form vertical cliff; basal 10 ft contains sparse coarse-grained parts and a few granules of chert and quartz and pebbles of siltstone. Unit forms extensive, light-colored cliff along canyon ---------- 38.2
2. Poorly exposed. Sparse outcrops indicate unit is siltstone (90 percent) and sandstone (10 percent). Siltstone is dusky yellow (5*Y* 6/4) and greenish gray (5*GY* 6/1), sparse medium gray (*N*5); weathers yellowish gray (5*Y* 8/1); firmly cemented, noncalcareous; stratification concealed; contains common limestone nodules or pebbles and, near top of unit, a few flakes of carbonaceous material. Sandstone is yellowish gray (5*Y* 8/1); weathers same color; fine to medium grained; well sorted; composed of angular grains of calcite; poorly cemented. Sandstone is present as thin, poorly defined horizontal beds interstratified with the siltstone. Unit weathers to form bench in lower part and slope in upper part. This unit is placed in the Moenkopi Formation because of the dominance of siltstone and clastic material and the presence of carbonaceous material, but it may be a weathered zone on top of San Andres Limestone (Kaibab Limestone) ---------- 12.2

Total Moenkopi Formation, Holbrook Member ---------- 50.4

San Andres Limestone (Kaibab Limestone) (incomplete):

1. Limestone, light-gray (*N*7) and yellowish-gray (5*Y* 8/1); weathers same colors; aphanitic to finely crystalline; very thinly to thinly horizontally bedded, beds slightly wavy with amplitude of 2 in.; weathers to form vertical cliff with minor slope breaks; unit contains a few chert nodules with maximum dimensions of 3–4 in. and a few very thin chert beds. Top 7 ft of unit contains about 20 percent yellowish-gray (5*Y* 8/1) fine-grained sandstone and siltstone, and intraformational conglomerate with angular fragments of limestone as large as 6 in. in diameter; this top 7 ft also contains a few pebbles of siltstone ---------- 63+

Base of section; base of exposure.

A11. SHINARUMP CLIFFS

[Measured, by L. C. Craig and T. E. Mullens, May 1952, about 4 miles east of Fredonia, sec. 7, T. 41 N., R. 1 W., GSRM. Section begins on lowest exposure of middle red member of the Moenkopi Formation; it bears S. 5° W. to corral and cattle tank, and, about 150 yds east of a fence, it bears slightly west of north. Coconino County]

Top of local exposure.

Chinle Formation (incomplete):

Shinarump Member (incomplete): *Feet*

12. Sandstone, conglomeratic sandstone, and conglomerate. Sandstone is grayish orange (10*YR* 7/4), pale yellowish orange (10*YR* 8/6), and very pale orange (10*YR* 8/2), locally pale yellowish brown (10*YR* 6/2); weathers same colors; fine and coarse grained, dominantly coarse grained, locally well sorted, but dominantly poorly sorted; composed of clear quartz with sparse black and white accessory minerals, grains mainly subangular; poorly to firmly cemented, calcareous. Conglomeratic sandstone and conglomerate have a matrix composed of sand. Coarse clasts are well rounded, granule sized to 4½ in. in maximum diameter, and consist mainly of gray quartzite, gray and tan chert, and uncommon clear quartz and gray fossiliferous limestone. Unit as whole has trough sets, 1–10 ft thick, of concave, low-angle cross-laminae. Basal strata of unit fills scours cut into the Moenkopi Formation, but angular discordance not noticed in line of section. Unit forms light-colored resistant cap and a long dip slope. Unit contains much silicified wood, mainly 6- to 18-in. fragments, but commonly trees as much as 4 ft in diameter. Wood structure well preserved. Entire thickness of Shinarump Member probably not exposed 30.0

Total incomplete Shinarump Member ... 30.0
Total incomplete Chinle Formation 30.0

Moenkopi Formation:

Upper red member:

11. Claystone, light-brownish-gray (5*YR* 6/1) to moderate-pink (5*R* 7/4); sparse very fine clear quartz grains; well cemented, calcareous; stratification concealed; locally highly fractured. Subparallel limolite-stained bands as much as 1½ in. thick. Dark-gray (*N*3) surface discoloration near contact with Shinarump Member 14.2
10. Unit very poorly exposed. Scattered outcrops of silty and sandy claystone and nonresistant sandstone. This unit same as unit 8 except it contains more clay 20.0
9. Sandstone, same as that in unit 8. Locally forms overhanging cliff. Thin ledge, but may be traced at least a mile to the east .. 7.2
8. Sandstone (90 percent) and claystone (10 percent). Sandstone, same as unit 7 except it does not form ledge and is micaceous. One ledge, about 5 ft above base of unit, is grayish-yellow (5*Y* 8/4) fine to very fine grained sandstone composed of clear quartz with sparse to common red, yellow, and black accessory minerals. Claystone, sandy to silty, grayish-red (10*R* 4/2), micaceous; contains carbonate cement. Unit forms small slope 15.8
7. Sandstone, pale-reddish-brown (10*R* 5/4) to light-brown (5*YR* 6/4); weathers reddish brown (10*R* 6/4); very fine grained; composed of amber-stained quartz, accessory minerals masked; highly calcareous cement; very thick bedded (5–10 ft) and thinly laminated, dominantly cuspate ripple laminated with local pseudocross-laminae. Unit forms double ledge in line of section, but forms only single ledge elsewhere along exposure. Lower ledge is 10 ft and upper ledge is 18 ft above base of unit 28.5
6. Sandstone (50 percent) and silty and sandy claystone (50 percent). Sandstone is pale reddish brown (10*R* 5/4) to dark reddish brown (10*R* 3/4) and light brown (5*YR* 6/4), fine to very fine grained; composed of subangular clear quartz with abundant to common orange, green, and black accessory minerals; poorly to firmly cemented, gypsiferous; thin to thick bedded (½–3 ft), horizontally to ripple-laminated, one group of asymmetrical ripple laminae indicates a N. 70° W. current direction. Claystone is grayish red (10*R* 4/2) to dark reddish brown (10*R* 3/4); papery to shaly splitting; micaceous; noncarbonate cement. Unit forms badland slope. Unit highly gypsiferous. Gypsum in beds, seams, and crosscutting veins. Basal part of upper red member differs from middle red member in having darker color and fissility of clays. Offset on top of unit so that overlying units measured 150 yds to east of underlying units 99.5

Total upper red member 185.2

Shnabkaib Member:

5. Sandstone (50 percent) and silty claystone (50 percent). Sandstone is very light gray (*N*8), yellowish gray (5*Y* 8/1) to light greenish gray (5*GY* 8/1), very fine to fine grained; composed of subangular clear quartz with uncommon orange, green, and black accessory minerals; predominantly poorly cemented, slightly calcareous, highly gypsiferous, a few resistant beds with more carbonate cement; thin bedded (½–3 in.), thinly laminated, and ripple laminated. Silty claystone is very light gray (*N*8) to light greenish gray (5*G* 8/1), variable content of silt; slight carbonate cement, highly gypsiferous; fissile; earthy, and frothy

A11. SHINARUMP CLIFFS—Continued

Moenkopi Formation—Continued

Shnabkaib Member—Continued | Feet

weathering. Unit highly gypsiferous, probably in large part secondary gypsum. Gypsum occurs in beds, stringers, and veinlets. Several beds as much as 3 ft thick contain irregular-shaped, probably primary, gypsum nodules. Basal 10 ft of unit forms resistant cap and may contain less gypsum than overlying part. Top 30 ft of unit consists of fine-grained dominantly horizontally bedded sandstone, composition and color as above. A 1 in.-thick bed of white to yellowish-gray (5*Y* 8/1) plastic clay, suggesting bentonite, 125 ft above base of unit. Pseudomorphs of limonite after pyrite common to abundant in lower part of unit. Unit forms bench with local badland topography. Top contact poorly exposed and marked by 1-ft-thick greenish- to yellowish-brown silty and sandy claystone. Basal contact at change from reddish brown below to light greenish gray above. This color change takes place in 3–4 in. of beds ---------- 217.0

Total Shnabkaib Member ---------- 217.0

Middle red member:

4. Same as unit 3, except lower half is slightly more resistant than unit 3 and stands out in short spurs, and lower part of unit 3 has more sand than upper part. Upper half forms steep slopes under Shnabkaib Member and contains about 25 percent gypsum. Gypsum is pure and crystalline, occurs as primary beds as much as 8 in. thick and as secondary veins and seams ---------- 44.4
3. Sandstone (50 percent) and silty to sandy claystone (50 percent). Sandstone, colored same as unit 2, very fine grained, silty; composed of clear quartz and sparse accessory minerals, slightly micaceous; cement and structures same as in unit 1. Claystone, grayish-red (10*R* 4/2) to moderate-reddish-brown (10*R* 4/4), local light-greenish-gray (5*GY* 8/1) irregular bleached patches; fissile to earthy weathering. Unit highly gypsiferous; gypsum occurs as stringers, beds, and vugs. Unit weathers to badlands. Unit capped by 6-in.-thick light-greenish-gray, very fine to fine-grained, micaceous, and ripple-laminated sandstone that forms a prominent light-colored band in exposure ---------- 74.2
2. Sandstone (60 percent) and clayey siltstone (40 percent). Sandstone is pale reddish brown (10*R* 6/4) to light brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4), very fine grained; composed of clear quartz and abundant green mica flakes, other accessory minerals masked; calcite and probably gypsum cement; thinly and irregularly bedded, thinly horizontally laminated, cuspate ripple marks, one group of asymmetrical ripple marks indicates a current moving S. 70° E., locally contains thin intraformational conglomerate of siltstone pebbles as much as ½ in. in diameter. Clayey siltstone is moderate reddish brown (10*R* 4/6); weathers same color; platy splitting; fissile to hackly weathering; contains greenish-gray mica and clear gypsum flakes on lamination planes. Unit weathers to moderate-reddish-brown (10*R* 4/6) slope with ledges of sandstone that contain stringers of light-gray to white gypsum which in places form protective caps for ledges. Ledges are 1½–4 ft thick. Most prominent ledges are 25, 46, 55, and 48 ft above base of unit. Top ledge forms prominent bench. Section offset on top of unit so that overlying units measured 300 yds northeast of underlying units ---------- 71.1
1. Siltstone and claystone (90 percent) and sandstone (10 percent). Siltstone and claystone, interlaminated, moderate-reddish-brown (10*R* 4/4), weathers moderate reddish brown (10*R* 4/6), slightly fissile; contains thin plates, seams, and veinlets of white gypsum; 1-ft-thick grayish-purple (5*P* 4/2) siltstone and claystone bed at 16 ft above base of unit. Sandstone, light-gray (*N*7) to pale-reddish-brown (10*R* 6/4), very fine grained; composed of pure quartz and sparse black accessory minerals; calcareous cement; thin bedded (bed as thick as 6 in.), thinly laminated, horizontally to ripple laminated, character of ripples indistinct. Sandstone forms thin white bands or weak ledges in moderate-reddish-brown slope. Unit as whole weathers to badlands. This unit separated from overlying unit on basis of slight color change and white sandstone beds. Basal contact of middle red member not exposed; it is somewhere in a 1-mile-long bench at the top of the Virgin Limestone Member ---------- 54.0

Total incomplete middle red member ---------- 243.7

Total incomplete Moenkopi Formation ---------- 645.9

Base of local exposure.

A12. EAST SUNSET MOUNTAIN

[Measured, by J. H. Stewart, F. G. Poole, and O. B. Raup, November 1954, from wash between East and West Sunset Mountains, up northwest side of East Sunset Mountain to most northerly part of basalt cap of East Sunset Mountain. Secs. 13 and 24, T. 17 N., R. 13 E., and sec. 19, T. 17 N., R. 14 E., GSRM. Coconino County]

Top of section; top of exposure.

Basalt: | Feet

25. Olivine basalt, medium-gray (*N*5); weathers black (*N*1); contains coarsely crystalline olivine phenocrysts, inconspicuous finely crystalline augite phenocrysts; vesicular,

A12. EAST SUNSET MOUNTAIN—Continued

	Feet
Basalt—Continued	
columnar jointing; weathers to form vertical cliff and forms cap of East Sunset Mountain	70±
24. Covered, basalt talus blocks	53.0
Chinle Formation (incomplete):	
Petrified Forest Member (incomplete):	
23. Clayey sandstone (60 percent) and siltstone to claystone (40 percent). Clayey sandstone, same as that in units 21 and 22. Siltstone to claystone, dominantly grayish-red-purple (5*RP* 4/2); weathers same color; otherwise same as that in unit 21. Some parts of top 50 ft poorly exposed. At 72.5 ft above base of unit away from line of section, a 6-in.-thick lens of limestone extends for about 10 ft along the exposure. The limestone is light greenish gray (5*GY* 8/1) and pale red purple (5*RP* 4/2), silty, aphanitic, well cemented; forms inconspicuous resistant layer. Limestone contains a few disseminated rounded pebbles of red and gray chert	128.8
22. Clayey sandstone and pebbly clayey sandstone, grayish-red (10*R* 4/2 and 5*R* 4/2) and light-greenish-gray (5*GY* 8/1); weathers same colors; fine- to medium-grained, poorly sorted; composed of subangular milky grains and 5 percent orange and green grains, 1 percent dark-green and white accessory mica; poorly cemented, clay binding; horizontally thinly to thickly bedded; weathers to form loose slope. Granules to cobbles occur disseminated and concentrated in thin sandstone layers and constitute about 5 percent of unit; 80 percent of them are composed of volcanic material (coarse crystals of biotite and potassic(?) feldspar in an aphanitic groundmass); chert and quartzite constitute remaining clasts. Pebbles are easily broken and highly weathered. The cobbles have a maximum diameter of 3⅛ in. Both chert and volcanic pebbles reach this diameter. Largest pebble noted, 3¼ by 2¼ by 1¼ in., was volcanic. Largest quartzite noted was 3⅛ by 1¾ by 1⅛ in	33.4
21. Claystone to siltstone (50 percent) and clayey sandstone (50 percent), pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), light-greenish-gray (5*GY* 8/1), pale-red-purple (5*RP* 4/2); weathers same colors; otherwise same as unit 19	94.6
20. Covered, weathers to form rubble-covered slope	141.7
19. Claystone to siltstone (85 percent) and clayey sandstone (15 percent), yellowish-gray (5*Y* 8/1), greenish-gray (5*GY* 6/1), pale-red-purple (5*RP* 6/2), and minor medium-gray (*N*5); weathers dominantly yellowish gray (5*Y* 8/1). Claystone to siltstone, appears to contain swelling clays; firmly cemented, noncalcareous; structureless. Clayey sandstone, same as that in unit 16; suggestion of medium-scale low-angle cross-stratification. Unit weathers to form frothy-surfaced slope. Unit is exposed only in small area and is not on same slope as exposure of unit 17	48.7
18. Covered; weathers to form rubble-covered slope	5.3
17. Claystone to siltstone, grayish-red (5*R* 4/2 and 10*R* 4/2), greenish-gray (5*GY* 6/1) mottling in lower part; weathers light brownish gray (5*YR* 6/1); apparently swelling clays; firmly cemented, noncalcareous; weathers to form frothy-surfaced slope. Unit exposed is very small area surrounded by basalt talus	17.8

NOTE.—The transfer of section about 2,500 ft from outlying exposure of Chinle to main part of East Sunset Mountain by sighting with hand level. Possibly thickness in error by many feet because of inaccuracies in method of estimating bedding attitude and in sighting.

	Feet
16. Clayey sandstone (80 percent) and claystone (20 percent). Clayey sandstone, light-greenish-gray (5*GY* 8/1) and light-brownish-gray (5*YR* 6/1), medium to coarse grained, poorly sorted; composed of angular to subangular milky grains and about 5 percent orange, green, and gray minerals, common dark-green accessory mica; poorly cemented, clay binding; stratification concealed. Claystone, grayish-red-purple (5*RP* 4/2), weathers same color, otherwise same as claystone in unit below; weathers to rubble-covered slope. Claystone forms very thick bed in middle of unit. Top of unit on south side of outlying exposure of Chinle on north end of east Sunset Mountain	23.2
15. Claystone to siltstone, grayish-red (10*R* 4/2), grayish-purple (5*P* 4/2), greenish-gray (5*GY* 6/1), and pale-reddish-brown (10*R* 5/4), variegated; weathers same colors; swelling clays; firmly cemented, noncalcareous; structureless; weathers to form steep frothy-surfaced slope. Unit contains a chert lens about 40 ft above base	65.1
Total Petrified Forest Member (incomplete)	558.6
Mesa Redondo(?) Member:	
14. Siltstone, pale-reddish-brown (10*R* 5/4), minor grayish-red (5*R* 4/2), and abundant grayish-red (5*R* 4/2) (20–50 percent) mottling; weathers same colors; very fine grained to sandy in parts; apparently nonswelling clays; common fine-grained accessory white and dark-green mica in places;	

A12. EAST SUNSET MOUNTAIN—Continued

Chinle Formation—Continued

Mesa Redondo(?) Member—Continued *Feet*

structureless; weathers to form steep rubble-covered slope. Unit does not weather to a frothy surface. Basal 10 ft of unit appears to be similar to unit 12 except unit 12 contains some sand and mica...... 46.2

Total Mesa Redondo(?) Member....... 46.2

Shinarump(?) Member:

13. Sandstone, very pale orange (10*YR* 8/2), pale-red-purple (5*RP* 6/2), and minor pale-red (10*R* 6/2), coarse-grained, poorly sorted; composed of subangular milky grains and common orange and gray accessory minerals; poorly cemented, calcareous; composed of thin trough and wedge sets of small-scale low-angle cross-laminae and thick to very thick tabular planar sets of medium-scale cross-laminae; weathers to form prominent light-gray ledge. Near base, unit contains a very thin layer composed of quartz, quartzite, and chert pebbles. Line of section passes 1,000 ft west of prospect pit. At a place 100 ft east of the prospect this unit overlies about 20 ft of greenish-gray claystone to sandstone which contains a small amount of carbonaceous material and which is typical of the rocks of the Chinle Formation. This claystone to sandstone is not present in the line of section, but possibly is represented by unit 12..... 20.0

Total Shinarump(?) Member.......... 20.0

Total incomplete Chinle Formation..... 624.8

Moenkopi Formation:

Holbrook Member:

12. Siltstone, pale-reddish-brown (10*R* 5/4); about 50 percent grayish purple (5*P* 4/2) in top 3 ft; weathers same colors; firmly to well cemented, noncalcareous; structureless; weathers to form steep slope........ 9.0

11. Sandstone (80 percent) and siltstone (20 percent). Sandstone, pale-brown (5*YR* 5/2), weathers same color; very fine to fine grained, fair sorted; composed of subangular milky and minor green grains and about 2 percent medium to very coarse grained white and dark-green mica; poorly cemented, calcareous; composed of thin trough and wedge sets of low-angle medium-scale cross-laminae. Sandstone contains a few thin intervals containing reddish-brown siltstone pebbles. Siltstone, pale-reddish-brown (10*R* 5/4), minor light-greenish-gray (5*GY* 8/1); weathers same colors; sparse fine-grained dark-green and white mica; firmly cemented, calcareous; stratification poorly exposed but appears to be horizontally laminated; unit as whole

A12. EAST SUNSET MOUNTAIN—Continued

Moenkopi Formation—Continued

Holbrook Member—Continued *Feet*

weathers to form vertical cliff in lower part and steep slope in upper part. The vertical cliff is the most prominent in the section and can be seen at several places on both East and West Sunset Mountains.. 64.2

10. Siltstone, pale-reddish-brown (10*R* 5/4); minor light-greenish-gray (5*GY* 8/1) and grayish red (5*R* 4/2) color bands; firmly cemented, calcareous; thick to very thick horizontally bedded; weathers to form steep slope.............................. 41.7

Total Holbrook Member............... 114.9

Moqui Member:

9. Heterogeneous unit: sandstone (60 percent), siltstone (38 percent), gypsum (2 percent). Sandstone, light-greenish-gray (5*G* 8/1) and pale-brown (5*YR* 5/2), very fine grained, well-sorted; about 2 percent medium- to coarse-grained dark mica; firmly cemented, calcereous; ripple-laminated. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; firmly cemented, calcareous; structureless; forms a thick bed near top of unit. Gypsum, which is lithologically similar to gypsum in unit 8, occurs as thin lens at top of unit. Unit as whole weathers to form ledgy slope. Lateral to line of section, the basal foot of unit contains a lenticular thin set of conglomeratic sandstone. Conglomeratic sandstone contains very coarse grains to pebbles of light-greenish-gray sandstone.......... 16.4

8. Siltstone and gypsum. Siltstone, pale-reddish-brown (10*R* 5/4), light brown (5*YR* 6/4); common thin to thick greenish-gray (5*GY* 6/1) and dusky-yellow (5*GY* 6/4) bands; common fine-grained accessory white mica; structureless and horizontally laminated. Gypsum, white (*N*9); weathers same color and pale reddish brown (10*R* 5/4); very finely crystalline, common coarsely crystalline parts, and common parts with acicular crystals; firmly to well cemented; present as thin to very thin horizontal beds and as very thin seams crosscutting stratification. Gypsum beds in places shows slight waviness. Unit from base to 78 ft is composed of about 20 percent gypsum and from 78 ft to top of about 5 percent gypsum. Unit weathers to form steep slope with minor ledges on gypsum beds. Upper part of unit measured up prominent canyon on northwest side of East Sunset Mountain. Top 30 ft of unit poorly exposed. Gypsum in places is present as nodules 1–2 in. in diameter.... 158.8

Total Moqui Member (may be incomplete) 175.2

A12. EAST SUNSET MOUNTAIN—Continued

	Feet
Moenkopi Formation—Continued	
Wupatki Member:	
7. Covered; unit weathers to form flat area about 1,500 ft wide	37.3
6. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; common very fine grained accessory white mica; poorly to well cemented, calcareous; stratification largely concealed, horizontally and ripple laminated in places. Unit exposed on small outlying knoll containing small resistant ledge. Top 3 ft of unit is about 50 percent grayish orange (10*YR* 7/4) and dusky yellow (5*Y* 6/4). These light colors may represent base of Moqui Member	33.2
5. Covered; a few poorly exposed places in lower half of unit suggest that unit may be reddish-brown siltstone. Unit forms a ½-mile-wide flat area	67.1
4. Siltstone and sandstone, poorly exposed. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; stratification concealed. Sandstone, light-brown (5*YR* 6/4); weathers same color; very fine grained, grades to siltstone; firmly cemented, calcareous; horizontally laminated. Sandstone forms top 2 ft of unit. Unit as whole weathers to form gentle reddish-brown slopes with small ledge in top 2 ft	5.3
3. Sandstone, grayish-orange (10*YR* 7/4); weathers light brown (5*YR* 6/4); very fine grained, well sorted; firmly cemented, calcareous; composed of thin planar sets of small-scale low-angle cross-laminae and of horizontal laminae; weathers to form rounded ledge. Unit called lower massive sandstone	6.9
2. Covered; weathers to form gentle reddish-brown slope. Probably basal siltstone unit of Moenkopi	4.0
Total Wupatki Member	153.8
Total Moenkopi Formation	443.9

Kaibab Limestone (unmeasured):

1. Limestone (80 percent) and sandstone (20 percent). Limestone, grayish-yellow (5*Y* 8/4) and light-olive-gray (5*Y* 6/1); weathers same colors; aphanitic; well indurated, horizontally thinly bedded, some waviness to beds, common medium-scale contorted stratification. Sandstone, yellowish-gray (5*Y* 8/1) and grayish-orange (10*YR* 7/4); weathers same colors; very fine grained, 1 percent medium to coarse grains, fair sorted; composed of subrounded clear quartz, no accessory minerals noted; firmly cemented, calcareous; stratification same as sandstone. Unit as whole weathers to form ledges and benches. The relation of the sandstone to the limestone cannot be easily seen, but the two appear to be

A12. EAST SUNSET MOUNTAIN—Continued

Kaibab Limestone—Continued

mostly separated into distinct beds and are intermixed in the contorted parts. Limestone grades to dolomite in places. Limestone in places contains molds of pelecypods. About 30 ft of unit is exposed.

Base of section; base of exposure. Base of section is N. 30° W. of most northerly outcrop of basalt on highest part of East Sunset Mountain.

A13. OWL ROCK

[Measured, by J. H. Stewart, September 1956, 2.9 miles N. 16° W. of Agathla Peak, long 110°14′10″ W., lat 36°52′10″ N. Section begins N. 9° E. of Owl Rock and N. 16° W. of Agathla Peak. Navajo County]

Top of section; top of exposure.

	Feet
Chinle Formation:	
Shinarump Member (unmeasured):	
12. Sandstone and conglomerate, yellowish-gray (5*Y* 8/1) and very light gray (*N*8), fine- to coarse-grained, fair to poorly sorted; composed of subangular to subround clear quartz and sparse black accessory minerals; poorly cemented, slightly calcareous; trough sets of medium-scale low-angle cross-strata; weathers to form vertical cliff. Gravels are of quartz, quartzite, and chert, and are as large as 2½ in. in maximum diameter. Basal contact sharp; channels cut into Moenkopi and filled with Shinarump are present and are as deep as 2 ft and at least as wide as 10 ft. About 60–70 ft of Shinarump is present. Only basal few feet of unit examined.	
Moenkopi Formation:	
Upper part:	
11. Siltstone similar to *types 1* and *2* in unit 8. *Type 1* is structureless in this unit; *type 2* is horizontally laminated and ripple laminated. Both cuspate and parallel ripple marks; types of ripple marks in about equal proportions. *Type 2* siltstone is almost entirely confined to two intervals: 19.5–27.3 ft and 56.3–58.9 ft above base of unit. Unit weathers to form steep slope with minor ledges on two layers of *type 2* siltstone. Top 0.2 ft of unit is altered to light greenish gray (5 *GY* 8/1)	69.7
10. Sandstone, very pale orange (10*YR* 8/2); weathers same color; very fine grained, well sorted; composed of subround clear quartz and sparse black and orange accessory minerals, well cemented, calcareous; composed of thin trough and tabular planar sets of small- to medium-scale cross-laminae; weathers to form capping part of ledge developed on underlying unit	5.0
9. Sandy siltstone to sandstone, pale-red (10*R* 6/2) and minor pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); very fine grained sandy siltstone to very fine grained sandstone; abundant very fine grained accessory white mica; well	

A13. OWL ROCK—Continued

Moenkopi Formation—Continued

Upper part—Continued — *Feet*

cemented, calcareous; horizontally laminated (50 percent) and ripple-laminated (50 percent), probably mostly cuspate ripples; weathers to form irregular ledge. This unit and overlying unit form upper of two prominent ledges in Moenkopi Formation. Unit grades into underlying unit — 16.1

8. Siltstone, *type 1* (50 percent) and *type 2* (50 percent), interstratified. *Type 1*, grayish-red (10*R* 4/2); weathers same color; grades to silty claystone; firmly cemented, noncalcareous; stratification concealed, poorly exposed. *Type 2*, pale-brown (5*YR* 5/2) to moderate-brown (5*YR* 4/4); weathers pale reddish brown (10*R* 5/4); grades to very fine grained sandy siltstone; abundant very fined grained accessory white mica; well cemented, calcareous; horizontally and ripple laminated, parallel-type ripples. *Type 2* siltstone weathers to form platy to slabby splitting ledges and *type 1* siltstone weathers to form intervening slopes. Most of *type 2* siltstone is in lower half of unit — 23.0
7. Siltstone, sandy, pale-red (10*R* 6/2), and sparse very pale orange (10*YR* 8/2), sandy (very fine grained), may grade to very fine grained sandstone in places; sparse fine-grained accessory white mica; well cemented, calcareous; horizontally and ripple laminated, cuspate type, and thin trough sets of very low angle small-scale cross-laminae, different types of stratification in about equal proportions; weathers to form prominent ledge. Ledge is lower of two prominent ledges in Moenkopi Formation — 7.7
6. Siltstone, grayish-red (10*R* 4/2), weathers same color; fine silt; firmly cemented, slightly calcareous; structureless, about 20 percent ripple and horizontally laminated. Ripple and horizontally laminated parts are very thin to thin sets interstratified with the siltstone. Unit weathers to form gentle slope. Parts of unit poorly exposed — 23.6
5. Silty sandstone to standstone, pale-red (10*R* 6/2), very pale orange (10*R* 8/2) and grayish-orange (10*YR* 7/4); weathers same colors; silty very fine grained sandstone to medium-grained sandstone, fair sorted; composed of subround clear quartz and sparse black accessory minerals; horizontally and ripple laminated, cuspate-type ripples, and minor thin trough sets of small-scale cross-laminae; weathers to form small bench. Unit is poorly exposed in places and may contain some thin beds of reddish-brown siltstone — 7.7
4. Sandstone, grayish-orange (10*YR* 7/4), weathers same color; medium- to coarse-grained, fair-sorted; composed of subangular to subround clear quartz, no accessory minerals noted; poorly cemented, calcareous; mostly small-scale contorted strata, some suggestion of horizontal laminae and small-scale cross-strata; weathers to form top of ledge on Hoskinnini Member. Unit contains a few medium grains to granules of chert in basal few inches. In places it also contains rectangular white gypsum fragments as large as 1 in. in maximum dimension. Basal contact is sharp; scours are cut a few inches into underlying unit. Unit is placed in upper part of Moenkopi Formation because of presence of chert grains and granules, gypsum fragments, and, possibly, cross-strata. The unit could, however, be considered an unusual part of the Hoskinnini Member — 2.9

Total upper part of Moenkopi Formation — 155.7

Hoskinnini Member:

3. Sandstone, similar to unit 2. About 50 percent of unit is grayish orange (10 *YR* 7/4) and very pale orange (10*YR* 8/2). Lighter colors occur in well-defined thin to thick beds that give unit banded appearance. Lighter colored beds are fine to medium grained and do not contain many course grains. Unit is horizontally laminated to thick bedded. Strata are contorted in broad folds generally 10–30 ft across and 1–3 ft high. Unit as whole weathers to form steep ledgy slope; it contains two prominent light-colored ledges—one at base and one in middle. Possibly the lower one may represent the "crinkly bed" but this correlation is very uncertain. Unit contains a few very thin beds of grayish-red (10*R* 4/2) siltstone — 14.2
2. Sandstone, grayish-red (10*R* 4/2) and minor mottling and irregular lenses of grayish-orange (10*YR* 7/4); weathers same colors; very fine to fine grained, minor medium to very coarse grains which in finer grained matrix occur as floating grains or "berries," poorly sorted; composed of subangular to round reddish-brown-stained quartz and sparse black accessory minerals; firmly cemented, calcareous; mostly structureless, some faint irregularly wavy horizontal laminae; weathers to form smooth rounded ledge. Basal contact covered but probably is flat and sharp — 20.4

Total Hoskinnini Member — 34.6

Total Moenkopi Formation — 190.3

A13. OWL ROCK—Continued

Cutler Formation (unmeasured):
De Chelly Sandstone Member (unmeasured):
1. Sandstone, very pale orange (10 *YR* 8/2 and minor light-brown (5*YR* 6/4), weathers same colors; fine- to medium-grained; sparse coarse grains, well sorted; composed of subrounded to rounded clear quartz and sparse orange and black accessory minerals; poorly cemented, slightly calcareous, large-scale cross-strata; weathers to form canyon and small bench at top. Only top 10 ft examined and was all one cross-strata set.

Base of section, not base of exposure.

COLORADO

C2. EAST BRUSH CREEK

[Measured, by F. G. Poole and C. H. Roach, July 1956, on north side of canyon in south-central part of sec. 7, T. 6 S., R. 83 W., about ½ mile east of Eagle-Thomasville road. Eagle County]

Top of section; not top of good exposure.
Chinle Formation (incomplete):
Gartra Member: *Feet*
6. Sandstone, fine to conglomeratic, mottled and banded white (*N*9), grayish-pink (5*R* 8/2), pale-reddish-brown (10*R* 5/4), pale-red (5*R* 6/2), grayish-red (5*R* 4/2 and 10*R* 4/2), pale-red-purple (5*RP* 6/2), and grayish-red-purple (5*RP* 4/2); weathers same colors; fine-grained sandstone to pebble conglomerate, minor percent of cobble gravels as much as 4 in. in maximum diameter in basal few feet, fair to poorly sorted; composed of subangular to rounded clear and milky quartz grains and common chert grains. Granule sand, pebble and cobble gravels are composed of vein quartz with subordinate chert and metaquartzite. Well cemented to poorly cemented, calcareous, siliceous, and clay binding; sandstone and conglomerate within unit are lenticular, very thin bedded to very thick bedded, thin units of medium- to small-scale planar and subordinate trough sets of high- and low-angle cross-laminae and crossbeds; flaggy to massive splitting. Basal 15 ft is silica cemented and weathers to form vertical cliff. The upper part has calcareous and clay cement and weathers to form steep slopes. The upper 10–20 ft is partly covered but seems to be friable coarse sandstone. Basal 15 ft contains thin conglomerate lenses and isolated gravels in a fine- to medium-grained sandstone matrix, whereas the upper part is chiefly medium to granule sand. Silicified logs were seen at base of unit 69.8

Total Gartra Member 69.8

Total incomplete Chinle Formation 69.8

C2. EAST BRUSH CREEK—Continued

Unconformity.
State Bridge Formation (incomplete):
Upper member (incomplete): *Feet*
5. Sandstone, moderate-red (5*R* 5/4), pale-red (5*R* 6/2) dark-reddish-brown (10*R* 3/4), and grayish-red (5*R* 4/2 and 10*R* 4/2); weathers same colors; very fine grained, well sorted; composed of rounded to well-rounded clear and amber-stained quartz grains and common white and black accessory minerals, abundant white and green coarse to very fine grained mica, firmly to well cemented, calcareous to noncalcareous; medium-scale, trough and planar sets of low angle, thinly cross-laminated to very thinly crossbedded; unit is laminated to very thick bedded, platy to massive splitting. Weathers to form cliff. Upper contact is an erosional unconformity. This sandstone unit is probably correlative with the sandstone directly below the Chinle Formation near Wolcott, Basalt, and Aspen, Colo 58.4
4. Coarse siltstone to very fine sandstone and claystone to silty claystone. Coarse siltstone to very fine sandstone, grayish-red (10*R* 4/2) and pale-reddish-brown (10*R* 5/4) with minor greenish-gray (5*GY* 6/1 and 5*G* 6/1) mottling; weathers same colors and minor red-purple (5*RP* 6/2) mottling; well sorted; very fine sandstone is composed of rounded to well-rounded clear and amber-stained quartz grains and common white and black accessory minerals, abundant white mica; firmly to well cemented, calcareous; persistent, parallel thinly laminated to thin-bedded ribs; many of the more resistant ribs contain cross-laminae of small-scale trough sets of low-angle cross strata. Many of these ribs contain ripple laminae; part of unit seems to be structureless, weathers to form alternating resistant ribs and less resistant slopes. Claystone to silty claystone, dark-reddish-brown (10*R* 3/4), grayish-red (10*R* 4/2 and 5*R* 4/2), pale-red-purple (5*RP* 6/2), grayish-red-purple (5*RP* 4/2) and greenish-gray (5*G* 6/1); weathers same colors; common very fine grained mica; firmly to well cemented, calcareous to noncalcareous; thinly laminated to laminated, papery to shaly splitting. This fraction makes up top 10–15 ft of unit. Upper contact seems to be an erosional disconformity 109.7
3. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color and moderate reddish orange (10*R* 6/6); very fine grained, well sorted; composed of rounded to well-rounded clear and amber-stained quartz grains and common black accessory mineral; firmly cemented, calcareous; very thin bedded to thin bedded; ripple laminated; flaggy to slabby splitting. Some bedding planes contain silt-

C2. EAST BRUSH CREEK—Continued

State Bridge Formation (incomplete)—Continued

Upper member (incomplete)—Continued — Feet

stone and claystone coating. Weathers to form conspicuous ledge — 4.5

2. Sandstone and silty claystone. Sandstone, pale reddish brown (10*R* 5/4), grayish red (10*R* 4/2), and light brown (5*YR* 6/4) with minor pale-olive (10*Y* 6/2) and grayish-green (10*GY* 5/2) mottling; weathers same colors; very fine grained, silty, fair to well sorted; composed of rounded to well-rounded clear, milky, and amber-stained quartz grains with common rounded to well-rounded coarse clear, smoky, and milky quartz grains, and common white and black accessory minerals, common fine-grained mica; firmly cemented, calcareous; thinly laminated to thin bedded; abundant ripple laminae of low ripple index (7–8); platy to slabby splitting. Weathers to form resistant ribs on steep slope. Numerous siltstone and silty claystone pockets within the sandstone. Silty claystone, dark-reddish-brown (10*R* 3/4); weathers pale reddish brown (10*R* 5/4) and light brown (5*YR* 6/4); common very fine grained mica; firmly cemented, noncalcareous; thinly ripple laminated to ripple laminated; papery to shaly splitting. Weathers to form thin less resistant ribs on steep slope — 86.8

1. Sandstone, pale-reddish-brown (10*R* 5/4) and light-brown (5*YR* 6/4); weathers same colors; very fine grained, well sorted; composed of rounded to well-rounded clear, milky, and amber-stained quartz grains with common rounded to well-rounded coarse clear, smoky, and milky quartz grains and common white and black accessory minerals; common fine-grained mica; firmly cemented, calcareous; very thin bedded to thick bedded; medium- to small-scale trough and planar sets of low-angle cross-laminations to very thin cross beds; flaggy to blocky splitting. Weathers to form smooth rounded ledge — 5.3

Total incomplete upper member — 264.7

Total incomplete State Bridge Formation — 264.7

Base of section; base of good exposure.

C3. SHEEPHORN CREEK

[Measured, by F. G. Poole and C. H. Roach, July 1956, up draw N. 70° W. from Heckendorf ranchhouse (white house with green roof). Line of section trends about N. 25° W. through sec. 1, T. 2 S., R. 82 W., 6th PM, Eagle County]

Top of section; base of Curtis or Morrison Formation.

Entrada Sandstone: — Feet

6. Sandstone, light-gray (*N*7) and light-greenish-gray (5*GY* 8/1); weathers same colors and greenish gray (5*GY* 6/1); very fine to medium grained, silty, abundant coarse grains, uncommon rounded granules and small pebbles in basal few feet of unit, fair to well sorted; composed of rounded to well-rounded clear and milky quartz and uncommon rose quartz and sparse red mineral; firmly to poorly cemented, very calcareous; weathers to smooth rounded cliff. Upper contact seems conformable — 38.0

Total Entrada Sandstone — 38.0

Unconformity.

Chinle Formation:

Mottled member and Gartra Member undifferentiated:

5. Sandstone to silty claystone (some pebble conglomerate), interbedded, pinkish-gray (5*YR* 8/1), light-brownish-gray (5*YR* 6/1), yellowish-gray (5*Y* 8/1), dark-reddish-brown (10*R* 3/4), very dusky red (10*R* 2/2), grayish-red-purple (5*RP* 4/2), and very dusky red-purple (5*RP* 2/2); weathers same colors and lighter shades with abundant iron stain; fair to poorly sorted, very fine grained sandstone to small pebble conglomerate, composed of subangular to rounded clear, milky, and amber-stained quartz, well to poorly cemented, slightly calcareous to noncalcareous; structureless and thinly laminated to thick bedded, papery to blocky splitting. Unit at this outcrop is believed to be the widespread mottled member found in other areas of northwestern Colorado. A few hundred yards southwest from line of section, however, this unit grades laterally into a very coarse to conglomeratic sandstone of the Gartra Member. Resistant beds weather to ledges and nonresistant parts to smooth slopes. Unit as a whole is poorly exposed — 15.0

Total mottled member and Gartra Member undifferentiated — 15.0

Total Chinle Formation — 15.0

NOTE.—Section offset northeast 100 feet along upper contract.

Unconformity.

State Bridge Formation:

Upper member:

4. Siltstone to very fine sandstone (90 percent) and fine sandstone to granule sandstone (10 percent). Siltstone to very fine sandstone, grayish-red (10*R* 4/2), dark-reddish-brown (10*R* 3/4), and minor yellowish-gray to light-gray (*N*7), weathering same colors and lighter shades, fair to well sorted; composed of subangular to rounded clear and amber-stained quartz, common muscovite and green mica (chloritic?), and common subangular to rounded, fine to very coarse, clear and amber-stained quartz and pink feldspar(?); firmly to well cemented, calcareous to

C3. SHEEPHORN CREEK—Continued

State Bridge Formation—Continued

Upper member—Continued — *Feet*

slightly calcareous; thinly laminated to thin bedded; papery to slabby splitting. Weathers to form smooth slope. Common symmetrical and asymmetrical parallel ripples of low index. Fine sandstone to granule sandstone, greenish-gray (5*GY* 6/1), light-greenish-gray (5*GY* 8/1), yellowish-gray (5*Y* 8/1), and grayish-red (10*R* 4/2); weathers same colors and lighter shades; fair to poorly sorted; composed of angular to rounded coarse grains to granules of quartz, feldspar, mica, schist, gneiss, and granite rock fragments; firmly to well cemented, calcareous, lenticular laminae to thin-bedded strata, platy to slabby splitting. Weathers to form smooth slopes 106.5

Total upper member (minimum) 106.5

3. Graywacke conglomerate (70 percent) and siltstone to fine sandstone (30 percent). Graywacke conglomerate; same as unit below except largest gravels are of pebble size. Siltstone to fine sandstone, grayish-red (10*R* 4/2), and pale-reddish-brown (10*R* 5/4), with minor pale-olive (10*Y* 6/2) and yellowish-gray (5*Y* 8/1); weathers same colors and lighter shades; silt sized to medium grained, fair to poorly sorted; composed of subangular to rounded quartz, feldspar, muscovite, and biotite mica; firmly to well cemented, calcareous, thinly laminated to thin bedded, papery to slabby splitting, symmetrical and asymmetrical parallel ripple marks (average wavelength 1 in. and average amplitude 0.1 in.); many of the siltstone strata are very limy and approach a silty limestone. A limy interval 20 feet below top of unit is probably the lateral equivalent of the South Canyon Creek Member; therefore, the upper 20 ft of unit 3 is tentatively considered as part of the upper member. Unit as a whole weathers to form smooth slope 41.5

Total upper member (maximum) 126.5

Lower member:

2. Graywacke conglomerate to silty graywacke conglomerate, greenish-black (5*G* 2/1 and and 5*GY* 2/1), dark-greenish-gray (5*GY* 4/1 and 5*G* 4/1), and yellowish-gray (5*Y* 7/2), and subordinate grayish-red (10*R* 4/2 and 5*R* 4/2); weathers same colors and lighter shades; fair to poorly sorted; composed of angular to rounded quartz, feldspar, mica, gneiss, schist, granite, and pegmatite rock fragments, as much as 11 in. in maximum diameter, forming a rubble breccia, firmly to well cemented, calcareous; thinly laminated to very thick bedded, laminae and beds are very lenticular and commonly wavy, medium- to small-scale trough and planar sets of low-angle cross-strata, thinly cross-laminated to very thinly crossbedded, cross-strata are uncommon; unit channels a few feet into underlying unit, shaly to massive splitting. Unit weathers to form steep slope 22.0

C3. SHEEPHORN CREEK—Continued

State Bridge Formation—Continued

Lower member—Continued — *Feet*

Total lower member (minimum) 22.0
Total lower member (maximum) 43.5
Total graywacke facies (units 2 and 3) 63.5

Total State Bridge Formation 170.0

Unconformity.

Precambrian metamorphic rocks (incomplete):

1. Hornblende granite gneiss and subordinate schist and pegmatite. Top 10 feet of unit is weathered; red siltstone of State Bridge fills fractures that extend as much as 10 ft into unit. Fractures are 2–3 in. wide near top and become smaller downward. Feldspar and ferromagnesian minerals appear to be altered where fractures are wide. Siltstone fracture fillings are grayish-red (10*R* 4/2) to pale-brown (5*YR* 5/2), with minor greenish-gray (5*GY* 6/1) mottling and stringers; fair to poorly sorted; composed of angular to rounded milky, smoky, and amber-stained quartz; feldspar, muscovite, biotite, and chlorite; firmly to well cemented, calcareous; structureless. Unit weathers to form jagged cliff 15.0

Total incomplete Precambrian metamorphic rocks 15.0

Base of section; not base of exposure.

C4. SOUTH CANYON CREEK

[Measured, by F. G. Poole and L. G. Schultz, April and May 1956. Section begins on west side of canyon S. 70° W. from bridge crossing Colorado River at mouth of South Canyon Creek, about 4½ miles west of Glenwood Springs, NW¼ of sec. 2, T. 6 S., R. 90 W., 6th PM Garfield County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Mottled member (incomplete):

10. Sandy siltstone to clayey siltstone (90 percent) and silty claystone (10 percent). Sandy siltstone to clayey siltstone, grayish-red-purple (5*RP* 4/2), yellowish-gray (5*Y* 8/1), dusky-blue (5*PB* 3/2), grayish-red (10*R* 4/2), dark-reddish-brown (10*R* 3/4), and grayish-purple (5*P* 4/2); weathers same colors and pale purple (5*P* 6/2) and pale red purple (5*RP* 6/2); common to sparse subrounded to well-rounded, medium to very coarse, clear and amber-stained quartz grains, and abundant to uncommon white mica; poorly to well cemented, fair to poorly sorted, calcareous to noncalcareous;

C4. SOUTH CANYON CREEK—Continued

Chinle Formation—Continued

Mottled member—Continued *Feet*

zone about two-thirds of way up in unit contains abundant red iridescent iron oxide blebs with streaks of soft white clay; irregular bedding and fracturing, thinly laminated to very thin bedded, some shaly splitting. Weathers to form steep slope. Unit is a pale to pale-red-purple and pinkish- to yellowish-gray zone at base of Chinle Formation. (Note: unit is lower half of mottled member of the Chinle Formation) ---------------------------- 9.3

Total incomplete mottled member------- 9.3

Total incomplete Chinle Formation----- 9.3

Unconformity.

State Bridge Formation:

Upper member:

9. Silty claystone (75 percent), siltstone (20 percent), and sandstone (5 percent). Silty claystone, pale-red (10*R* 6/2 and 5*R* 6/2); weathers same color, micaceous; firmly cemented, slightly calcareous to noncalcareous; shaly splitting to irregular fracturing. Siltstone, grayish-red (10*R* 4/2 and 5*R* 4/2); weathers same color, abundant white and dark-green (chloritic?) mica; firmly cemented, noncalcareous; irregular fracturing. Sandstone, grayish-red (10*R* 4/2), greenish-gray (5*G* 6/1), dark-greenish-gray (5*GY* 4/1), and light-greenish-gray (5*G* 8/1); weathers same colors; very fine to very coarse grained, fair to poorly sorted; composed of rounded to well-rounded clear and milky quartz and abundant white and dark-green (chloritic?) mica, the coarse to very coarse grains are well-rounded milky quartz; well cemented, calcareous to noncalcareous; very thin bedded, fine to very fine grained sandstone is ripple laminated; lenticular sandstones are present at base and near top of unit. Weathers to form small resistant ribs on steep slope. Unit as whole weathers to form steep dark-red slope --------------------------------- 19.5
8. Siltstone to clayey siltstone (55 percent) and coarse siltstone to very fine grained sandstone (45 percent), pale-reddish-brown (10*R* 5/4), dark-reddish-brown (10*R* 3/4), and grayish-red (10*R* 4/2) with minor light-greenish-gray (5*G* 8/1) mottling; weathers same colors; clayey siltstone to very fine grained sandstone with sparse well-rounded, medium-milky- and amber-stained quartz grains and common white and dark-green (chloritic?) mica; firmly to well cemented, calcareous to slightly calcareous; ripple laminated (10 percent estimated) and horizontal thin to thick bedded (90 percent estimated); irregular fracturing. Weathers to form steep ribbed orange-

C4. SOUTH CANYON CREEK—Continued

State Bridge Formation—Continued

Upper member—Continued *Feet*

red slope, with coarse fraction (45 percent) forming three ribs and fine fraction (55 percent) forming rubble-covered intervening slope ---------------------------------- 36.1

Total upper member------------------ 55.6

South Canyon Creek Member:

7. Dolomite (70 percent) and limestone (30 percent). Dolomite, greenish-gray (5*GY* 6/1) to light-olive-gray (5*Y* 6/1); makes up lower 4 ft of unit. Limestone, light-gray (*N*7) to dark gray (*N*3), depending on amount of solid hydrocarbon; finely crystalline calcite, vuggy, wavy to crinkled laminae, some chert lenses, sparse fossil shell fragments; makes up upper 1.6 ft. Unit as whole weathers yellowish gray (5*Y* 8/1) to pinkish gray (5*YR* 8/1), and forms a conspicuous light-colored ledge about two-thirds of way up in State Bridge Formation. Upper contact is sharp (disconformable?) with overlying unit--------------- 5.6

Total South Canyon Creek Member----- 5.6

Lower member:

6. Siltstone and minor very fine grained sandstone, grayish-red (10*R* 4/2) with minor greenish-gray (5*GY* 6/1) mottling; basal 16 ft of unit is dark gray (*N*3), dark greenish gray (5*GY* 4/1), greenish gray (5*GY* 6/1), light olive gray (5*Y* 5/2), and olive gray (5*Y* 4/1), the drab colors (reduced?) may be due to solid hydrocarbon derived from Weber Sandstone; unit weathers to pale reddish brown (10*R* 5/4) and grayish yellow green (5*GY* 7/2). Unit contains uncommon medium grains and sparse coarse grains, except in lower 45 ft which contains scattered medium to very coarse grains. Siltstone and sandstone is fair to well sorted, composed of subrounded to well-rounded scattered clear, smoky, milky, and amber-stained quartz and possibly some feldspar, contains uncommon white and black mica and uncommon orange and green accessory minerals in greenish-gray mottled part; firmly to well cemented, calcareous; very thick bedded to horizontally laminated, grades into wavy thin laminations that may be ripple laminae; unit seems to be mostly structureless. Weathers to form massive steep rubble-covered slope. Upper contact is gradational with overlying unit------------- 98.5

Total lower member------------------- 98.5

Total State Bridge Formation--------- 159.7

Unconformity?

C4. SOUTH CANYON CREEK—Continued

Weber Sandstone: *Feet*

5. Sandstone (90 percent) and conglomeratic sandstone (10 percent), very light gray (*N*8), light-gray (*N*7) to grayish-black (*N*2); about 10 percent grayish-red (10*R* 4/2), pale-reddish-brown (10*R* 5/4), and grayish-red (5*R* 4/2) very fine grained sandstone occurs interbedded in basal part of Weber and is similar to sandstone in the underlying Maroon Formation; unit weathers same colors and lighter shades; very fine to very coarse grained with the coarser fraction containing common granules and pebbles and sparse cobbles as much as 4 in. in maximum diameter. Gravels: rounded pebbles and cobbles of milky (vein) quartz and minor quartzite grayish-green chert, and white feldspar and uncommon metamorphic and acidic igneous rocks; poorly to well sorted; composed of subangular, subrounded, and rounded clear quartz grains and abundant white, green (chloritic?), and black mica and uncommon pale-green accessory mineral; poorly to well cemented, calcareous and clay binding; abundant and variable amounts of interstitial and grain-coating solid hydrocarbon which, upon weathering, imparts light- to dark-gray colors to the unit; horizontally laminated to very thick bedded with common thin to thick trough sets of medium- and small-scale low-angle cross-stratification; pyrite grains and contorted crossbedding were seen in interval of about 30 ft near middle of unit; common parallel symmetrical and uncommon parallel asymmetrical ripple marks near top of unit strike N. 60° W. to S. 60° E. (not corrected for regional dip), ripple index (4–8) is low with wavelengths of 1.5–2.0 and 2.5–3.0 in. and average amplitudes of 0.30 and 0.37 in. respectively. Weathers to form steep ribbed slope with small hogback ridges. Unit is a conspicuous light-colored band in red-bed sequence. Upper contact is sharp (unconformable?) and is placed just above ripple-marked dip slope of small hogback ridge — 161.8

Total Weber Sandstone — 161.8

Maroon Formation (incomplete):

4. Claystone, grayish-red (10*R* 4/2) and greenish-gray (5*GY* 6/1); weathers same colors; abundant layered silt-sized to very fine white mica, firmly cemented, calcareous; horizantally laminated to thinly laminated, shaly to papery splitting. Weathers to form steep slope. Upper contact is sharp with overlying light-colored sandstone unit — 2.0

C4. SOUTH CANYON CREEK—Continued

Maroon Formation—Continued *Feet*

3. Sandstone, pale-red (10*R* 6/2 and 5*R* 6/2) and grayish-red (10*R* 4/2 and 5R 4/2); light-greenish-gray (5*GY* 8/1) mottling; very fine to very coarse grained, common granules and small pebbles as much as 8 mm in maximum diameter; fair to poorly sorted, composed of subangular to subrounded milky and amber-stained quartz and common gray feldspar and white and dark-green (chloritic?) mica; poorly to well cemented, calcareous; thin to very thick bedded, few trough sets of medium- and small-scale, low-angle cross-laminae. Weathers to form steep slope. Upper contact is undulatory but conformable with overlying unit — 32.8

2. Sandstone, pale-reddish-brown (10*R* 5/4) and light-brown (5*YR* 6/4), with minor light-greenish-gray (5*GY* 8/1 and 5*G* 8/1) mottling; weathers moderate reddish-orange (10*R* 6/6) and light brown (5*YR* 6/4); very fine to medium grained with minor siltstone pockets, and scattered coarse to very coarse subrounded to rounded milky and amber-stained quartz and white mica, fair sorted; composed of subrounded to rounded milky and amber-stained quartz and common white and green (chloritic?) mica and uncommon black accessory mineral; firmly cemented, calcareous; horizontally laminated to very thick bedded, few trough sets of medium-scale, low-angle cross-laminae. Weathers to form steep slope. Upper contact is undulatory but conformable with overlying unit — 62.7

1. Conglomeratic sandstone, pale-red (5*R* 6/2 and 10*R* 6/2) with minor light-gray (*N*7) and greenish-gray (5*GY* 6/1) mottling; weathers same colors and grayish orange (10*YR* 7/4), pale reddish brown (10*R* 5/4), and dark yellowish orange (10*YR* 6/6); fine-grained sandstone to cobble conglomerate consists mainly of poorly sorted coarse and very coarse grains (80 percent) and granules, pebbles, and cobbles (20 percent); composed of subangular to subrounded clear, milky, and rose quartz and gray and pink feldspar and abundant fine to coarse white, green (chloritic?), and black mica. Gravels: rounded pebbles and cobbles as much as 7 in. in maximum diameter of porphyritic to coarse granite, aplite, milky (vein) quartz, pink and white feldspar, pegmatitic suites, sedimentary quartzite, and metamorphic quartzite, gneiss, and schist — 15.6

Total incomplete Maroon Formation — 113.1

Base of section measured; not base of exposure.

C8. THE PALISADE

[Measured, by J. H. Stewart, E. M. Shoemaker, H. F. Albee, and D. A. McManus, August 1954, about 200 ft west of the southernmost part of The Palisade, northeast part of sec. 16, T. 51 N., R. 19 W., NMPM. Mesa County]

Top of section, not top of exposure.

Chinle Formation (incomplete):

Red siltstone member (incomplete): *Feet*

10. Siltstone (70 percent) and siltstone (containing limestone and limy siltstone clasts) to limestone granule conglomerate (30 percent). Siltstone, pale-reddish-brown (10*R* 5/4) and minor grayish-red (10*R* 4/2); weathers same colors; well cemented, calcareous; horizontally very thin to thick bedded. Siltstone (containing limestone and limy siltstone clasts) to limestone granule conglomerate, same colors as siltstone except for sparse light greenish gray (5*GY* 8/1) and pale red purple (5*RP* 6/2), weathering same colors; grades from siltstone containing about 10 percent very coarse grains, granules, and pebbles of red and gray limestone and limy siltstone to limestone granule conglomerate composed of rounded gray limestone granules in a lime and silt matrix; poorly to well cemented, calcareous; present as thin to very thick horizontal beds and lenses. Unit as whole weathers to form steep slope containing many ledges. The siltstone containing limestone and limy siltstone clasts and the limestone granule conglomerate are not everywhere easily separable from the remainder of the unit and vary considerably laterally; some limestone grains appear to be detrital in origin whereas others may be limy nodules. All gradations from siltstone to limestone granule conglomerate occur ---------- 76.7
9. Claystone to clayey siltstone, grayish-red (5*R* 4/2 and 10*R* 4/2), weathers pale red (5*R* 6/2); contains rare (5 percent) fine to coarse grains of clear quartz; poorly cemented, noncalcareous; structureless; weathers to form steep slope. Upper of unit contains abundant (30 percent) limestone nodules averaging about 1.5 in. in diameter ---------- 14.0

Basal sandstone unit of red siltstone member:

8. Sandstone, grayish-red-purple (5*RP* 4/2), light-greenish-gray (5*GY* 8/1), and minor grayish-red (5*R* 4/2); weathers pale pink (5*RP* 8/2); fine to coarse grained; abundant interstitial silt, poorly sorted; composed of angular to subangular clear quartz; poorly cemented, noncalcareous; structureless and sparse thin horizontal lenses; weathers to form conspicuous white or pinkish-gray ledge. Unit contains 2 percent very coarse grains to pebbles of clear and milky quartz. Unit commonly grades to sandy siltstone ---------- 7.8

C8. THE PALISADE—Continued

Chinle Formation—Continued

Basal sandstone unit of red siltstone member—Con. *Feet*

Total basal sandstone unit of red siltstone member ---------- 7.8

Total incomplete red siltstone member ---------- 98.5

Total incomplete Chinle Formation ---------- 98.5

Contact of Chinle and Moenkopi Formations placed at color change from browns of Moenkopi to purples of Chinle. This contact marks a change from sandstone of the Moenkopi containing dominantly granite, quartz, and feldspar granules and pebbles to sandstone of the Chinle containing quartz granules and pebbles.

Moenkopi Formation:

Ali Baba Member:

7. Conglomerate and minor conglomeratic sandstone, pale-red (5*R* 6/2); weathers same color; composed of granules to cobbles of granite, feldspar, schist, and quartz in a medium to very coarse grained matrix of quartz and feldspar, minor silt, poorly sorted; a few percent of medium- to coarse-grained biotite; poorly cemented, calcareous in parts; stratification indistinct but appears to be mostly thin horizontally bedded, sparse small-scale cross-strata in basal 10 ft. Unit weathers to form steep loose slope. Sparse grayish-red (5*R* 4/2) very thin to thin siltstone sets ---------- 39.7
6. Siltstone and sandstone (80 percent) and conglomeratic sandstone (20 percent). Siltstone and sandstone, grayish-red (5*R* 4/2 and 10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); weathers same colors; grades from siltstone to fine-grained sandstone, fair sorted; composition concealed, a few percent of coarse-grained biotite; firmly to well cemented, calcareous; horizontally laminated to very thinly bedded, minor ripple laminae. Conglomeratic sandstone to conglomerate, pale-red (5*R* 6/2), mottled with light greenish gray (5*GY* 8/1); weathers same colors; granules and minor pebbles of feldspar, granite, and quartz in a fine to very coarse grained matrix, poorly sorted; a few percent of coarse-grained biotite and white mica; poorly to firmly cemented, calcareous; composed of thin to very thin horizontal beds and minor sets of small-scale cross-laminae. Unit as a whole is tabular and weathers to form ledgy slope ---------- 13.3

Total Ali Baba Member ---------- 53.0

C8. THE PALISADE—Continued

Moenkopi Formation—Continued
Tenderfoot Member:
Fourth unit: *Feet*

5. Siltstone, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), and sparse greenish-gray (5*GY* 6/1), in very thin horizontal bands; weathers same colors; abundant medium- to coarse-grained accessory grains of biotite and white mica; poorly to well cemented, calcareous; in parts horizontally laminated to thinly bedded, sparse very thin sets of ripple laminae; platy to slabby splitting; weathers to form steep slope. Unit contains abundant sets containing from a few percent to as much as 50 percent medium to coarse rounded quartz grains. Upper 5 ft of unit is darker and contains abundant coarse grains, mainly of quartz and of some feldspar. Clay chips are locally concentrated. Stratification is discontinuous laterally — 66.7

Total fourth unit — 66.7

Third unit:

4. Silty sandstone to sandy siltstone, pale-reddish-brown (10*R* 5/4) to grayish-red (10*R* 4/2) and sparse greenish-gray (5*GY* 6/1); weathers pale reddish brown (10*R* 5/4); grades from siltstone with minor fine to very coarse grains to fine to very coarse grained sandstone with minor silt, poorly sorted composed of subrounded to rounded grains of quartz, 2–3 percent of fine to very coarse grains of biotite and pale mica; poorly cemented, clay binding and slightly calcareous; mostly structureless, sparse discontinuous horizontally laminated parts and common contorted and disrupted stratification; weathers to form steep slope. Contorted stratification forms many funnel-shaped structures. Unit contains some coarse sand, granules, and pebbles, as large as ½ in. in diameter. The coarser grains are disseminated and in vaguely defined stringers — 30.4

Total third unit — 30.4

(Note: second unit of Tenderfoot Member is missing.)

First unit:

3. Silty sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine to fine grained, fair sorted; about 5 percent coarse to very coarse grained biotite; firmly cemented, calcareous; horizontally laminated to very thinly bedded, sparse ripple laminae; weathers to form vertical cliff continuous with that of the underlying unit — 4.9

2. Conglomerate (70 percent) and sandy siltstone (30 percent), pale-reddish-brown (10*R* 5/4), minor moderate-red (5*R* 5/4), and sparse grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4). Unit grades from conglomerate composed of granules to cobbles of granite, schist, bull quartz, and quartzite in a medium to very coarse grained matrix to a siltstone with minor medium to very coarse grains. Unit is poorly sorted; composed of subangular quartz and feldspar grains and abundant medium to very coarse grained accessory biotite; poorly cemented, clay binding and slightly calcareous; composed of thin horizontal beds, and sparse cross-stratification; weathers to form conspicuous vertical cliff. Unit contains cobbles as large as 6 in. in diameter. Two fairly thin continuous silty beds occur in the middle of the unit — 18.1

Total first unit — 23.0

Total Tenderfoot Member — 120.1

Total Moenkopi Formation — 173.1

Cutler Formation (unmeasured):

1. Sandstone, pale-red (5*R* 6/2) and minor light-greenish-gray (5*GY* 8/1), medium- to coarse-grained, minor granules and pebbles of feldspar and granite, poorly sorted; composed of subangular feldspar and quartz grains and of about 5 percent medium to very coarse grains of biotite; poorly cemented, clay binding and slightly calcareous; irregular stratification containing some thin horizontal beds and thin sets of medium-scale cross-laminae; weathers to form steep slope. Top 1.4 ft is pale-reddish-brown (10*R* 5/4) fine-grained sandstone.

Base of section measured; not base of exposure.

C11. MILLER CREEK

[Measured, by F. G. Poole and J. H. Stewart, September 1956, west of Miller Creek water gap on south flank of Skull Creek anticline in secs. 28 and 33, T. 4 N., R. 101 N., Moffat County]

Top of section; not top of exposure.
Chinle Formation (incomplete):
Gartra Member:

10. Sandstone and conglomeratic sandstone, white (*N*9), pale-red (10*R* 6/2), grayish-pink (5*R* 8/2), pale-reddish-brown (10*R* 5/4), and minor grayish-red-purple (5*RP* 4/2) and grayish-orange (10*YR* 7/4); weathers same colors; coarse sand to granules and minor amounts of very fine to medium sand and small pebbles, fair to poorly sorted; composed of subangular to rounded clear, milky, smoky, and amber-stained quartz, minor feldspar and gray chert grains and sparse mica; firmly to poorly cemented, noncalcareous to slightly

C11. MILLER CREEK—Continued

Chinle Formation—Continued

Gartra Member—Continued — *Feet*

calcareous; clay binding; lenticular layers of very thin to thick trough and planar sets of small- and medium-scale low-angle cross-laminae to very thin crossbeds, unit contains many horizontal laminae to very thick beds. Weathers to form conspicuous white ledge. Sparse sandy siltstone partings in unit. Granules and pebbles are composed of subrounded to well-rounded quartz and subordinate chert as much as 1.2 in. in diameter. Pebbles occur in thin lenses and as isolated clasts. Many of the pebbles are disk shaped and imbricated. Top of unit gradational with overlying unit — 19.2

Total Gartra Member — 19.2

Mottled strata:

9. Clayey siltstone to sandy siltstone, mottled dark-reddish-brown (10*R* 3/4), grayish-red-purple (5*RP* 4/2), pale-red-purple (5*RP* 6/2), and minor grayish-yellow (5*R* 8/4) and light-greenish-gray (5*GY* 8/1); weathers same colors and lighter shades; contains abundant subrounded to well-rounded medium-size grains to granules of clear, milky, and amber-stained quartz and sparse to common sparse white mica; poorly cemented, slightly calcareous; horizontally laminated to structureless. Weathers to form smooth steep slope continuous with that on underlying unit. Unit appears to represent a reworking of material from the Moenkopi Formation — 2.0

Total mottled strata — 2.0

Total incomplete Chinle Formation — 21.2

NOTE.—Section offset, so that units 9 and 10 were measured about 1½ miles east of underlying units. Section offset across water gap where Miller Creek turns south and crosses Chinle Formation.

Unconformity.

Moenkopi Formation:

8. Fine to coarse siltstone (45 percent) and clayey siltstone to silty claystone (55 percent). Fine to coarse siltstone, light-brown (5*YR* 6/4) to grayish-red (10*R* 4/2), minor light greenish-gray (5*GY* 8/1) and (5*G* 8/1); weathers same colors; coarse fraction composed of rounded to well-rounded clear and amber-stained quartz grains and abundant to sparse white and dark-green mica; firmly to well cemented, calcareous; horizontally laminated and sparse ripple laminae of cuspate and parallel type and sparse small scours; shaly to massive splitting. Clayey siltstone to silty claystone,

C11. MILLER CREEK—Continued

Moenkopi Formation—Continued — *Feet*

colors same as in fine to coarse siltstone, contains common dark-green mica; firmly to well cemented, calcareous; horizontally thinly laminated to structureless; shaly and flaggy splitting. Unit as whole weathers to form steep ledgy slope. Ledges form on fine to coarse siltstone, and slopes form on clayey siltstone to silty claystone. Most prominent ledges are coarse siltstone. Unit contains two prominent ledges; one 0.0–27.2 ft and one from 67.2–87.6 ft above base of unit. Top half of unit is largely clayey siltstone to silty claystone — 220.8

7. Siltstone, light-brown (5*YR* 6/4) to pale-reddish-brown (10*R* 5/4) with minor light-greenish-gray (5*GY* 8/1); weathers same colors; contains sparse coarse silt; common white and dark-green mica; firmly to well cemented, calcareous; horizontally laminated to thin bedded, about 40 percent ripple-laminae (cuspate and parallel types), about 10 percent small-scale very low angle cross-laminae; shaly to slabby splitting. Weathers to form steep ribbed slope. Sparse thin sets contain reddish-brown siltstone pellets. Upper contact placed at the base of the overlying slabby to massive siltstone — 61.2

6. Siltstone, light-greenish-gray (5*GY* 8/1), yellowish-gray (5*Y*8/1 and 5*Y* 7/2), and light-olive-gray (5*Y* 6/1); contains common white mica and black mineral (possibly solid hydrocarbon and (or) iron oxide) and common thin stringers of gypsum; firmly cemented, calcareous, argillaceous, and gypsiferous; about 40 percent of unit contains parallel ripple laminae with sparse cuspate ripples and small-scale cross-laminae, parallel and persistent horizontal laminae to thin beds; shaly to slabby splitting. Weathers to form smooth steep slope. Upper contact is gradational with overlying unit. Unit is differentiated from overlying and underlying units primarily on color rather than on lithology. Unit is uppermost yellowish-gray zone in Moenkopi Formation — 200.0

5. Clayey siltstone to silty claystone, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), and minor very pale orange (10*YR* 8/2) and light-greenish-gray (5*G* 8/1); weathers same colors; common white mica and gypsum laminae; firmly cemented, slightly calcareous; horizontally thinly laminated to very thin bedded and sparse ripple laminae; shaly and flaggy splitting. Weathers to form rounded knolls with smooth gentle slopes. Unit is conspicuous pale-reddish-brown zone in lower part of Moenkopi Formation between two prominent yellowish-gray zones — 44.1

C11. MILLER CREEK—Continued

Moenkopi Formation—Continued *Feet*

4. Siltstone and minor silty claystone, grayish-orange (10*YR* 7/4), yellowish-gray (5*Y* 7/1), and moderate-yellowish-brown (10*YR* 5/4); weathers same colors; contains common white coarse fragments that may be either microfossils or siliceous grains and common black accessory mineral that appears to be unweathered iron oxide and solid hydrocarbon; firmly to poorly cemented, calcareous, gypsiferous; horizontally thinly laminated to very thin bedded, sparse ripple laminae; shaly and flaggy splitting. Weathers to form rounded knolls with smooth gentle slopes. Unit as a whole is poorly exposed. Unit is differentiated from the one above primarily on color rather than on lithology 89.7

Total Moenkopi Formation 615.8

Park City Formation:

3. Siltstone, yellowish-gray, description similar to siltstone in unit 4 of Moenkopi Formation 76.0
2. Sandstone, light-olive-gray (5*Y* 6/1), light-brownish-gray (5*YR* 6/1) and light-gray (*N*7) to medium-gray (*N*5); weathers same colors; very fine to fine grained with common well-rounded medium and coarse grains, uncommon well-rounded very coarse grains, and sparse rounded granules, well to fair sorted; composed of rounded to well-rounded clear, milky, and smoky quartz grains and uncommon rounded feldspar(?) and gray chert grains; abundant interstitial black solid hydrocarbon; firmly to well cemented, very calcareous; horizontal wavy laminae to thin beds; platy to slabby splitting. Weathers to form smooth slope. Unit appears to be largely reworked Weber Sandstone and probably, in part, reworked Park City sandstone and chert. Upper contact appears conformable with overlying yellowish-orange unit. Unit is poorly exposed in upper part 58.8

Total Park City Formation 134.8

Unconformity?

Weber Sandstone (unmeasured):

1. Sandstone, white (*N*9) to dark-gray (N8), minor limonitic stain, shades of gray are controlled by amount of solid hydrocarbon present; weathers same colors; very fine to fine grained, well sorted; composed of subrounded to well-rounded clear and milky quartz grains and uncommon feldspar, abundant interstitial black solid hydrocarbon; firmly to well cemented, calcareous; thin to very thick trough and planar sets of medium-scale and minor small- and large-scale cross-laminae to thin crossbeds.

C11. MILLER CREEK—Continued

Weber Sandstone—Continued

Weathers to form cliff and steep dip slope. Only top 30 ft examined. Upper contact is irregular and gently undulatory.

Base of section; not base of exposure. Base of section in Miller Creek at base of long dip slope formed on Weber Sandstone.

C15. PARADOX VALLEY

[Measured, by J. H. Stewart, E. M. Shoemaker, H. F. Albee, and D. A. McManus, August 1954, on a point south of the Dolores River at junction of the south face of the Dolores River Canyon with the northeast face of Paradox Valley, north-central part of sec. 10, T. 47 N., R. 18 W., NMPM. Montrose County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Red siltstone member (incomplete): *Feet*

14. Limestone to limestone-grain sandstone (calcarenite), pale-red (10*R* 6/2) and minor light-gray (*N*7) and light-greenish-gray (5*GY* 8/1); weathers light brown (5*YR* 6/4). Unit ranges in composition from dense limestone containing abundant remnants of pale-reddish-brown (10*R* 5/4) siltstone to sandstone composed of coarse grains to pebbles of limestone and siltstone in a lime matrix; well cemented; structureless in lower 5 ft and crudely horizontally thinly bedded in top 1.2 ft; weathers to form nodular-weathering ledge. Unit contains textures difficult to interpret. Basal half of unit gives impression of having once been siltstone and then of being saturated with lime so that only angular granule- and pebble-sized remnants of the siltstone remain. The top half of the unit, however, is composed of grains that appear to be detrital in origin, although probably locally derived. No definite contact can be located between these two textures; one appears to grade upward into the other 6.2
13. Siltstone, pale-reddish-brown (10*R* 5/4), and grayish-red (10*R* 4/2); weathers same colors; firmly cemented, slightly calcareous; stratification mostly concealed, but sparse exposures indicate horizontal stratification planes and minor horizontal and ripple laminae; weathers to form steep loose slope. One thin bed of grayish-orange (10*YR* 7/4) siltstone seen near top of unit 81.3

Basal sandstone unit of red siltstone member:

12. Sandstone and siltstone. Sandstone, pale-red (10*R* 6/2), grayish-red (10*R* 4/2) and minor light-greenish-gray (5*GY* 8/1); weathers light brown (5*YR* 6/4); consists of all gradations from sandstone composed of fine to medium grains of quartz and feldspar to sandstone composed dominantly of reddish very coarse grains and granules of siltstone and very fine grained sandstone, fair to poorly sorted; well ce-

C15. PARADOX VALLEY—Continued

Chinle Formation—Continued

Basal sandstone unit of red siltstone member—Con. *Feet*

mented, interstitial spaces appear to be filled with calcite although rock effervesces only very slightly in acid; composed of very thin to thin irregular wavy horizontal beds and minor very thin to thin planar sets of small-scale cross-laminae. Bedding planes are bounded by silt film. Top 1 ft of unit locally is sandstone composed of medium to very coarse grains and minor granules of limestone and siltstone in a lime matrix. Siltstone, grayish-red (5*R* 4/2); weathers same color; very fine grained sand in parts, well cemented, noncalcareous; structureless. Siltstone is present from 1.3 to 3.1 ft above base of unit. Unit as whole weathers to form ledge 13.2

11. Sandstone, pale-red-purple (5*RP* 6/2), light-greenish-gray 5*GY* 8/1) and uncommon grayish-red-purple (5*RP* 4/2) and white (*N*9); weathers same colors; medium to very coarse grained; common interstitial silt, fair sorted; composed of angular to subangular milky grains; poorly cemented, slightly calcareous, generally has no cohesion; stratification only rarely exposed but where seen is composed of horizontal laminae to thin beds and minor thin planar sets of small-scale cross laminae; weathers to form steep rubble-covered slope. Top 1.4 ft of unit is grayish-red-purple (5*RP* 4/2) siltstone containing minor medium to very coarse grains. All except top 1.4 ft of unit contains a few percent of quartz granules and pebbles 17.4

Total basal sandstone unit of red siltstone member 30.6

Total incomplete red siltstone member 118.1

Total incomplete Chinle Formation 118.1

Moenkopi Formation:

Sewemup Member:

10. Siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); weathers same colors; common fine-grained accessory light and dark mica; firmly cemented, noncalcerous; structureless to horizontally and ripple laminated; weathers to form steep rubble-covered slope. About 10 percent of unit is thin sets of siltstone that in places grade to very fine grained sandy siltstone; these sets are mostly pale reddish brown and ripple laminated. Unit from 88.6 to 93 ft is sandstone. Sandstone, pale-red (5*R* 6/2) and pale-reddish-brown (10*R* 5/4); weathers pale reddish brown; very fine to fine grained, firmly cemented, slightly calcareous, horizontally laminated, minor thin planar sets of small-scale cross-laminae.

Moenkopi Formation—Continued

Sewemup Member—Continued *Feet*

This sandstone weathers to form minor ledge in middle of unit. Unit contains a similar sandstone from 12 to 9 ft below top. Some of the finer grained grayish-red siltstone beds are very thinly laminated and are markedly more fissile than siltstone in lower members. Uppermost 2–3 ft of siltstone, mottled green gray and grayish red and purple, is evidently an alteration zone immediately beneath the basal sandstone of the Chinle Formation 122.0

Total Sewemup Member 122.0

Ali Baba Member:

9. Sandstone, *type 1* (60 percent) and *type 2* (20 percent), and siltstone (20 percent). Sandstone, *type 1*, pale-brown (5*YR* 5/2); weathers light brown (5*YR* 6/4); very fine grained; firmly cemented, noncalcareous; ripple laminated and horizontally laminated to very thin bedded. Sandstone, *type 2*, pale-red (10*R* 6/2 and 5*R* 6/2); weathers same colors; fine to medium grained, common coarse to very coarse grains, poorly sorted; composed of subrounded to subangular white feldspar, amber-colored quartz, and minor black grains; poorly cemented, noncalcareous, composed of thin planar sets of small-scale cross-laminae. Siltstone, similar to siltstone in unit 6. Siltstone is present as laminae to very thin beds interstratified with very thin to thin sets of sandstone *type 1* and thin sets of sandstone *type 2*. Unit contains conglomeratic sandstone from 4 to 1 ft below top of unit consisting of granules and pebbles of feldspar, granite, schist, and quartz in a sand matrix similar to sand in *type 2* sandstone. Mud-crack fillings composed of sandstone *type 2* are present in one bed of siltstone. Spacing of cracks is 0.3–1 ft. Cracks tend to form a rectilinear pattern 15.4

8. Conglomeratic sandstone to sandstone (50 percent) and sandstone (50 percent). Conglomeratic sandstone, pale-red (5*R* 6/2) and sparse very pale orange (10*YR* 8/2); weathers same colors; medium to coarse grained, with parts containing granules, pebbles, and minor cobbles of quartz, granite, schist, and feldspar, poorly to fair sorted; composed of subangular to subrounded amber quartz and milky feldspar, and minor black minerals; interstices filled with white material (probably kaolin derived from feldspar); poorly cemented, slightly calcareous; composed of thin to thick planar sets of cross-laminae. Sandstone, light-brown (5*YR* 6/4), to pale-brown (5*YR* 5/2); weathers light brown (5*YR* 6/4); fine to very fine grained, fair

C15. PARADOX VALLEY—Continued

Moenkopi Formation—Continued

Ali Baba Member—Continued — *Feet*

sorted; firmly cemented, slightly calcareous; composed of horizontal laminae and thin trough and planar sets of small- to medium-scale cross-laminae; cross-laminae in lower half are very low angle. The sandstone is present as thin to thick cosets interstratified with the conglomeratic sandstone to sandstone in lower two-thirds of unit and forms entire top 7 ft of unit. Unit as a whole weathers to form the uppermost of the two most prominent cliffs in the Moenkopi. Large cobble-sized angular chunks of grayish-red siltstone are scattered through the sandstone near base of unit. Base of unit is a smooth plane except for well-developed mud-crack fillings projecting into underlying unit — 19.7

7. Siltstone, grayish-red (10*R* 4/2); weathers same color, sparse parts contain fine- to coarse-grained dark mica; well cemented, noncalcareous; horizontally laminated to very thin bedded, sparse ripple laminae; weathers to form vertical cliff — 5.8

6. Sandstone, grayish-red-purple (5*RP* 4/2); weathers pale reddish brown (10*R* 5/4); very fine grained, well sorted; composition concealed; well cemented, noncalcareous; composed of thin trough sets of small-scale cross-laminae; weathers to form vertical cliff. In places unit contains a few percent of fine to coarse quartz grains, and sparse pebbles of siltstone — 5.2

5. Silty sandstone to siltstone. Grayish red (5*R* 4/2), and pale reddish brown (10*R* 5/4); weathers same colors; grades from very fine grained sandstone to siltstone, contains abundant coarse-grained dark mica; firmly cemented, calcareous; horizontally laminated to thin-bedded, minor ripple laminae. Siltstone, grayish-red (10*R* 4/2); weathers same color; well cemented, noncalcareous; very thin to thinly horizontally bedded. Siltstone is present as very thin to thin sets interstratified with thin to thick sets of silty sandstone to siltstone. Unit as a whole weathers to form steep slope with small ledges on silty sanstone to siltstone sets. Unit contains abundant mud-crack fillings in top 10 ft — 47.3

4. Conglomeratic sandstone (75 percent) and sandstone *types 1* and *2* (25 percent). Conglomerate sandstone, grayish-red (10*R* 4/2); weathers same color; medium to very coarse grained, poorly sorted; composed of subangular to rounded amber quartz grains and feldspar grains, minor granules and pebbles of granite, schist, sandstone, and quartz; well cemented, clay binding, noncalcareous; composed of thin to thick planar sets of medium-scale cross-laminae to very thin beds. Sandstone, *type 1*, grayish-orange (10*YR* 7/4) to pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); very fine to fine grained; firmly cemented, slightly calcareous; composed of planar type of cross-laminae. Sandstone, *type 2*, grayish orange (10*YR* 7/4), fine grained, fair sorted; composed of subangular grains of clear and amber quartz with abundant fine to medium grains of black mica; firmly cemented, noncalcareous; composed of trough sets of small-scale cross-laminae. Near the top of unit, *type 1* sandstone contains abundant ripple laminae. Conglomeratic sandstone and sandstone, types 1 and 2, are found in alternating cosets and alternating sets within a coset. The *type 1* sandstone occurs only in basal 2 ft of unit. At base of some cosets of coarse conglomeratic sandstone are conspicuous soft rock compression features. Entire unit weathers to form a ledgy to vertical cliff — 33.8

Total Ali Baba Member — 127.2

Tenderfoot Member:

Fourth unit:

3. Siltstone and silty sandstone. Siltstone, grayish-red (10*R* 4/2); weathers same color; common fine-grained angular amber quartz grains and common dark and light accessory mica; well cemented, slightly calcareous in parts; horizontally thin bedded. Silty sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; fine to coarse grained, poorly sorted; composed of subangular to well-rounded amber quartz and feldspar grains; firmly cemented, slightly calcareous; horizontally thin to thick bedded; sparse ripple-laminated intervals. Unit as a whole weathers to form rough ledgy slope. Common thin horizontal greenish-gray (5*GY* 6/1) beds are present. Silty sandstone occurs interbedded with siltstone and as wispy stringers between the siltstone beds. Sandier units are more common near base of unit, where they contain scattered coarse grains and vague stringers of coarse grains as in unit 2. Near the top, the unit is composed entirely of moderately fissile siltstone and very fine grained silty sandstone. Uncommon current lineation occurs in the silty sandstone — 71.7

Total fourth unit — 71.7

C15. PARADOX VALLEY—Continued

Moenkopi Formation—Continued
Tenderfoot Member—Continued

Third unit: *Feet*

2. Silty sandstone to sandy siltstone, pale-reddish-brown (10*R* 5/4), minor grayish-red (10*R* 4/2); weathers pale reddish brown 10*R* 5/4); grades from fine- to medium-grained sandstone with minor coarse to very coarse grains and silt to a siltstone with minor fine to coarse grains, poorly sorted; (grains are dominantly rounded amber quartz) abundant medium-grained accessory dark mica; firmly cemented, clay binding, mostly noncalcareous. Stratification exposed only in top 15 ft, where it is indistinct but contains wavy horizontal laminae and small-scale contorted stratification. Unit weathers to form a steep slope. Unit contains minor light-greenish-gray (5*GY* 8/1) mottlings and stringers. Lower part of unit covered with scree about 2–3 in. thick; lithology can be determined by digging, but bedding is indeterminable. Bedding is generally vague and irregular, but near top it becomes more regular and one well-defined 2½-ft-thick bed of massive sandy siltstone is included in sequence. Coarse grains are scattered through rock and also concentrated in vague pockets and stringers ---------- 71.5

Total third unit ---------- 71.5

(Note: First and second units of Tenderfoot Member are missing.)

Total Tenderfoot Member ---------- 143.2

Total Moenkopi Formation ---------- 392.4

Cutler Formation (unmeasured):

1. Sandstone, moderate-red (5*R* 5/4) and pale-red (5*R* 6/2); weathers same colors; medium grained, poorly sorted; composed of amber quartz and feldspar, subangular to subrounded grains, abundant coarse-grained accessory dark and golden mica; poorly cemented, clay binding; stratification poorly exposed but contains some low-angle cross-stratification; weathers to form steep ledgy slope. Only top 15 ft of unit examined. Unit contains a few percent of granules to cobbles of quartz, granite, and schist. Contact between Cutler and Moenkopi Formations is poorly exposed but placed at change from purple arkosic sandstone of the Cutler to brown sandy siltstone containing fine to coarse rounded amber grains of the Moenkopi.

Base of section; not base of exposure.

C18. MEEKER

[Measured, by F. G. Poole, L. G. Schultz, and Carl Koteff, April, May, and August 1956, at Oak Ridge on north side of White River valley and north of Colorado Highway 132 on K/K Ranch. Section begins in draw approximately 60 yds north of highway about ¼ mile west of old schoolhouse where Highway 132 ends and Colorado Highway 8 begins. Line of section is approximately due north except for unit 7 which follows roadcut N. 30° W., parallel to highway. NE¼ sec. 23, sec. 24, T. 1 S., R. 93 W., 6th PM. Rio Blanco County]

Top of section; not top of exposure. Chinle Formation is about 387 ft thick, and above unit 15 it consists mostly of reddish-brown siltstone of the red siltstone member.

Chinle Formation (incomplete):

Mottled member: *Feet*

15. Claystone, dark-reddish-brown (10*R* 3/4) to pale-reddish-brown (10*R* 5/4) with minor light-greenish-gray (5*G* 8/1); weathers grayish red (10*R* 4/2 and 5*R* 4/2) and grayish red purple (5 *RP* 4/2); silty, calcareous to slightly calcareous. Unit as a whole weathers to form smooth deeply weathered slope ---------- 18.0
14. Sandstone to siltstone, mottled pale-red-purple (5*RP* 6/2), grayish-red-purple (5*RP* 4/2), grayish-purple (5*P* 4/2), pale-blue (5 *PB* 7/2), white (*N*9), and grayish-yellow (5*Y* 8/4); weathers same colors. Sandstone is very fine to medium grained, silty, fair to poorly sorted; composed of subrounded clear and amber-stained quartz grains, common coarse to very coarse clear and amber-stained subrounded quartz grains, a few red and black mineral grains, most larger quartz grains seen were 2–3 mm in maximum diameter, sparse red chert grains as much as 6 mm in maximum diameter noted at top of unit; well cemented, calcareous, siliceous, especially near top; bedding poorly defined. Gray, yellow, brown, and red secondary(?) chert beds in upper 2–3 ft of unit; some of the chert has wavy laminae; chert beds average 3–5 in. in thickness but may be as much as 1 ft thick. Unit weathers to form resistant ledge ---------- 17.0
13. Sandstone, mottled grayish-red-purple (5*RP* 4/2), grayish-red (5*R* 4/2), grayish-purple (5*P* 4/2), and very light gray (*N*8); weathers to lighter shades; very fine to very coarse grained; lower 2 ft very silty, poorly sorted; composed of subangular to subrounded clear and amber-stained quartz grains, common subangular quartz grains as much as 3 mm in maximum diameter, micaceous; friable, noncalcareous to very slightly calcareous; structureless, weathers to form smooth slope ---------- 6.6

Total mottled member ---------- 41.6

Total incomplete Chinle Formation ---------- 41.6

C18. MEEKER—Continued

Unconformity.

State Bridge Formation:

Upper member: *Feet*

12. Siltstone (90 percent) and sandstone (10 percent). Siltstone, dark-reddish-brown (10*R* 3/4) and grayish-red (10*R* 4/2); weathers pale-red (10*R* 6/2) and moderate reddish-brown (10*R* 4/6); argillaceous, micaceous; firmly cemented; horizontally thinly laminated to very thin bedded. Sandstone, light-greenish-gray (5*G* 8/1 and 5*GY* 8/1); weathers to lighter shades; very fine to medium grained, fair sorted, composed of subrounded to rounded clear quartz with orange and black accessory minerals, abundant green and black mica; poorly cemented, calcareous, very thin bedded; unit as a whole weathers to form smooth slope — 31.0

11. Sandstone (70 percent) and clayey siltstone to silty claystone (30 percent). Sandstone, light-greenish-gray (5*GY* 8/1), very light gray (*N*8), and pale-red (10*R* 6/2); weathers lighter shades; very fine to coarse grained, fair to poorly sorted; composed of subrounded to rounded clear and amber-stained quartz and common black, orange, and green accessory minerals; a few medium- to small-scale trough and planar sets of low-angle cross-laminae, few parallel symmetrical and asymmetrical ripple marks, cuspate ripples, and mud cracks. Weathers to form ribs on smooth slope. Clayey siltstone to silty claystone, dark-reddish-brown (10*R* 3/4) with minor greenish-gray (5*GY* 6/1) and 5*G* 6/1) mottling; weathers moderate reddish brown (10*R* 4/6); firmly cemented, calcareous; horizontally laminated to thinly laminated. Weathers to form smooth slope — 21.3

10. Silty claystone (90 percent) and siltstone (10 percent), grayish-red (5*R* 4/2 and 10*R* 4/2) with minor greenish-gray (5*G* 6/1) mottling; weathers pale red (5*R* 6/2) and greenish gray (5*G* 6/1); siltstone varies from clayey siltstone to coarse siltstone, micaceous; well cemented, calcareous; horizontally laminated to thinly laminated. Weathers to form smooth slope — 9.8

9. Sandstone, light-greenish-gray (5*G* 8/1) to greenish-gray (5*GY* 6/1), very fine to coarse-grained with minor fine and medium grains, fair- to well-sorted; composed of rounded to well rounded clear and milky quartz and common black accessory mineral; unit contains conspicuous red, orange, black, and gray coarse-grained berries; firmly cemented, calcareous; thick bedded; common parallel symmetrical ripple marks with low ripple index (6–8), wavelength 2.0–2.5 in. with an amplitude of 0.3 in.; numerous mud cracks seen; blocky splitting. Unit weathers to form prominent rounded ledge — 7.0

C18. MEEKER—Continued

State Bridge Formation—Continued

Upper member—Continued *Feet*

8. Siltstone, grayish-red (10*R* 4/2) and minor greenish-gray (5*G* 6/1); weathers pale red (10*R* 6/2) and greenish gray (5*GY* 6/1), some greenish-gray (5*G* 6/1) mottling in the grayish-red siltstone; siltstone to coarse siltstone, well sorted; composed of subrounded to rounded amber-stained quartz and abundant white and black mica; firmly cemented, calcareous; horizontally laminated to thin bedded; much of unit is ripple laminated; shaly splitting. Weathers to form smooth slope — 74.2

7. Sandstone, siltstone, claystone. Sandstone, dark-yellowish-brown (10*YR* 4/2), light-olive-gray (5*Y* 6/1), olive-gray (5*Y* 4/1) dark-gray (*N*3), grayish-red (10*R* 4/2), pale-red (5*R* 6/2), and grayish-yellow-green (5*GY* 7/2); weathers lighter shades. Sandstone, very fine grained, well-sorted; composed of subrounded to rounded quartz, very micaceous; firmly to well cemented, calcareous; horizontally laminated to thin bedded, shaly to flaggy splitting; weathers to form minor resistant ribbed slope. Siltstone, similar to sandstone, fine to coarse. Claystone, olive-gray (5*Y* 4/1) and greenish-gray (5*GY* 6/1); weathers lighter shades; micaceous; secondary gypsum; horizontally laminated to thinly laminated; shaly to papery splitting; weathers to form slope between more resistant ribs. (Note: sandstone, siltstone, and claystone are all intricately interbedded. Gray colors may be controlled by petroliferous content. Unit as a whole weathers to shades of light gray and yellow and appears as bleached zone between less resistant red-bed units above and below.) — 235.0

6. Covered interval. Traverse N. 28° E. to base of unit 9 of Meeker section. Base of sandstone contains well-rounded varicolored grains and greenish-gray (5*G* 6/1) silty claystone pockets and chips; ripple marked. NOTE.—Section transferred about 1 mile southwest to Colorado Highway 132 roadcut. This offset may tend to thicken section — 125.2

Total upper member — 503.5

South Canyon Creek Member:

5. Sandy limestone, light-gray (*N*7), very light gray (*N*8), yellowish-gray (5*Y* 8/1), and light-greenish-gray (5*GY* 8/1), sandy to silty; weathers yellowish gray (5*Y* 8/1), light greenish gray (5*GY* 8/1), and pale red (10*R* 6/2); well-sorted abundant rounded to well-rounded clear quartz and common white mica; well cemented; laminated to thin bedded, platy to slabby splitting. Weathers to form ledgy slope. Unit is very vuggy and porous. Upper

C18. MEEKER—Continued

State Bridge Formation—Continued

South Canyon Creek Member—Continued — *Feet*

contact is not exposed. Upper 1.5-ft-thick ledge of unit contains brownish-gray (5*YR* 4/1) chert lenses and stringers and wavy to crinkled laminae — 4.8

Total South Canyon Creek Member — 4.8

Lower member:

4. Limy sandstone to siltstone, mottled grayish-red (10*R* 4/2) and light-greenish gray (5*G* 8/1); weathers pale red (10*R* 6/2 and 5*R* 6/2) and yellowish gray (5*Y* 8/1); very fine grained and silty, well sorted; composed of rounded to well-rounded clear and amber-stained quartz and common white mica; firmly cemented, very calcareous; laminated to thin bedded, platy to slabby and irregular splitting. Weathers to form steep slope. Unit appears to be very porous with common vugs. Top of unit appears gradational with overlying unit — 6.0

3. Siltstone, grayish-red (10*R* 4/2), light-brown (5*YR* 6/4), and pale-reddish brown (10*R* 5/4), minor light-greenish-gray (5*G* 8/1) and greenish-gray (5*GY* 6/1) mottling; weathers same colors and lighter shades; well sorted, abundant very fine grained white mica; firmly to well cemented, slightly calcareous; structureless and thinly laminated to thin bedded, shaly to slabby splitting, structureless part of unit weathers to angular fragments. Weathers to form steep slope. Unit as a whole is poorly exposed — 83.9

Total lower member — 89.9

Total Sate Bridge Formation — 598.2

NOTE.—Section transferred about 300 yds N. 30°W. to top of Weber Sandstone in next wash.

Unconformity (?).

Weber Sandstone:

2. Sandstone, yellowish-gray (5*Y* 7/2), pale-greenish-yellow (10*Y* 8/2), light-olive-gray (5*Y* 5/2), white (*N*9) to grayish-black (*N*2); intervening shades of gray depend upon amount of solid hydrocarbon present; weathers pale yellowish orange (10*YR* 8/6), grayish-orange (10*Y* 7/4), light brown (5*YR* 6/4), and various shades of gray; very fine grained, well sorted; composed of rounded to well-rounded clear quartz grains and common white mica; firmly to well cemented, calcareous; thinly laminated to very thick bedded; platy to massive splitting; medium- to small-scale trough and planar sets of medium-angle, thin cross-laminae to thin crossbeds. Weathers to form vertical cliff. Varying amounts of solid hydrocarbon seen throughout unit. Base of unit not exposed. (NOTE: Many bedding planes, especially crossbedding surfaces, contain abundant subrounded to rounded medium sand to granules of clear, milky, and smoky quartz and common white mineral (feldspar or chert?) Sparse very small pebbles (5 mm) were seen.) — 152.8

C18. MEEKER—Continued

Weber Sandstone—Continued — *Feet*

Total Weber Sandstone — 152.8

Maroon Formation (incomplete):

1. Micaceous sandstone, very dusky red (10*R* 2/2), grayish-red (5*R* 4/2 and 10*R* 4/2), and minor light-greenish-gray (5*G* 8/1 and 5*GY* 8/1); weathers same colors; very fine to coarse grained, common very coarse grains, silty, poorly sorted; composed of subangular to rounded milky, smoky, and amber-stained quartz grains and abundant white mica and chlorite and common black (jet or pitch) mineral with conchoidal fracture (chert or solid hydrocarbon), noncalcareous to very slightly calcareous, poorly to firmly cemented; very thick bedded. Upper contact is sharp but conformable — 6.0

Total incomplete Maroon Formation — 6.0

Base of section; base of exposure.

NEVADA

N1. HORSE SPRING VALLEY

[Measured, by J. H. Stewart, R. F. Wilson, and William Thordarson, November 1955, in Horse Spring valley east of Tramp Ridge about 2 miles north of Horse Spring and 3 miles south of Mud Well, line of section averages about N. 60° E. (including offsets), secs. 13 and 14 (unsurveyed), T. 18 S., R. 70 E., MDM. Clark County]

NOTE.—This section is measured in an area containing many small faults, and therefore some of the unit thicknesses may be in error because of concealed faults.

Top of section, not top of exposure.

Chinle Formation (restricted) (incomplete):

Probable equivalent of Petrified Forest Member (incomplete):

25. Sandstone to clayey sandstone (95 percent), and conglomeratic sandstone (5 percent). Sandstone to clayey sandstone, pale-red-purple (5*RP* 6/2) with sparse light-greenish-gray (5*GY* 8/1), greenish-gray (5*GY* 6/1) and grayish-red (10R 4/2); weathers same colors and light brownish gray (5*YR* 6/1); fine to coarse grained, fair to poorly sorted with as much as 15 percent clay matrix; composed of angular to subangular clear, milky, and reddish-brown quartz and orange chert with abundant accessory light and dark mica and dark mineral; well to poorly cemented, calcareous in part, clay binding; stratification largely concealed, but some horizontal laminae and beds and some thin to thick

N1. HORSE SPRING VALLEY—Continued

Chinle Formation—Continued

Probable equivalent, etc.—Continued *Feet*

planar and trough sets of low-angle cross-laminae. Conglomeratic sandstone, similar to sandstone except it contains granules and pebbles of chert and quartz. Unit as a whole weathers to form partly covered hill and slope. Several thin to thick sets of relatively well sorted fine-grained sandstone which is well cemented with calcite and cross-laminated in planar sets and forms thin ledges near base of unit. This unit differs from unit 24 in color and in having a poorer sorting and a higher clay content 92.0

Total probable equivalent of Petrified Forest Member 92.0

Shinarump(?) Member:

24. Sandstone (80 percent) and conglomeratic sandstone to conglomerate (20 percent). Sandstone, white (*N*9) and grayish-orange (10*YR* 7/4); weathers same colors and pale yellowish orange (10*YR* 8/6); medium to coarse grained, fair to well sorted with some clay matrix; composed of subangular to subrounded clear and yellowish-stained quartz with common to abundant accessory dark mica and dark and orange mineral; firmly cemented, calcareous in part, clay binding; stratification largely obscured, but some thin to thick trough sets of low-angle medium-scale cross-laminae and some horizontal laminae. Conglomeratic sandstone to conglomerate, similar to sandstone except it contains granules and pebbles of black, orange, and gray chert, quartzite, and white quartz. The conglomeratic sandstone to conglomerate is present as thin sets interstratified with the sandstone. As a whole, the unit weathers to form part of valley floor with several protruding sandstone ledges. Unit contains common fragments of silicified wood 28.7

Total Shinarump(?) Member 28.7

Total incomplete Chinle Formation (restricted) 120.7

Moenkopi Formation:

Upper red member:

23. Silty to sandy claystone to clayey sandstone. Silty to sandy claystone, greenish-gray (5*GY* 6/1), light-greenish-gray (5*GY* 8/1), and minor pale-purple (5*P* 6/2); weathers light greenish gray; contains varying amounts of very fine sand and silt grains, grades to siltstone and sandstone; clays are apparently bentonitic and swell when wet; well cemented, noncalcareous; stratification concealed. Clayey sandstone, light-greenish-gray (5*GY* 8/1) with minor pale-red-purple (5*RP* 6/2) mottling; weathers same colors; very fine grained, fair to poor sorting with clay matrix approximately 25 percent; composition mostly concealed but where seen it consists of subrounded quartz and possibly some limestone grains; firmly to poorly cemented, noncalcareous; stratification concealed. Unit as whole weathers to form covered slope with poor exposures below ledge of Shinarump(?) Member. The lithology of this unit is much more similar to that of the overlying units of the Chinle Formation than to that of the underlying units of the Moenkopi Formation, and, therefore, the unit could be part of the Chinle Formation 8.0

NOTE.—Units 23–25 measured at northernmost good exposures of the Moenkopi and Chinle Formations in the main part of Horse Spring Valley.

22. Siltstone, grayish-red (10*R* 4/2), weathers same color; medium-size silt grains; common accessory white mica; firmly cemented, calcareous in part, clay binding; stratification concealed; weathers to form part of slope between unit 21 and the Shinarump(?) Member of the Chinle Formation 12.3

21. Calcarenite, similar to unit 19 except it is coarser grained with sparse quartz and granules and pebbles of limestone; weathers to form small ledge 4.5

20. Siltstone, light-brown (5*YR* 6/4) and grayish-red (10*R* 4/2); weathers same colors; medium to coarse silt, sandy (very fine grained) in part, abundant very fine grained accessory white mica; poorly to firmly cemented, calcareous; stratification concealed, weathers to form slope between ledges of underlying and overlying units 14.3

19. Calcarenite, grayish-yellow-green (5*GY* 7/2), weathers olive gray (5*Y* 4/1); fine to medium grained with scattered coarse grains and granules of limestone, fair sorted; composed of rounded to subrounded grains of limestone and lesser amounts of quartz with common accessory white mica; well cemented, calcareous; horizontally very thin bedded; weathers to form small ledge in valley floor. Unit contains about 3 in. of limestone and siltstone pebble conglomerate at base. (Note: offset at top of this unit so that overlying units were measured 2,000 ft northeast of underlying units.) 3.0

18. Siltstone, *type 1* (85 percent) and *type 2* (10 percent), and gypsum (5 percent). Siltstone, *type 1*, pale-reddish brown (10*R* 5/4), moderate brown (10*YR* 4/4), and grayish red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); fine silt; sparse very fine grained accessory white mica;

N1. HORSE SPRING VALLEY—Continued

Moenkopi Formation—Continued

Upper red member—Continued *Feet*

poorly to firmly cemented, calcareous in part; horizontally thinly laminated to very thick bedded. Siltstone, *type 2*, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), minor grayish-orange (10*YR* 7/4), and sparse light-greenish-gray (5*GY* 8/1); weathers same colors; medium to coarse silt, sandy (very fine grained) in a few layers; common very fine grained accessory white mica; well cemented, calcareous; ripple laminated, minor horizontal laminae. Gypsum, white (*N*9); weathers same color; fibrous; firmly cemented; present as horizontal laminae to very thin beds interstratified with siltstone. Siltstone *type 2* is present as thin to thick sets interstratified with siltstone (*type 1*), and is found predominantly in basal 240 ft of unit. Unit as a whole weathers to form low hills ---------------------------------- 658.7

17. Siltstone, light-greenish-gray (5*GY* 8/1) to white (*N*9), and minor pale-yellowish-brown (10*YR* 6/2); weathers same colors, coarse silt; firmly to well cemented, calcareous in part; horizontally laminated, sparse ripple laminae of the cuspate type; weathers to form basal one-third of back side of hogback in middle of Horse Spring valley. Unit is differentiated from overlying unit primarily on color rather than on lithology---------------------------- 46.8

16. Sandy siltstone, yellowish-gray (5*Y* 8/1) and very light gray (*N*8); weathers yellowish-gray (5*Y* 8/1); grades from coarse silt to very fine grained sand; well cemented, noncalcareous; horizontally laminated to very thick bedded, sparse medium-scale low-angle cross-strata; weathers to form top ledge and most of back side of hogback in middle of Horse Spring valley---- 51.7

15. Siltstone, pale-reddish-brown (10*R* 5/4) and moderate-red (5*R* 5/4); weathers same colors; medium to coarse silt; uncommon very fine grained accessory white mica; poorly to firmly cemented, calcareous; structureless; weathers to form steep slope in upper part of hogback in middle of Horse Spring valley. Unit is poorly exposed in part-------------------------- 15.6

14. Siltstone to sandy siltstone, grayish-orange (10*YR* 7/4) and yellowish-gray (5*Y* 7/2); weathers grayish orange (10*YR* 7/4); grades from coarse silt to very fine grained sand; firmly to well cemented, calcareous; horizontally laminated and very thick bedded; weathers to form steep bare rock slope of irregular ledge in lower half of hogback in middle of Horse Spring valley-- 50.7

N1. HORSE SPRING VALLEY—Continued

Moenkopi Formation—Continued

Upper red member—Continued *Feet*

13. Siltstone, light-brown (5*YR* 6/4) to moderate-brown (5*YR* 4/4) and grayish-red (10*R* 4/2); weathers moderate brown (5*YR* 4/4); fine to coarse silt; common very fine grained accessory white mica; firmly cemented, noncalcareous; stratification concealed; weathers to form gentle slope near base of hogback in middle of Horse Spring valley. Section passes along north boundary of Beckly Claim No. 2----- 19.5

12. Siltstone, grayish-orange (10*YR* 7/4); weathers dark yellowish brown (10*YR* 4/2); coarse silt; firmly to well cemented, calcareous; ripple laminated; weathers to form small ledge at base of small hogback in lower part of the upper red member. Unit is provisionally selected as base of upper red member because it is above thick gypsum beds and because it contains the lowest rock types characteristic of the upper red member elsewhere------------- 2.5

Total upper red member--------------- 887.6

Shnabkaib Member:

11. Siltstone (70 percent), gypsum (25 percent), and limestone (5 percent). Siltstone, moderate-brown (5*YR* 4/4) and sparse greenish-gray (5*GY* 6/1); weathers pale reddish brown (10*R* 5/4); otherwise similar to siltstone in underlying unit. Gypsum, similar to gypsum in underlying unit. Most of gypsum is greenish gray (5*GY* 6/1) and horizontally laminated. Limestone, similar to limestone in underlying unit. Limestone and gypsum concentrated in lower half of unit. Upper half of unit mostly reddish-brown siltstone. Unit as a whole weathers to form low hills. Line of section crosses road about 40 ft below top of unit---------------------------------- 104.3

10. Limestone (25 percent), siltstone (60 percent), and gypsum (15 percent). Limestone, very light gray (*N*8), light-gray (*N*7), and light-olive-gray (5*Y* 6/1); weathers same colors and white (*N*9); dense and minor oolitic parts; well cemented; horizontally very thin to thin bedded. Siltstone, greenish-gray (5*GY* 6/1) and minor yellowish-gray (5*Y* 7/2); weathers light greenish-gray (5*GY* 6/1); abundant very fine grained accessory white mica; poorly to firmly cemented; noncalcareous; stratification concealed. Gypsum, light-greenish-gray (5*GY* 8/1), greenish-gray (5*GY* 6/1), and white (*N*9); weathers same colors; dense to coarse crystalline; well cemented; stratification concealed. Limestone and

N1. HORSE SPRING VALLEY—Continued

Moenkopi Formation—Continued

Shnabkaib Member—Continued *Feet*

gypsum are present as very thin to very thick sets interstratified with siltstone. Unit as a whole weathers to form low greenish-gray hills in western part of Horse Spring valley. Much of lithology of this unit is difficult to see because of crusty surface weathering. Almost all limestone beds contain poorly preserved pelecypods and gastropods. Gypsum beds are concentrated in upper one-fourth of unit 288.3

Total Shnabkaib Member 392.6

Siltstone unit:

9. Siltstone (80 percent) and gypsum (20 percent). Siltstone, moderate-brown (5*YR* 4/4), pale-reddish-brown (10*R* 5/4), and grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); fine to coarse silt, abundant very fine grained accessory dark and light mica; firmly cemented, noncalcareous; structureless and horizontally laminated. Gypsum, white (*N*9) and greenish-gray (5*GY* 6/1); weathers same colors; dense to finely crystalline; well cemented; horizontally laminated to very thin bedded. Gypsum is present as horizontal laminae to thick sets interstratified with siltstone and as seams cutting across stratification. Unit as a whole weathers to form gentle slope between hogback on west and rolling hills formed on overlying unit on east. Much of unit is covered along line of section, but most of unit can be seen lateral to line of section. Gypsum is most abundant in lower 100 ft of unit, where it forms 50 percent of strata. Amount of gypsum decreases to 10–20 percent in upper half of unit. About 2,000 ft south of line of section exposure of basal 30 ft of unit contains several limestone beds. The limestone is grayish orange (10*YR* 7/4) and medium gray (*N*5), dense, and horizontally very thin to thick bedded. Limestone is present as thin to thick sets interstratified with siltstone and gypsum and constitutes about 2 percent of unit 399.9

Total siltstone unit 399.9

Lower unit (provisionally assigned to Moenkopi Formation):

8. Limestone and probably minor dolomite, very light gray (*N*8) and white (*N*9); weathers same colors; dense; well cemented; horizontally thin to thick bedded; weathers to form ledge and basal part of hogback formed mostly on Kaibab Limestone. Unit contains 5 percent irregular chert nodules. At one point along exposure of unit, near line of section, a conglomeratic limestone

N1. HORSE SPRING VALLEY—Continued

Moenkopi Formation—Continued

Lower unit—Continued *Feet*

is present near the stratigraphic position of this unit. The conglomerate is composed of granules to cobbles of chert and limestone in a lime matrix. (Note:—section offset so that overlying units measured 1,000 ft northeast of underlying units.) 16.5

7. Covered; poor exposures lateral to line of section indicate unit is pale-reddish-brown (10*R* 5/4) siltstone; weathers to form slope ±6.0

6. Limestone, pinkish-gray (5*YR* 8/1), yellowish-gray (5*Y* 8/1), and very light gray (*N*8); weathers yellowish gray (5*Y* 8/1); dense to very finely crystalline; well cemented; structureless and some horizontal laminae to thick beds; weathers to form ledge and lower one-fourth of back side of hogback formed mostly on Kaibab Limestone. Unit contains about 20 percent very light gray (*N*8) chert which forms irregular nodules mostly 4–5 in. in diameter. Brachiopods occur 3 ft above base 51.1

5. Siltstone (80 percent) and gypsum (20 percent). Siltstone, pale-reddish-brown (10*R* 5/4) and moderate-red (5*R* 5/4); weathers pale reddish brown (10*R* 5/4); fine to coarse silt; firmly to well cemented, calcareous; stratification mostly concealed, a few strata were horizontally laminated. Gypsum, white (*N*9); weathers same color, completely recrystallized at surface. Unit as a whole weathers to form steep slope. Unit poorly exposed. Gypsum present in top half of unit and has flowed downslope. Siltstone at one place contains siltstone pellets 37.2

4. Limestone, yellowish-gray (5*Y* 8/1) to light-olive-gray (5*Y* 6/1); weathers yellowish gray (5*Y* 7/2); dense, well cemented, horizontally laminated to thick bedded; weathers to form minor ledge. About 40 percent of unit is white (*N*9) to yellowish-gray (5*Y* 8/1) chert. The chert forms irregular nodules and very thin horizontal lenses 13.9

3. Limestone, medium-gray (*N*5), yellowish-gray (5*Y* 8/1) in top 2 ft; weathers same colors; dense; well cemented; horizontally laminated to thin bedded; weathers to form fairly persistent dark-gray ledge above white Kaibab Limestone. Limestone has a fetid odor when broken. Unit contains sparse poorly preserved pelecypods. Unit closely resembles basal unit of Moenkopi in St. George section A (loc. U47a) 8.4

2. Conglomerate (50 percent) to limestone (50 percent). Conglomerate, pale-reddish-brown (10*R* 5/4) and grayish-orange (10*YR* 7/4); weathers same colors; composed of angular to rounded limestone and chert granules to possibly boulders in a very fine

N1. HORSE SPRING VALLEY—Continued

Moenkopi Formation—Continued

Lower unit—Continued *Feet*

to fine-grained sand matrix composed of grains of quartz and calcite; poorly cemented; structureless. Limestone, yellowish gray (5*Y* 8/1); weathers same color; dense; well cemented; structureless. Conglomerate is present in basal half of unit and grades upward into limestone. Much of the lithology of this unit is difficult to ascertain. Unit as a whole weathers to form reentrant which is covered in most places — 3.0

Total lower unit (provisionally assigned to Moenkopi Formation) — ±136.1

Total Moenkopi Formation (lower contact uncertain) — ±1,816.2

Kaibab Limestone (unmeasured):

Beta member (unmeasured):

1. Limestone, light-brownish-gray (5*YR* 6/1) to light-gray (*N*7); weathers very light gray (*N*8); dense with some fine to coarse disseminated crystals; well cemented; horizontally very thin to thin bedded, sparse horizontally laminated to ripple-laminated parts; weathers to form main part of back side of hogback formed mostly on Kaibab Limestone. About 20 percent of unit is gray chert. Chert occurs as irregular nodules and lenses along stratification planes. Brachiopods, corals, and crinoids occur 65.8 ft below top of unit. Unit is at least 200 ft thick but only top 30 ft examined in detail.

Base of section; not base of exposure. Base of section is about 1½ miles N. 82° W. from minor hill at north end of a ridge formed on the Horse Spring Formation (Tertiary).

NEW MEXICO

NM1. CHAVEZ-PREWITT

[Measured, by J. H. Stewart and R. F. Wilson, April 1956, about 3 miles east of Bluewater Reservoir; units 1 and 2, measured on north side of a small canyon in the east-central part of sec. 36, T. 13 N., R. 12 W.; units 3–6, measured along a north line starting in wash and heading toward a prominent point along cliffs north of Bluewater Canyon, central and north-central part of sec. 36, T. 13 N., R. 12 W., NMPM. McKinley County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Petrified Forest Member (incomplete):

6. Clayey siltstone to silty claystone grayish-purple (5*P* 4/2); weathers same color; swelling clays; firmly indurated, noncalcareous clay binding; structureless; weathers to form frothy-surfaced badlands. Basal 10 ft is light-gray (*N*7) and grayish-purple (5*P* 4/2), silty, very fine grained sandstone containing common fine to coarse-grained accessory white mica. This silty sandstone weathers as a slope with rest

NM1. CHAVEZ-PREWITT—Continued

Chinle Formation—Continued

Petrified Forest Member—Continued *Feet*

of the unit. Unit contains several horizons of limestone nodules — 67.2

Total incomplete Petrified Forest Member — 67.2

Lower red member (upper contact uncertain):

5. Sandstone (50 percent) and limestone pebble conglomerate (50 percent). Sandstone, very light gray (*N*8); weathers same color; very fine grained, well sorted; composed of clear quartz; well cemented, calcareous; horizontally laminated to thin bedded, sparse low-angle cross-strata, one occurrence of contorted laminae seen. Limestone pebble conglomerate, brownish-gray (5*YR* 4/1); weathers same color; composed of granules to pebbles, as large as 2 in. in maximum diameter, of limestone in a limy sand matrix similar to rest of the unit. Limestone pebble conglomerate is well cemented, structureless, and forms most of upper two-thirds of unit. Unit as a whole weathers to form ledge. Lateral to line of section, unit is about twice as thick and is mostly horizontally laminated and ripple-laminated sandstone — 5.6
4. Silty claystone, dark-gray (*N*3) to light-gray (*N*7), minor grayish-purple (5*P* 4/2); weathers same colors; swelling clay; firmly indurated, noncalcareous clay binding; structureless; weathers to form frothy-surfaced badlands — 44.8

Total lower red member (upper contact uncertain) — 50.4

Mottled strata:

3. Sandstone (90 percent) to conglomerate (10 percent), mottled white (*N*9), grayish-purple (5*P* 4/2), and minor very dusky red purple (5*RP* 2/2) and dark-yellowish-orange (10*YR* 6/6); weathers same colors. Conglomerate confined to basal 2.5 ft and composed of granules and pebbles of yellow and minor gray, black, and red chert, sparse black quartzite, and white quartz. Granules and pebbles average ¼–½ in. in diameter and are as large as 2½ in. A few granules and pebbles are scattered throughout rest of unit. Sandstone and matrix of conglomerate is fine grained with minor fine and medium grains and abundant interstitial white silt or clay, poorly to fair sorted; composition largely concealed; about 20 percent of grains are black and red; well cemented, noncalcareous. Stratification is largely concealed by mottled colors but the stratification, where visible, is thin tabular planar sets of small and sparse medium-scale low-angle cross-laminae. Unit as a whole weathers to form ledge

NM1. CHAVEZ-PREWITT—Continued

Chinle Formation—Continued

Mottled strata—Continued *Feet*

and locally underlies bench. Unit probably correlates with the mottled strata at base of Chinle at Fort Wingate 19.0

Total mottled strata 19.0

Total incomplete Chinle Formation 136.6

Unconformity. Basal contact of unit is undulatory and is sharp. Scours as deep as 0.5 ft are present along the contact.

Moenkopi (?) Formation:

2. Siltstone (60 percent) and sandstone (40 percent). Siltstone, grayish-red (10*R* 4/2 and minor 5*R* 4/2); weathers same colors; sandy (very fine grained) in parts, common very fine grained white mica; well indurated, noncalcareous; structureless, sparse ripple-laminated and horizontally laminated parts, one thin tabular planar set of medium-scale cross-laminae (may be delta foreset). Sandstone, pale-red (5*R* 6/2 and minor 10*R* 6/2); weathers same colors and grayish red (5*R* 4/2); very fine grained, silty in parts, fair to well sorted; composition concealed; well cemented, calcareous in parts; horizontally laminated to thin bedded, sparse thin trough sets of low-angle, small-scale cross-laminae. Sandstone is present as thin to very thick sets and cosets interstratified with siltstone. Unit as a whole weathers to form steep slope. Thin bed of grayish-red-purple (5*RP* 4/2) limestone granule and pebble conglomerate 4 ft above base of unit. Unit highly variable in lithology along outcrop; locally it appears to be dominantly siltstone. Within 2 miles of section, Moenkopi locally contains conglomerate beds consisting of granules and pebbles of quartz, quartzite, and chert. (Note: section offset so that overlying units measured 1,000 ft west of this unit.) 25.8

Total Moenkopi (?) Formation 25.8

Unconformity; 3- to 5-ft-high folds at top of San Andres Limestone are truncated by overlying beds.

San Andres Limestone (unmeasured):

Limestone member (unmeasured):

1. Limestone, moderate-orange-pink (10*R* 7/4) and light olive-gray (5*Y* 6/1); weathers light brownish gray (5*YR* 6/1); dense; some parts contain many small pores; well cemented, horizontally thin to thick bedded; weathers to form vertical cliffs along sides of wash.

Base of section; base of exposure. Base of section in wash bottom.

NM16. RILEY

[Measured, by J. H. Stewart and R. F. Wilson, June 1956, about 1½ miles northeast of Riley, eastern part of sec. 24, T. 2 N., R. 4 W., NMPM. Socorro County]

Top of section; top of good exposure. Overlying rocks probably faulted.

Chinle Formation (incomplete):

Petrified Forest Member (incomplete): *Feet*

12. Silty claystone, grayish-purple (5*R* 4/2) and minor light-greenish-gray (5*GY* 8/1); weathers pale purple (5*P* 6/2); composed of swelling clays; firmly cemented, slightly calcareous; stratification concealed; weathers to form hills and gullies. Unit contains several zones of limy nodules as large as 2 in. in diameter. Only basal 20 ft of unit examined.

11. Siltstone to sandstone, light-olive-gray (5*Y* 6/1), greenish-gray (5*G* 6/1), dark-greenish-gray (5*G* 4/1); weathers light greenish gray (5*GY* 8/1) and light olive gray (5*Y* 6/1); grades from coarse siltstone to very fine grained sandstone, composed of greenish-gray-stained quartz and abundant dark and light accessory minerals; firmly to well cemented, slightly calcareous in part, clay binding in part, siliceous in part; stratification mostly concealed, but some horizontally thin bedded to laminated sets; weathers to form slope 16.0

10. Sandstone, light-olive-gray (5*Y* 6/1) to medium-light-gray (*N*6); weathers light olive gray (5*Y* 6/1); medium to fine grained, fair to poorly sorted; composed of clear and greenish-gray-stained quartz in a fine-grained matrix of unknown composition; well cemented, calcareous; composed of planar sets of medium-scale low-angle cross-laminae; weathers to form ledge. Unit contains scattered layers of granules and pebbles, as large as 3½ in. in maximum diameter, of red, gray, and black quartzite and chert. Unit contains poorly preserved plant fragments and silicified wood 2.3

9. Clayey siltstone, light-greenish-gray (5*GY* 8/1) and pale-red-purple (5*RP* 6/2); weathers same colors; contains swelling clays; firmly indurated, noncalcareous clay binding; stratification concealed; weathers to form slope 6.0

Total incomplete Petrified Forest Member 24.3

Total incomplete Chinle Formation 24.3

Moenkopi (?) Formation:

8. Siltstone to sandy siltstone, pale-red (5*R* 6/2) to grayish-red (5*R* 4/2); weathers same colors; grades from medium siltstone to very fine grained sandy siltstone, at

NM16. RILEY—Continued

	Feet
Moenkopi(?) Formation—Continued	
places near base sandy siltstone grades to very fine grained sandstone, siltstone commonly contains scattered very fine to medium grains; firmly cemented, calcareous; structureless, 10 percent of unit is horizontally laminated; weathers to form slope. Conglomerate, which is similar to that in unit 7, is present from 11.0 to 11.8 ft. Top 4 ft of unit is grayish red (5*R* 4/2) but contains more purple than rest of unit	51.7
7. Conglomerate, pale-red (5*R* 6/2); weathers same color; composed of coarse sand grains to pebbles of reddish-brown siltstone and minor gray limy siltstone to limestone. The coarse grains to pebbles are in a matrix of very fine grained sand and silt. Pebbles are as large as 2 in. in maximum diameter. Conglomerate is firmly cemented, calcareous; horizontally laminated to very thin bedded, possibly some very low angle cross-strata; weathers to form ledge	11.0
6. Siltstone, similar to unit 4. A ledge is present from 15.9 to 18.9 ft above base of unit. This ledge is composed of pale-red (5*R* 6/2) to grayish-red (5*R* 4/2) siltstone to very fine grained sandstone. Unit from 4 to 7 ft and from 19 to 21 ft above base contains abundant limestone nodules as large as 2 in. in maximum diameter. At 7 ft above base of unit, limestone nodules coalesce to form an irregular porous mass of limestone	29.6
5. Sandstone to conglomeratic sandstone, light-brownish-gray (5*YR* 6/1), pale-red (5*R* 6/2), and very light gray (*N*8); weathers light brownish gray (5*YR* 6/1); fine to medium grained, fair sorted; composed of subangular clear and reddish-brown-stained quartz and black mineral (10 percent); well cemented, calcareous; composed of thin to thick planar sets of small- to medium-scale low-angle cross-laminae; weathers to form ledge. Conglomeratic sandstone is confined to basal 2 ft although a few granules and pebbles are present in rest of unit. Conglomeratic sandstone contains granules and pebbles of quartz, quartzite, and chert. Largest pebble seen was 1¾ in. in maximum diameter	10.6
4. Siltstone, grayish-red (10*R* 4/2); common light-greenish-gray (5*GY* 8/1) color bands; weathers same colors; sandy (very fine grained) in places; firmly to well cemented, calcareous; structureless, possibly some horizontal laminae; weathers to form slope	28.5
3. Siltstone (70 percent) and silty sandstone to sandstone (30 percent). Siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2 and 5*R* 4/2); weathers same colors; common fine- to coarse-grained accessory white and dark mica; firmly cemented, calcareous; structureless. Silty sandstone to sandstone, grayish-red (5*R* 4/2), pale-red (5*R* 6/2), and minor very pale orange (10*YR* 8/2); weathers same colors; all lithologic types from silty, very fine grained sandstone to medium-grained sandstone, fair sorted, coarser sandstone composed of subangular clear quartz and sparse black accessory mineral; firmly to well cemented, calcareous; ripple laminated (cuspate type) and thin trough and planar sets of low-angle small- to medium-scale cross-laminae in thin to very thick sets interstratified with siltstone. Unit as a whole weathers to form slope and small ledges on the silty sandstone to sandstone parts of unit	29.5
Total Moenkopi(?) Formation	160.9
San Andres Limestone (incomplete):	
2. Gypsum (70 percent) and siltstone (30 percent). Gypsum, white (*N*9); weathers white (*N*9), yellowish gray (5*Y* 7/2) and pinkish gray (5*YR* 8/1); fine to medium crystalline; firmly to well indurated; structureless. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; firmly indurated, noncalcareous, gypsiferous in places; stratification mostly concealed, but where seen it is thin to thick horizontal beds or sets interstratified with gypsum. This unit is provisionally placed in the San Andres Limestone. The siltstone resembles that seen in the overlying Moenkopi Formation	16.0
1. Limestone (30 percent) and gypsum (70 percent). Limestone, dark-gray (*N*3) to light-gray (*N*7), and minor light-olive-gray (5*Y*6/1); weathers same colors, but dominantly light gray (*N*7); dense to very finely crystalline; well indurated. Limestone highly fractured but is probably thin to thick horizontal beds interstratified with gypsum. Gypsum, white (*N*9), recrystallized at surface to porous, very fine to fine crystalline mass, original lithology is indeterminable. Unit as a whole weathers to form hills and gullies, and limestone beds form minor ridges. Only top 30 ft of unit examined. Unit is probably at least 100 ft thick. Unmeasured.	
Total incomplete San Andres Limestone	16.0

Base of section; not base of exposure. Base of section is S. 81°E. of La Jara, and approximately N. 55°E. of Riley.

NM17. SEVILLETA GRANT

[Measured, by J. H. Stewart and R. F. Wilson, June 1956, in southeastern part of Sevilleta Grant, 16 miles northeast of Socorro, south-central part of sec. 10 (unsurveyed), T. 1 S., R. 2 E., NMPM. Socorro County]

Top of section; top of exposure.

Chinle Formation (incomplete):

Petrified Forest Member (incomplete): *Feet*

15. (Unmeasured.) Probably 200 ft of the Chinle Formation is exposed above unit 14, but strata are highly contorted by many small faults and, therefore, thicknesses cannot be measured. Most of this 200 ft is composed of purplish-red, greenish-gray, and reddish-brown silty claystone containing swelling clays. One reddish-brown thin horizontally laminated set of siltstone and one thick set of conglomerate are present. The conglomerate contains granules and pebbles of gray chert and gray siltstone and limestone.
14. Sandstone, yellowish-gray (5*Y* 8/1); weathers same color; fine grained, well sorted; composed of subangular to subrounded clear quartz and sparse black accessory mineral and accessory white mica; firmly to well cemented, calcareous; composed of thin to thick trough and planar sets of low-angle small- to medium-scale cross-laminae; weathers to form vertical cliff. Unit is prominent light-colored cliff in Chinle Formation. Basal 2 ft of unit is siltstone pebble conglomerate. Thickness of unit estimated. This unit is lithologically similar to the Sonsela Sandstone Bed but is not in exactly the same stratigraphic position ±40
13. Silty claystone, grayish-red-purple (5*RP* 4/2), medium-light-gray (*N*6), minor grayish-blue (5*PB* 5/2) and light-greenish-gray (5*GY* 8/1), grayish-red (10*R* 4/2) from 3 to 30 ft below top of unit, greenish-gray (5*GY* 6/1) and dusky-yellow (5*Y* 6/4) in top 3 ft; weathers same colors; composed of swelling clays; firmly cemented, noncalcareous, structureless; weathers to form frothy-surfaced slope. Unit contains a few horizons of limestone nodules 117.6
12. Clayey siltstone to silty claystone (85 percent) and silty limestone (15 percent). Clayey siltstone to silty claystone, light-gray (*N*7) to light-greenish-gray (5*GY* 8/1); weathers same colors; possibly contains some swelling clay; firmly cemented, calcareous; horizontally laminated to thin bedded. Silty limestone, light-greenish-gray (5*GY* 8/1) to greenish-gray (5*GY* 6/1); weathers same colors and moderate yellowish brown (10*YR* 5/4); dense; well cemented; very thin to thin horizontal beds interstratified with rest of unit. Unit as a whole weathers to form small ridge with conspicuous greenish-gray color along exposure. Unit contains two thin well-cemented siltstone beds. One is 6 ft below top of unit and the other is at top of unit. Lower siltstone is medium light gray (*N*6) and greenish gray (5*GY* 6/1), and upper siltstone is greenish gray (5*GY* 6/1) 30.9
11. Silty claystone, grayish-red-purple (5*RP* 4/2) and medium-light-gray (*N*6); weathers same colors; composed of swelling clays; firmly cemented, calcareous in parts; structureless; weathers to form frothy-surfaced slope. Unit contains poorly exposed layer containing light-gray (*N*7) limestone nodules in top third of unit 13.7
10. Limestone and clayey siltstone. Limestone is present as 1-ft-thick bed at base of unit and 0.8-ft-thick bed at top of unit. Basal limestone is dusky yellow (5*Y* 6/4) and grayish olive (10*Y* 4/2); top limestone is medium light gray (*N*6) to light olive gray (5*Y* 6/1); both limestone beds weather dark yellowish brown (10*YR* 4/2), and are dense, well cemented, and occur as horizontal thin beds. Clayey siltstone, pale-yellowish-orange (10*YR* 8/6) to grayish yellow (5*Y* 8/4); weathers same colors; firmly cemented, calcareous; stratification concealed; unit as a whole weathers to form slope with ledges formed on limestone beds at top and bottom of unit 12.0
9. Silty claystone, medium-gray (*N*5) to greenish-gray (5*GY* 6/1), sparse dark-yellowish-orange (10*YR* 6/6) mottling in top 10 ft; weathers same colors in lower half of unit and moderate yellowish brown (10*YR* 5/4) in top half; composed of swelling clays; firmly cemented, noncalcareous, structureless; weathers to form frothy-surfaced slope. Unit very poorly exposed in top 10 ft. Unit contains a thin bed or vein of clear crystalline gypsum in top 3 ft and is seen as float in upper part of unit 29.4
8. Limestone, light-olive-gray (5*Y* 6/1); weathers moderate yellowish brown (10*YR* 5/4); dense; well cemented; unit is horizontal bed; weathers to form ledge. Unit is highly fractured 2.5
7. Silty claystone to clayey siltstone, grayish-purple (5*P* 4/2), sparse dark-yellowish-orange (10*YR* 6/6) mottling; weathers same colors; contains swelling clays; firmly cemented, noncalcareous, clay binding; structureless; weathers to form steep slope. Unit is poorly exposed in some parts. Top 18 ft of unit is poorly exposed but is probably composed mostly of light-greenish-gray (5*GY* 8/1) and grayish-yellow (5*Y* 8/4) silty claystone 36.3
6. Covered, weathers to form slope 15.0

Total incomplete Petrified Forest Member ±297.4

Total incomplete Chinle Formation ±297.4

NM17. SEVILLETA GRANT—Continued

Moenkopi Formation(?): *Feet*

5. Siltstone to sandy siltstone, grayish-red (5*R* 4/2); weathers same color; sandy (very fine grained) in parts; sparse fine-grained accessory white and dark-green mica; firmly cemented, calcareous; mostly structureless, some ripple-laminated to horizontally laminated sets; weathers to form slope. Unit contains common pale-red and light-greenish-gray limestone nodules 10.5
4. Sandstone (90 percent) and silty sandstone (10 percent). Sandstone, pale-red (5*R* 6/2) and minor light-greenish-gray (5*GY* 8/1); weathers same colors; fine to medium grained, sparse coarse-grained parts, fair sorted; composed of subangular clear and reddish-brown-stained quartz and about 10 percent black mineral and about 5 percent greenish-gray mineral (possibly greenish-gray-stained quartz); firmly to well cemented, calcareous; composed of thin to thick trough and planar sets of low-angle small- to medium-scale cross-laminae, some very low angle cross-laminae, and possibly some horizontal laminae to thin beds. Silty sandstone, grayish-red (5*R* 4/2 and 10*R* 4/2); weathers same colors; silty very fine grained sandstone with sparse fine to medium grains; composition concealed; firmly cemented, calcareous; horizontally laminated with possibly some structureless parts; thin sets interstratified with sandstone. Unit as a whole weathers to form ledge. Unit contains several thin lenses of pebbly sandstone containing granules and pebbles of reddish-brown siltstone, gray limestone(?), and gray and white chert .. 44.1
3. Siltstone to sandy siltstone (90 percent) and sandstone (10 percent). Siltstone to sandy siltstone, grayish-red (10*R* 4/2); weathers same color; sandy (very fine grained) in parts; contains common fine- to medium-grained accessory white mica; firmly cemented, calcareous; structureless and some horizontally laminated parts. Sandstone, pale-red (5*R* 6/2) and minor light-greenish-gray (5*GY* 8/1); weathers same colors; very fine grained, fair sorted; composed of subangular clear quartz and about 5 percent medium- to coarse-grained dark-green mica; firmly to well cemented, calcareous; ripple laminated (cuspate type) and horizontal laminae to thin beds. Sandstone occurs as thin sets interstratified with rest of unit. A few thin beds of sandstone occur in upper half of unit. This sandstone is composed of medium grains to granules of tan limestone(?) in a very fine grained sand matrix. Unit as a whole weathers to form slope. Small ledges occur in the sandstone parts of the unit 46.6

Total Moenkopi(?) Formation 101.2

NM17. SEVILLETA GRANT—Continued

San Andres Limestone (incomplete):

Upper member: *Feet*

2. Sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; coarse siltstone, sandy (very fine grained); common very fine grained accessory white mica; well cemented, calcareous; structureless, possibly some horizontal laminae to thin beds; weathers to form slope. Unit is greenish gray (5*GY* 6/1) in basal 3 ft. Unit contains a thin bed of sandstone about 6 ft above base of unit. Sandstone is very pale orange (10*YR* 8/2), very fine to fine grained, composed of clear quartz and sparse black accessory mineral. Sandstone contains abundant scattered medium to very coarse rounded quartz grains 24.5

Total upper member 24.5

Limestone member (unmeasured):

1. Limestone, yellowish-gray (5*Y* 8/1), white (*N*9), and very pale orange (10*YR* 8/2); weathers very pale orange (10*YR* 8/2); dense to coarsely crystalline; well indurated; horizontally laminated to thick bedded; highest beds of unit weather to form a hogback.

Total incomplete San Andres Limestone . 24.5

Base of section; not base of exposure.

NM20. MESA GALLINA

[Measured, by J. H. Stewart and R. F. Wilson, May 1956, on southeast side of Mesa Gallina, east-central part of sec. 10, T. 5 N., R. 4 W., NMPM. Valencia County]

Top of section; top of exposure. *Feet*

16. Covered; slump blocks of basalt.

Chinle Formation (incomplete):

15. Clayey siltstone to silty claystone, grayish-purple (5*P* 4/2), grayish-red-purple (5*RP* 4/2) medium-gray (*N*5), common light-greenish-gray (5*GY* 8/1) mottling; weathers same colors; contains swelling clays; firmly indurated, slightly calcareous clay binding; stratification concealed; weathers to form frothy-surfaced, partly covered slope .... 20+

Mottled strata:

14. Sandstone (70 percent) to conglomeratic sandstone (30 percent), pinkish-gray (5*YR* 8/1), grayish-red (10*R* 4/2), and minor grayish-purple (5*P* 4/2); weathers same colors; very fine to medium grained, silty in parts, fair to poorly sorted, composed of subangular clear quartz and about 20 percent orange mineral (chert?); well cemented, noncalcareous; structureless; weathers to form small ledge. Conglomeratic sandstone contains granules and some pebbles. Pebbles are as large as ½ in. in maximum diameter. Granules and pebbles are composed of red or orange chert(?) and some white or orange quartz 4.0

NM20. MESA GALLINA—Continued

Chinle Formation—Continued

Mottled strata—Continued *Feet*

13. Siltstone to Sandy siltstone, mottled grayish-red (10*R* 4/2) and light-greenish-gray (5*GY* 8/1); abundant grayish-purple (5*P* 4/2) mottling in some parts of unit; grades from siltstone containing a few scattered very fine grains to granules to a sandy siltstone containing about 30 percent fine to medium grains; grains appear to be mostly subangular clear quartz and orange chert(?); well indurated, noncalcareous; structureless; weathers to form steep slope. Unit contains a few (5 percent) thin lenses of silty sandstone similar to that in overlying unit. The lowest of these lenses is 10 ft above base of unit ---------- 20.9

Total mottled strata ---------- 24.9

Total incomplete Chinle Formation --- 44.9+

Moenkopi(?) Formation:

NOTE.—Contact between Chinle Formation and Moenkopi(?) Formation placed at color change from dominantly reddish-brown siltstone below to mottled purple, white, and red siltstone above. This contact also marks a change from siltstone below that contains no sand grains to siltstone above that contains numerous disseminated very fine grains to granules. Basal unit of Chinle also contains some lenses of sandstone and conglomerate. Exact position of contact may be in error as much as 3 ft because of poor exposure and because of only minor differences in rock types above and below contact.

12. Siltstone, similar to siltstone in unit 3. Weathers to form steep slope. Top 3 ft of unit contains a few thin bands that are mottled grayish purple (5*P* 4/2) and light greenish gray (5*GY* 8/1) ---------- 54.0
11. Siltstone to sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; sandy (very fine grained) in parts; abundant very fine grained accessory white mica; horizontally laminated, possibly some ripple laminae; weathers to form gentle slope. Unit is poorly exposed ---------- 25.1
10. Conglomerate, pale-red (10*R* 6/2) and pale-reddish-brown (10*R* 5/4); weathers grayish red (5*R* 4/2); composed of coarse grains to pebbles of reddish-brown siltstone and of minor amounts of gray limy siltstone or silty limestone in a fine to medium sand matrix; well cemented, calcareous; horizontally very thin to thin bedded, minor low-angle small-scale cross-laminae; weathers to form ledge. A few bone fragments are present. A few parts of the unit are fine- to medium-grained sandstone ---------- 3.4

NM20. MESA GALLINA—Continued

Moenkopi(?) Formation—Continued *Feet*

9. Poorly exposed, probably mostly siltstone similar to that in unit 3. Weathers to form gentle slope ---------- 5.0
8. Sandstone, pale-red (5*R* 6/2) to grayish-red (5*R* 4/2); weathers grayish red (5*R* 4/2); fine grained; possibly medium grained in parts, silty in parts, fair sorted; composition concealed; composed of thin to thick tabular planar and, to a lesser extent, of trough sets of small low-angle cross-laminae; weathers to form ledge. Unit does not appear to be persistent along outcrop. Some sets contain disseminated coarse grains to granules of reddish-brown and gray siltstone ---------- 11.0
7. Covered; probably siltstone similar to that in unit 3. Weathers to form rubble-covered slope ---------- 8.3
6. Silty sandstone, grayish-red (5*R* 4/2); weathers same color; silty, very fine grained, fair sorted; composition concealed; well cemented, calcareous; horizontally laminated to thin bedded in lower half, composed of thin trough sets of low-angle small-scale cross-laminae in upper half; weathers to form small ledge ---------- 5.2
5. Mostly covered; a few exposures lateral to line of section indicate that unit is mostly siltstone similar to that in unit 3 and that unit may also contain a few sets of sandy siltstone similar to those in unit 3. Unit weathers to form rubble-covered slope ---------- 10.0
4. Sandstone to pebbly sandstone, pale-red (5*R* 6/2); weathers grayish red (5*R* 4/2); very fine to medium grained; silty in parts, fair sorted; composition mostly concealed, sparse coarse-grained accessory dark-green mica; composed of thin to thick, lenticular trough, tabular planar, and wedge planar sets of small- to medium-scale low-angle cross-laminae; weathers to form most prominent ledge in Moenkopi(?) Formation. About 20 percent of unit is pebbly sandstone that occurs mainly in lower half of unit. Pebbly sandstone contains granules and pebbles of gray and yellowish-gray chert and, to a lesser extent, white quartz. Pebbles are as large as ¾ in. in maximum diameter. Granules and pebbles are in a sand matrix similar to the sand in rest of unit ---------- 20.6
3. Siltstone (70 percent) and sandy siltstone (30 percent). Siltstone, pale-reddish-brown (10*R* 5/4) to grayish-red (10*R* 4/2); weathers same colors; fine silt; sparse fine-grained accessory white mica; firmly cemented, calcareous; structureless. Sandy siltstone, grayish-red (5*R*

NM20. MESA GALLINA—Continued

Moenkopi (?) Formation—Continued *Feet*

4/2); weathers same color; sandy (very fine grained), sparse medium-grained accessory white mica; well cemented, calcareous; horizontally laminated to thin bedded. Sandy siltstone may grade to very fine grained sandstone in places. Sandy siltstone is present as very thin to thick sets interstratified with rest of unit. Unit as a whole weathers to form steep slope with ledges formed on sandy siltstone sets ____ 43.6

2. Limy siltstone, possibly silty limestone in places, yellowish-gray (5*Y* 7/2) and pale-greenish-yellow (10*Y* 8/2); weathers same colors; common medium-grained accessory white mica; poorly cemented, calcareous; stratification concealed; weathers to form rubble-covered slope. Parts of unit covered or poorly exposed ____ 26.0

Total Moenkopi (?) Formation ____ 212.2

San Andres Limestone (unmeasured):

Upper limestone member (unmeasured):

1. Limestone, light-olive-gray (5*Y* 6/1) and pinkish-gray (5*YR* 8/1); weathers light olive gray (5*Y* 6/1); dense to very finely crystalline; sparse medium-crystalline parts; well indurated; horizontally very thin to thick bedded; weathers in places to form a steep ledgy slope and in other places, a vertical cliff.

Base of section; not base of exposure. Base of section N. 50° W. from Oxsheer Ranch, N. 26° W. from Ladron Peak, and N. 10° W. from Yriart Ranch.

UTAH

U2. BLOCK MOUNTAIN

[Measured, by J. H. Stewart and C. H. Scott, July 1953. Lower part measured to about 1,000 ft east of main road about 6 miles northeast of Tan Seep on west side of the San Rafael Swell, sec. 29 (unsurveyed), T. 23 S., R. 11 E., SLM, long 110°42′25″ W., lat 38°47′15″ N.; upper part measured to prominent mesa to the northwest, secs. 19, 29, 30 (unsurveyed), T. 23 S., R. 11. E., SLM, long 110°44′10″ W., lat 38°48′00″ N. Emery County]

Top of section; not top of exposure.

Chinle Formation (unmeasured):

11. Sandy siltstone to sandstone, light-gray (*N*7); weathers same color, silty with minor medium to very coarse grains to medium and coarse grained with minor silt; sand grains poorly sorted; rounded to well rounded, composed of clear to milky quartz with abundant gray accessory minerals; poorly cemented, calcareous; stratification poorly defined, but unit contains abundant horizontal laminae; flaggy to blocky splitting; weathers to form ledge.

Unconformity. Abrupt change in lithology; scours into underlying Moenkopi as much as 4 in. deep.

U2. BLOCK MOUNTAIN—Continued

Moenkopi Formation:

NOTE.—The cliff-forming member either (1) has been removed from the area by pre-Chinle erosion or (2) is indistinguishable from the upper slope-forming member.

Upper slope-forming member: *Feet*

10. Clayey siltstone (80 percent) and siltstone (20 percent), grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); common fine-grained accessory white mica; firmly cemented, calcareous; stratification mostly concealed, but probably mainly horizontally laminated; splitting concealed; weathers to form steep slope with minor ledges in the siltstone. Siltstone occurs as thin to thick horizontal sets interbedded with clayey siltstone. Sparse (3 percent) grayish-orange (10*YR* 7/4) and very pale orange (10*YR* 8/2), very thin beds of siltstone throughout unit. Unit from 157.5 to 162.4 ft above base is light olive gray and contains copper stain and an unknown material forming ½- to 1-mm-diameter black spots. Unit from 162.4 to 166.7 ft above base is light greenish gray (5*GY* 8/1) ____ 166.7

Total upper slope-forming member ____ 166.7

Ledge-forming member:

9. Siltstone (80 percent) and sandy siltstone (20 percent). Siltstone is grayish red (10*R* 4/2), pale reddish brown (10*R* 5/4) and uncommon greenish gray (5*GY* 6/1) and grayish yellow (5*Y* 7/4); weathers pale reddish brown (10*R* 5/4), sparse grayish yellow (5*Y* 8/4); abundant fine-grained accessory white mica; poorly to firmly cemented, calcareous; horizontally laminated and thinly laminated, minor ripple laminae; papery to platy splitting. Sandy siltstone is pale reddish brown (10*R* 5/4), pale red (10*R* 6/2), and grayish orange (10*R* 7/4); weathers pale reddish brown (10*R* 5/4) and grayish orange (10*YR* 7/4); sandy (very fine grained), some parts grade to very fine grained sandstone; well cemented, calcareous; ripple laminated, minor thin trough sets of medium-scale low-angle cross-laminae in sandy siltstone. Sandy siltstone set from 59.9 to 62.2 ft has platy to slabby splitting. Sandy siltstone occurs as thin to very thick sets interbedded with siltstone. Some sets as thick as 10 ft. Unit from 89.8 to 124.6 ft consists of about 50 percent sandy siltstone that is olive gray (5*Y* 4/1) and petroliferous; remainder of this interval is entirely greenish gray (5*GY* 6/1) siltstone. Unit as a whole is tabular and weathers to form slope with many ledges ____ 163.4

U2. BLOCK MOUNTAIN—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

8. Sandstone, olive-gray (5*Y* 4/1) and minor light-olive-gray (5*Y* 6/1) and yellowish-gray (5*Y* 8/1); weathers yellowish gray (5*Y* 7/2); very fine grained; firmly cemented, slightly calcareous; petroliferous; lower two-thirds of unit composed of poorly formed sets of medium-scale low-angle cross-laminae. Upper one-third of unit is ripple laminated, has flaggy to massive splitting, and weathers to form most conspicuous light-colored ledge in Moenkopi ---- 24.5
7. Siltstone (50 percent) and sandy siltstone (50 percent). Siltstone is yellowish gray (5*Y* 8/1), greenish gray (5*GY* 6/1), and light greenish gray (5*G* 8/1); weathers pale greenish yellow (10*Y* 8/2); common fine-grained accessory white mica; noncalcareous; horizontally thinly laminated and ripple laminated; papery to platy splitting. Sandy siltstone is light olive gray (5*Y* 6/1), olive gray (5*Y* 4/1), and pale yellowish orange (10*YR* 8/6), sandy (very fine grained), some parts grade to very fine grained sandstone, commonly limy; well cemented, calcareous; highly petroliferous; horizontally and ripple laminated; platy to massive splitting. Sandy siltstone occurs as thin to very thin sets interbedded with siltstone. Unit weathers to form gentle slope in lower part and steep slope in upper part. Unit forms conspicuous light-colored interval above Sinbad Limestone Member ---- 72.0

Total ledge-forming member ---- 259.9

Sinbad Limestone Member:

6. Limestone (50 percent) and siltstone (50 percent). Limestone is light olive gray (5*Y* 6/1); weathers grayish orange (10*YR* 7/4); otherwise similar to limestone in unit below. Siltstone is grayish yellow (5*Y* 8/4) and greenish gray (5*GY* 6/1), clayey in parts; uncommon fine-grained accessory white mica; firmly cemented, slightly calcareous; horizontally and ripple laminated; papery to platy splitting. Unit as a whole weathers to form part of bench ---- 9.2
5. Limestone, pale-yellowish-orange (10*YR* 8/6), yellowish-gray (5*Y* 7/2), and minor light-olive-gray (5*Y* 6/1); weathers grayish yellow (5*Y* 8/4); aphanitic to very fine grained granular; well cemented; tabular unit of horizontal laminae, thin trough to planar sets of low-angle small-scale cross-laminae and sparse ripple laminae; slabby to blocky splitting; weathers to form steep slope with vertical cliff in lower half and prominent bench in upper half. Unit from 34.6 to 39.3 ft forms vertical cliff along line of section. About 50 percent of unit covered; some covered intervals may contain siltstone similar to unit 4 ---- 52.0

Total Sinbad Limestone Member ---- 61.2

NOTE.—Section transferred so that unit 5 measured 1 mile northwest of unit 4. Transfer on base of Sinbad Limestone Member of Moenkopi Formation; base of Sinbad Limestone Member was traced along discontinuous exposures. The transfer may have caused a loss or gain of as much as 15 ft in thickness of formation.

Lower slope-forming member:

4. Siltstone, grayish-yellow (5*Y* 8/4) and minor dusty-yellow (5*Y* 6/4); weathers grayish yellow (5*Y* 8/4); abundant very fine grained accessory white mica; well cemented, slightly calcareous; tabular unit of horizontal and thin ripple laminae; platy to flaggy splitting; weathers to form steep slope. Ripple marks average about 1 in. in wavelength. Thin set of limestone, similar to limestone in unit below, occurs 13 ft above base of unit ---- 42.2
3. Siltstone (70 percent) and limestone (30 percent). Siltstone is yellowish gray (5*Y* 8/1), minor grayish yellow (5*Y* 8/4) and light greenish gray (5*GY* 8/1); weathers yellowish gray (5*Y* 8/1) and, on outcrops to west, white (*N*9); firmly cemented, noncalcareous; stratification concealed, papery splitting in part. Siltstone very poorly exposed and includes much claystone. Limestone is light olive gray (5*Y* 6/1); weathers yellowish gray (5*Y* 8/1); finely crystalline to very fine grained granular; well cemented; petroliferous; horizontally and ripple laminated; platy to flaggy splitting. Limestone includes unknown quantity of silt. Limestone occurs as thin sets interbedded with siltstone. Exact proportion of limestone difficult to determine because of poor exposures. Limestone seems to comprise at least 50 percent of unit near base, but proportion decreases upward. Top of unit placed at color change from whitish colors below to yellowish colors above although color change locally seems to crosscut contact. Unit weathers to form gentle slope with very minor ledges in some limestone sets ---- 68.0
2. Covered ---- 6.0

Total lower slope-forming member ---- 116.2

Total Moenkopi Formation ---- 604.0

"Kaibab Limestone" (unmeasured):

1. Limestone, light-gray (*N* 7) and minor pale-yellowish-orange (10*YR* 8/6); weathers yellowish gray (5*Y* 8/1); composed of very coarse 1–2 mm) shell fragments, aphanitic lime mud and crystals of calcite as large as

U2. BLOCK MOUNTAIN—Continued

"Kaibab Limestone"—Continued

¼ in. in diameter enclose the shell fragments, porosity about 10–20 percent; well cemented; mostly structureless with some suggestion of horizontal bedding planes, massive splitting; weathers to form ledge and prominent bench. About 15 ft of unit exposed along sides of creek. No chert seen.

Base of section; base of local exposure.

U6. MUDDY RIVER

[Measured, by J. H. Stewart, June 1953, near the Muddy River beginning at first outcrop of "Kaibab Limestone" up the river along the east side of the San Rafael Swell and continuing to southwest from the river, long 110°58'00" W., lat 38°34'30" N. Emery County]

Top of section; not top of outcrop.

Chinle Formation (incomplete):

Moss Back Member:

	Feet
17. Sandstone and conglomeratic sandstone, light-greenish-gray (5*GY* 8/1), yellowish-gray (5*Y* 8/1), light-gray (*N* 7), pale-olive (10*Y* 6/2), and minor amounts of grayish-red (10*R* 4/2); weathers light brown (5*YR* 6/4) and grayish red (10*R* 4/2); fine to medium grained; (some thick sets contain minor amounts of coarse-grained sand); fair to well-sorted. About 30 percent of unit is conglomeratic. Conglomeratic parts contain granules and pebbles that average ¼ in. in diameter and reach a maximum diameter of 2 in. Granules and pebbles are composed dominantly of light-brown-weathering siltstone and limy siltstone and to a lesser extent of gray and white quartz and white chert. Where present, granules and pebbles constitute about 30–40 percent of rock and occur in a sand matrix. Sand matrix and sandstone are composed of fine- to medium-grained (rarely coarse grained) clear quartz and uncommon black accessory minerals, sparse fine-grained white mica; firmly to well cemented, calcareous; some possible petroliferous material; some parts contain abundant interstitial clay; composed of thin to thick trough sets of low-angle, medium-scale cross-laminae, upper one-third of unit either is horizontally laminated or composed of very low angle cross laminae; platy splitting; weathers to form prominent cliff	71.2
Total Moss Back Member	71.2

Monitor Butte Member:

	Feet
16. Siltstone, grayish-red-purple (5*RP* 4/2) in lower part and moderate-red (5*R* 5/4) in upper part; weathers moderate red (5*R* 5/4) and pale red purple (5*RP* 6/2); firmly cemented, slightly calcareous; stratification concealed; weathers to form steep earthy slope. Unit from 3 to 0.7 ft below top is dusky yellow (5*Y* 6/4) and from 0.7 ft below top to top is light greenish gray (5*G* 8/1). Top 5 ft of unit contains irregular thin beds, seams, and irregular nodules of light-greenish-gray (5*GY* 8/1) and grayish-yellow (5*Y* 8/4) limestone. One thin set of ripple-laminated siltstone seen about 8 ft above base of unit	46.8
15. Sandy siltstone, light-greenish-gray (5*GY* 8/1) in lower two-thirds, grayish-red (5*R* 4/2) with irregular mottling of moderate yellow (5*Y* 7/6) in top third; weathers light greenish gray (5*GY* 8/1) and pale red (5*R* 6/2); sandy (very fine grained); common medium-grained white and dark mica; firmly cemented, slightly calcareous; stratification concealed; weathers to form steep frothy slope	4.1
14. Siltstone, grayish-red-purple (5*RP* 4/2), about 20 percent is light-greenish-gray (5*GY* 8/1) irregular spots and mottles; well cemented, noncalcareous; stratification concealed; weathers to form steep frothy slope. Common limestone nodules averaging 4 in. in diameter of light-greenish-gray (5*GY* 8/1) and pale-red-purple (5*RP* 6/2) aphanitic to very coarse grained calcite. Unit forms conspicuous band on outcrop	8.1
13. Siltstone, grayish-red (10*R* 4/2), with common yellowish-gray (5*Y* 8/1) spots and irregular mottles; weathers pale reddish brown (10*R* 5/4); common medium-grained dark-green mica; stratification concealed; weathers to form steep frothy slope	37.9
12. Sandstone to sandy siltstone and siltstone. Sandstone to sandy siltstone very pale green (10*G* 8/2), weathers same color; very fine grained sandstone to very fine grained sandy siltstone; abundant very fine grained dark-green mica; firmly cemented, slightly calcareous; thinly ripple laminated; papery splitting. Siltstone, grayish red (10*R* 4/2), weathers pale red (5*R* 6/2), abundant very fine grained white mica; firmly cemented, noncalcareous; splitting concealed. Unit as a whole weathers to ledgy slope at base of Chinle Formation. Basal Chinle in line of section and on distant cliffs is marked by light-greenish-gray band. Thickness of unit variable along outcrop	2.7
Total Monitor Butte Member	99.6
Total incomplete Chinle Formation	170.8

U6. MUDDY RIVER—Continued

Moenkopi Formation:

Cliff-forming member: *Feet*

11. Siltstone, similar to unit 10 except 33 percent of unit is ripple laminated (mostly parallel ripples); weathers to form steep ledgy slope and vertical cliff. Basal 35 ft of unit is mostly structureless siltstone and grades into underlying unit. Abundant gypsum nodules. Top 1.5 ft of unit contains abundant pale-red-purple (5*RP* 6/2) and light-greenish-gray mottling — 114.0

Total cliff-forming member — 114.0

Upper slope-forming member:

10. Siltstone, grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); abundant very fine grained white mica; firmly to well cemented, noncalcareous; thinly horizontally laminated to structureless, 10 percent ripple laminated (parallel and sparse cuspate ripples); papery to slabby splitting; weathers to form steep slope. About 5 percent of unit consists of very thin to thick beds of light-greenish-gray (5*GY* 8/1) siltstone. Unit contains abundant gypsum in seams cutting across bedding and as irregular nodules elongated along bedding planes — 161.7

Total upper slope-forming member — 161.7

Ledge-forming member:

9. Siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); abundant fine-grained white mica; firmly to well cemented, noncalcareous; stratification is mostly concealed, but where seen it is ripple and thinly laminated. Ripple marks average about 1 in. in wavelength. Unit has papery to platy splitting and weathers to form earthy slopes with minor ledges. Bottom half of unit contains about 10 percent thin to thick resistant ledges; top half contains about 5 percent resistant ledges. Unit is differentiated from units above and below by its resistant ledges. Upper half of unit contains common very thin sets of yellowish-gray (5*Y* 8/1) siltstone. Entire unit contains abundant seams of white gypsum that cut across stratification at all angles — 180.3

8. Sandy siltstone to sandstone; yellowish gray (5*Y* 7/2) in lower 8 ft and pale reddish brown (10*R* 5/4) in rest of unit; weathers pale reddish brown (10*R* 5/4) and very pale orange (10*YR* 8/2); siltstone with minor amounts of very fine sand, grades to very fine grained sandstone; very fine grained sandstone mostly in lower 8 ft; common very fine grained white mica; well cemented, slightly calcareous; lower 8 ft horizontally laminated (minor ripple laminae) mixed with thin planar and trough sets of medium-scale cross-laminae, rest of unit ripple laminated; platy to massive splitting; weathers to form prominent ledge that caps vertical cliff formed on units below. Basal strata fill scours cut as deep as about 1 ft into underlying unit — 15.4

7. Silty claystone to sandy siltstone, grayish-red (10*R* 4/2), pale-reddish-brown (10*R* 5/4), minor grayish-orange (10*YR* 7/4); weathers pale reddish brown (10*R* 5/4); silty clay to silt with minor very fine grained sandstone; abundant very fine white mica; firmly to well cemented, slightly calcareous; tabular unit of horizontal thin laminae and minor ripple laminae. Ripple laminae average about 1 in. in wavelength. Unit contains sparse thin trough sets of low-angle, small-scale cross-laminae. Unit has platy to massive splitting and weathers to form steep slope with abundant vertical ledges and cliffs. Unit contains about 40 percent slabby- to massive-splitting, well-cemented, thin to very thick sets that weather to form prominent ledges and cliffs. These resistant sets are generally sandy and commonly grayish orange. Bottom 6 ft of unit is grayish yellow (5*Y* 8/4). Abundant very thin vertical and horizontal seams of white gypsum. Section measured across fault with displacement of about 3 ft — 133.9

Total ledge-forming member — 329.6

NOTE.—Section offset on top of unit 6, so that overlying units measured ½ mile S. 70° W.

Sinbad Limestone Member:

6. Limestone and siltstone, similar to unit 5. Proportion of limestone and siltstone cannot be determined because of very poor exposures. Weathers to form slope above prominent capping ledge — 6.4

5. Limestone (85 percent) and siltstone (15 percent). Dominantly grayish orange (10 *YR* 7/4), minor yellowish gray (5*Y* 7/2), pale yellowish orange (10*YR* 8/6) and olive gray (5*Y* 4/1); weathers grayish orange (10*YR* 7/4); composed of very fine to coarse oolites and aphanitic calcite; well-cemented; dominantly horizontally thinly laminated and laminated, minor thin trough sets of small-scale low-angle cross-laminae, medium-scale high-angle cross-laminae, and ripple laminae; platy to slabby splitting. Siltstone, pale-olive (10*Y* 4/2), greenish-gray (5*GY* 6/1), minor pale-red (10*R* 6/2); weathers same colors; abundant very fine grained white mica; firmly cemented, noncalcareous; hori-

U6. MUDDY RIVER—Continued

Moenkopi Formation—Continued

Sinbad Limestone Member—Continued *Feet*

zontally laminated; platy to flaggy splitting. Siltstone occurs as very thin to thick sets interbedded with limestone throughout unit. Unit as a whole is tabular and weathers to form ledgy light-colored cliff 79.7

Total Sinbad Limestone Member 86.1

Lower slope-forming member:

4. Limy siltstone, light-brown (5*YR* 6/4), grayish-orange (10*YR* 7/4) and minor grayish-red (10*R* 4/2; weathers grayish red (10*R* 4/2) and grayish orange (10*R* 7/4); abundant very fine grained mica; firmly to well cemented, calcareous; horizontally and ripple laminated; flaggy to slabby splitting; weathers to form steep slopes and cliffs 34.4
3. Limy siltstone and limestone. Limy siltstone is grayish orange (10*YR* 7/4), sparse dusky yellow (5*Y* 6/4); weathers grayish orange (10*YR* 7/4); abundant fine-grained mica; firmly to well cemented; calcareous; sparse sandy (very fine grained) sets; ripple and horizontally laminated; platy to slabby splitting. Limestone is olive gray (5*Y* 4/1); weathers grayish orange (10*YR* 7/4); finely to very coarsely crystalline; well cemented; ripple and horizontally laminated; flaggy to slabby splitting. Limestone sets interbedded with limy siltstone sets in lower 20 ft of unit; limestone beds are petroliferous. Unit as a whole is tabular and weathers to form cliffs and steep earthy slopes 91.1

Total lower slope-forming member 125.5

Conglomeratic sandstone unit:

2. Conglomeratic sandstone (80 percent) and limestone (20 percent). Conglomeratic sandstone is medium light gray (*N*6); weathers light olive gray (5*Y* 6/1); coarse grained, fair sorted; composed of about 20 percent subangular to subrounded granules and pebbles of gray and white chert, 50 percent subrounded milky mineral and clear quartz grains; granules, pebbles, and grains all in medium to very coarsely crystalline calcite matrix, calcite matrix probably 30 percent of rock; well cemented; abundant petroliferous material; tabular unit of very thin to thick beds; flaggy to slabby splitting. Limestone is very light gray (*N*8) and light greenish gray (5*GY* 8/1); weathers light olive gray (5*Y* 6/1); aphanitic; well cemented; very thin bedded; flaggy splitting. Unit as a whole is tabular and grades into overlying unit. Weathers to form ledgy cliff. Basal 0.5 ft is pale-green (5*G* 7/2) claystone 4.1

Total conglomeratic sandstone unit 4.1

Total Moenkopi Formation 821.0

"Kaibab Limestone" (unmeasured):

1. Dolomitic limestone, grayish-yellow (5*Y* 8/4), yellowish-gray (5*Y* 8/1), and light-gray (*N*7); weathers very light gray (*N*6); aphanitic; well cemented; very thick to thick bedded; massive splitting; weathers to form cliff at edge of river. Contains green fragments (apatite?) and molds of sponge spicules(?). Light-gray parts may be petroliferous. Top 3 ft contains about 10 percent white and very light gray irregular chert nodules as large as 6 in. in diameter. Sparse light-red (5*R* 6/6) areas, about 1 ft in diameter, contain pyrite nodules.

Base of section; base of exposure.

U7. STRAIGHT WASH

[Measured, by J. H. Stewart and A. C. Gorveatt, July 1953, along south side of Straight Wash and up cliff on east side of San Rafael Swell; sec. 29, T. 23 S., R. 13 E., SLM. Emery County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Moss Back Member: *Feet*

(Note: units 15–20 are provisionally assigned to the Moss Back Member, but they may be Monitor Butte Member.)

23. Sandstone, poorly exposed but where seen it is similar to sandstone of unit 21 .... 4.7
22. Sandstone, pale-yellowish-brown (10*YR* 6/2); weathers same color; medium to coarse grained, well sorted; composed of subangular to subrounded clear quartz and sparse gray accessory mineral; poorly cemented, highly calcareous; composed of thick planar sets of medium-scale cross-laminae; flaggy splitting; weathers to form small ledge back from vertical cliff of underlying unit. Unit contains sparse granules and pebbles as large as ½ in. in maximum diameter 7.0
21. Sandstone, light-olive-gray (5*Y* 6/1), yellowish-gray (5*Y* 8/1), and light-gray (*N*7); weathers yellowish gray (5*Y* 8/1); fine to medium grained, well sorted: composed of subrounded to rounded clear quartz, sparse accessory fine-grained white mica, poorly to firmly cemented, calcareous; composed of thick planar and subordinate trough sets of low-angle medium-scale cross-laminae, possibly some horizontal laminae; weathers to form most conspicuous cliff in Chinle Formation. Unit contains a vary-

U7. STRAIGHT WASH—Continued

Chinle Formation—Continued

Moss Back Member—Continued *Feet*

ing proportion (probably from a few percent to as much as 20 percent) of conglomeratic sandstone. Conglomeratic sandstone is generally fine to very coarse grained and contains minor amounts of granules and pebbles. The granules and pebbles are composed of gray quartzite, quartz, and limestone and to a lesser extent of light-brown limestone and white quartz granules and pebbles. Granules and pebbles are in a matrix of subangular to subrounded clear quartz grains. Conglomeratic sandstone generally occurs in lower 10 ft of unit, but also occurs rarely as thin sets in rest of unit. Pebbles reach a maximum diameter of 2 in.; all gradations are found from conglomeratic sandstone to sandstone ---------- 41.7

20. Siltstone, greenish-gray (5*GY* 6/1) and pale-olive (10*Y* 6/2); weathers light greenish gray (5*GY* 8/1); firmly cemented, noncalcareous; possibly some horizontal bedding; one example of deformed bedding seen about 100 ft southwest of line of section. Deformed bedding consists of siltstone and sandstone dipping at high angles to regional dip. About 10 ft of beds is deformed. Unit contains one thin set of very fine grained ripple-laminated sandstone about 5 ft above base of unit. This sandstone is similar to that in the deformed beds----- 14.2

19. Sandstone, yellowish-gray (5*Y* 8/1), very light gray (*N*8) and pale-yellowish-brown (10*YR* 6/2); weathers pale yellowish brown (10*YR* 6/2); very fine grained, well sorted; composed of subangular to subrounded clear and milky quartz and uncommon black accessory mineral; abundant limonite spots; well cemented, highly calcareous, intergranular spaces are completely filled with calcite(?); composed of thin trough sets of small- to medium-scale low-angle cross-laminae; weathers to form small ledge ---------- 13.3

18. Very poorly exposed. Partial outcrops indicate that most of unit is siltstone. Siltstone, greenish-gray (5*GY* 6/1); weathers light greenish gray (5*GY* 8/1); firmly cemented, calcareous; stratification concealed; papery splitting. Partial exposure in middle of unit reveals a thin set of very fine grained micaceous ripple-laminated sandstone ---------- 7.2

17. Sandstone, very light gray (*N*8) with abundant light-brown (5*YR* 5/6) spots; weathers pale yellowish brown (10*YR* 6/2); fine grained; well sorted; composed of subrounded clear quartz and sparse black accessory mineral; abundant light-brown limonite spots, well cemented, highly calcareous, intergranular spaces completely filled with calcite(?); composed of thin trough sets of small- to medium-scale cross-laminae; weathers as upper part of prominent ledge contiguous with unit below---- 9.1

16. Sandstone, light-greenish-gray (5*GY* 8/1), yellowish-gray (5*Y* 8/1), and white (*N*9); weathers brownish gray (5*YR* 4/1); medium grained, except contains about 10 percent scattered coarse to very coarse grains and less than 1 percent granules, fair sorted; composed of subangular to subrounded clear quartz, abundant limonite spots; well cemented, highly calcareous, all intergranular spaces filled with calcite(?); composed of thin trough sets of low-angle medium-scale cross-laminae; weathers to form conspicuous ledge at base of Chinle---------- 9.3

15. Siltstone to sandstone, grayish-yellow (5*Y* 8/4) and dark-yellowish-orange (10*YR* 6/6); weathers same colors; color probably from abundant limonite; siltstone to coarse-grained sandstone with minor silt, medium and coarse sand grains are subangular to subrounded clear quartz and abundant gray accessory mineral; firmly cemented, probably with limonite binding; stratification concealed; weathers to form slight reentrant---------- 2.6

Total Moss Back Member---------- 109.1

Total incomplete Chinle Formation---- 109.1

Moenkopi Formation:

Upper slope-forming member:

(Note: The cliff-forming member either (1) has been removed by pre-Chinle erosion or (2) is indistinguishable from the upper slope-forming member.)

14. Siltstone, yellowish-gray (5*Y* 7/2) and grayish-yellow (5*Y* 7/4); weathers grayish yellow (5*Y* 7/4); firmly to well cemented, calcareous; horizontally and ripple laminated; weathers to form overhanging ledge below cliff of Moss Back Member. Basal 0.5 ft of unit is composed of dark-yellowish-orange (10*YR* 6/6) and light-brown (5*YR* 5/6) powdery siltstone mixed with siltstone similar to that in rest of unit. Unit contains 2 percent cubes and spheres of limonite(?) pseudomorphic after pyrite ---------- 10.7

13. Siltstone, pale-olive (10*Y* 6/2), grayish-yellow (5*Y* 7/4), and light-olive-gray (5*Y* 6/1); weathers pale yellowish orange (10*YR* 8/6); sparse very fine grained accessory white mica; firmly cemented, noncalcareous; stratification mostly concealed; 5 percent thin to thick ripple-laminated

U7. STRAIGHT WASH—Continued

Moenkopi Formation—Continued

Upper slope-forming member—Continued *Feet*

sets; weathers to form steep slope. Unit does not contain conspicuous resistant ledges that characterize unit below, and it weathers to more yellowish colors than unit below. Unit contains 2 percent brown cubes and spherical masses of limonite(?) pseudomorphic after pyrite. Top few feet of unit is light greenish gray (5*G* 8/1) and contains 2 percent small pyrite crystals 115.8

Total upper slope-forming member 126.5

Ledge-forming member:

12. Siltstone, similar to unit 10. Unit contains about 10 percent sandy siltstone, similar to that in unit 10. Sandy siltstone occurs in very thin to thin sets and forms a hogback ridge in top 4 ft of unit. Outcrops to north across Straight Wash contain a conspicuous hogback formed on strata near base of upper quarter of unit 131.6

11. Sandy siltstone, light-olive-gray (5*Y* 6/1) and light-gray (*N*7); weathers same colors; sandy (very fine grained); uncommon very fine grained accessory white mica; well cemented, calcareous; petroliferous; ripple laminated; platy splitting; weathers to form hogback 11.6

10. Siltstone, grayish-yellow (5*Y* 7/4), light-olive-gray (5*Y* 6/1), yellowish-gray (5*Y* 8/1), minor light-greenish-gray (5*G* 8/1) and dusky-yellow (5*Y* 6/4); weathers grayish yellow (5*Y* 7/4) and light olive gray (5*Y* 6/1); sparsely sandy (very fine grained) parts, common fine-grained accessory white mica; firmly cemented, slightly calcareous; petroliferous; stratification poorly exposed, but probably mostly horizontally thinly laminated to laminated; papery to platy splitting; weathers to form small valleys and ridges. Unit contains common very thin and sparse thin to thick sets of ripple-laminated sandy siltstone interbedded with siltstone. This sandy siltstone is commonly highly calcareous 60.4

9. Sandstone, yellowish-gray (5*Y* 8/1) to light-olive-gray (5*Y* 6/1); weathers grayish yellow (5*Y* 7/4); very fine grained, well sorted; firmly cemented, calcareous; lenticular unit, ripple laminated; weathers to form minor hogback. Unit pinches out a few hundred feet both north and south of section 12.0

8. Siltstone, grayish-yellow (5*Y* 8/4), olive-gray (5*Y* 4/1), light-greenish-gray (5*G* 8/1), sparse light-brown (5*YR* 5/6); weathers grayish yellow (5*Y* 7/4); commonly clayey; sparse very fine grained accessory white mica; firmly cemented, noncalcareous; stratification poorly exposed, but probably mostly horizontally laminated; weathers to form steep slope. Upper 9 ft contains common very thin sets of light-olive-gray (5*Y* 6/1) horizontally laminated limestone and limy siltstone 41.2

U7. STRAIGHT WASH—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

Total ledge-forming member 256.8

Sinbad Limestone Member:

7. Limestone, medium-light-gray (*N*6) to light-gray (*N*7) and olive-gray (5*Y* 4/1); weathers light gray (*N*7); aphanitic; minor fine-grained oolites; well cemented; tabular unit of horizontal and ripple laminae and minor very thin to thin trough and possibly planar sets of low-angle cross-laminae. Limestone from 26.3 to 36.5 ft above base of unit is entirely cross-stratified. Limestone is platy to slabby splitting. Unit weathers to form most prominent hogback in exposures of Moenkopi. Poorly preserved pelecypods(?) seen at one place in middle of unit. Possibly the limestone in unit 6 coalesces with the Sinbad to the south 36.5

Total Sinbad Limestone Member 36.5

Lower slope-forming member:

6. Limestone (70 percent) and siltstone (30 percent). Limestone, light-gray (*N*7) and light-olive-gray (5*Y* 6/1); weathers very light gray (*N*8); aphanitic; well cemented; horizontally and ripple laminated, platy to flaggy splitting. Siltstone, light-olive-gray (5*Y* 6/1), grayish-orange (10*YR* 7/4) and medium-light-gray (*N*6); weathers light olive gray (5*Y* 6/1); uncommon fine-grained accessory white mica; horizontally and ripple laminated; papery to platy splitting; laminae to thin sets of siltstone are interstratified with very thin filled with calcite (?); composed of thin to thin sets of limestone. Base of unit placed at lowest limestone, but unit 5 grades into unit 6 through about 8 ft of strata. Unit as a whole weathers to form cliffs and steep slopes 31.6

5. Siltstone, grayish-yellow (5*Y* 7/4) and light-olive-gray (5*Y* 6/1); weathers grayish yellow (5*Y* 8/4); uncommon accessory white mica; firmly cemented, mostly noncalcareous, sparse calcareous parts; stratification poorly exposed, but where seen is horizontally and ripple laminated; platy splitting; weathers to form steep slope. Lower 10 ft of unit contains sparse very thin beds of light-gray (*N*7) limestone 33.6

Total lower slope-forming member 65.2

U7. STRAIGHT WASH—Continued

Moenkopi Formation—Continued

Conglomerate unit: *Feet*

4. Conglomerate, medium-light-gray (*N*6) and grayish-orange (10*YR* 7/4); weathers same colors; composed of granules and pebbles (60 percent) of gray subangular chert, coarse to very coarse grains of subangular chert and well-rounded clear quartz (15 percent) set in an aphanitic calcite matrix (25 percent); poorly sorted, firmly to well cemented; stratification poorly exposed but probably mostly very thin to thin horizontally bedded; weathers to form small ledge. Granules and pebbles average ¼ in. in diameter, but pebbles are as large as 1½ in. in diameter. Unit rarely contains pale-yellowish-orange (10*YR* 8/6) siltstone as very thin lenticular beds. Unit is placed in Moenkopi Formation because it contains abundant detrital material and some beds of siltstone — 1.8

Total conglomerate unit — 1.8

Total Moenkopi Formation — 486.8

"Kaibab Limestone":

3. Limestone, yellowish-gray (5*Y* 8/1) and light-gray (*N*7); weathers yellowish gray (5*Y* 8/1) and white (*N*9); aphanitic; firmly to well cemented, very few parts powdery and chalky; tabular unit of thin to thick horizontal beds; slabby splitting; weathers to form ledges and slopes. Uncommon gray and white chert nodules commonly have a calcite core — 46.5

2. Sandstone, medium-light-gray (*N*6) to very light gray (*N*8) and minor pale-yellowish-orange (10*YR* 8/6); weathers pale yellowish brown (10*YR* 6/2); fine to medium-grained with sparse coarse grains; well sorted; composed of subrounded to rounded clear quartz and sparse orange and gray accessory minerals; poorly to well cemented, calcareous; unit is tabular, poorly stratified, but is probably composed mostly of thin to thick horizontal beds, minor contorted bedding. Weathers to form ledge and bench. Bottom few feet locally weathers to form cliff contiguous with underlying "Coconino." Unit contains sparse, very thin irregular limestone beds and irregular thin beds containing chert nodules; highly petroliferous. Unit is provisionally placed in "Kaibab" because it contains limestone chert beds and nodules, is sharply defined at base, and bedding in it seems to resemble bedding in rest of "Kaibab." An alternative interpretation would be to place unit in the upper part of the "Coconino Sandstone" — 22.4

Total "Kaibab Limestone" — 68.9

U7. STRAIGHT WASH—Continued

"Coconino Sandstone" (unmeasured):

1. Sandstone, very pale orange (10*YR* 8/2), pale-yellowish-orange (10*YR* 8/6), grayish-orange (10*YR* 7/4), medium-dark-gray (*N*4), and olive-gray (5*Y* 4/1), fine- to medium-grained, well-sorted; composed of subrounded to rounded clear quartz and sparse gray accessory mineral; common very thick layers of sandstone in which intergranular spaces are filled with calcite. Sandstone is poorly to well cemented; calcareous; commonly petroliferous; composed of very thick trough and planar sets of large-scale cross-laminae; massive splitting; weathers to form cliff. Calcite is present as intergranular filling or spherical masses, enclosing sand grains, 1/16–1½ in. in diameter.

Base of section; base of exposure.

U8. TEMPLE MOUNTAIN

[Measured, by J. H. Stewart and C. H. Scott, July 1953, from wash 1 mile north of north Temple Mountain to middle of north side of north Temple Mountain on east side of San Rafael Swell, long 110°40'30" W., lat 38°41'40" N. Emery County]

Top of section; top of good exposure. Section ends straight downslope from small mine.

Chinle Formation:

Temple Mountain Member (unmeasured):

14. Siltstone, grayish-purple (5*P* 4/2), minor pale-pink (5*RP* 8/2) and pale-purple (5*P* 6/2) irregular mottles, spots, and irregular seams; silt with <1 percent medium to very coarse grains of quartz; well cemented, noncalcareous; stratification and splitting concealed, but some suggestion of horizontal laminae; weathers to form steep slope.

NOTE.—Contact between Chinle and Moenkopi Formations placed at conspicuous color change from purples and whites of the Chinle to reddish browns of the Moenkopi. This color break also represents a lithologic change. The Chinle above contains medium to very coarse grains of quartz whereas the Moenkopi does not.

Moenkopi Formation:

NOTE.—The cliff-forming member either (1) has been removed by pre-Chinle erosion or (2) is indistinguishable from the upper slope-forming member.

Upper slope-forming member:

13. Siltstone (90 percent) and sandy siltstone (10 percent). Siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); common fine-grained accessory white mica; firmly to well cemented, slightly calcareous; stratification poorly exposed, but where seen, commonly consists of ripple and horizontal laminae; splitting poorly exposed, but where seen is platy and flaggy. Sandy siltstone, very pale orange (10*YR* 8/2) with minor light-brown (5*YR* 6/4) and pale-reddish-brown (10*R* 5/4); weathers same colors; sandy (very fine grained); common fine-grained accessory mica; well cemented, calcareous; hori-

U8. TEMPLE MOUNTAIN—Continued

Moenkopi Formation—Continued

Upper slope-forming member—Continued — *Feet*

zontally and ripple laminated; platy to slabby splitting. Sandy siltstone occurs in thin to thick horizontal sets interbedded with siltstone. Unit as a whole is tabular and weathers to form steep slope with small ledges. Unit is differentiated from one below by its less prominent and thinner silty sandstone ledges — 226.9

Total upper slope-forming member — 226.9

Ledge-forming member:

12. Siltstone (90 percent) and sandy siltstone (10 percent). Siltstone, grayish-red (10*R* 4/2), pale-reddish-brown (10*R* 5/4) and sparse yellowish-gray (5*Y* 7/2); weathers pale reddish brown (10*R* 5/4); common very fine grained white accessory mica; firmly cemented, calcareous; horizontally and ripple laminated; platy splitting. Sandy siltstone, light-olive-gray (5*Y* 6/1) and yellowish-gray (5*Y* 7/2); weathers grayish orange (10*YR* 7/4); sandy (very fine grained); uncommon fine-grained accessory white mica; well cemented, slightly calcareous in parts; ripple laminated, minor horizontal laminae and sparse small-scale cross-laminae; platy to massive splitting. Sandy siltstone grades to silty sandstone in a few places. Silty sandstone forms minor ledges throughout unit and prominent ledges from 30.8 to 39.2 and 127.4 to 145.6 ft above base of unit. Percent of sandy siltstone in unit changes laterally — 145.6
11. Silty sandstone to sandy siltstone, yellowish-gray (5*Y* 7/2) and light-olive-gray (5*Y* 6/1); weathers yellowish gray (5*Y* 7/2); very fine grained sandstone with minor silt to siltstone with minor very fine sand grains; well cemented, calcareous; composed of ripple laminae, horizontal laminae, and minor thick to thin trough sets of medium- to large-scale low-angle cross-laminae; platy to massive splitting; weathers to form prominent ledge beneath broad bench. Unit contains both thick massive parts (probably stream-channel deposits) and thin slabby parts — 13.9

NOTE.—Unit 10 and underlying units measured about 1,500 ft north of unit 11 and perhaps as much as 5 ft of beds was lost or gained in this transfer.

10. Siltstone to sandy siltstone, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2) and minor light-brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4); sandy (very fine grained); abundant fine-grained accessory white mica; well cemented, calcareous; tabular unit of horizontal and ripple laminae; stratification generally poorly exposed and poorly defined; platy to slabby splitting; weathers to form slope — 19.3
9. Limy sandy siltstone, grayish-orange (10*YR* 7/4); weathers same color; sandy (very fine grained); well cemented; tabular unit of horizontal and ripple laminae; ripple laminae average 1–2 in. in wavelength, (some are as large as 4½ in.); platy to slabby splitting; weathers to form prominent ledgy interval; forms cliff away from line of section — 23.6
8. Siltstone, grayish-red (10*R* 4/2), pale-reddish-brown (10*R* 5/4), and grayish-orange (10*YR* 7/4) in lower few feet and commonly in rest of unit; weathers pale reddish brown (10*R* 5/4) with minor grayish orange (10*YR* 7/4); common to abundant fine-grained accessory white mica; well cemented, calcareous; tabular unit of horizontal and ripple laminae; ripple marks average about 1½ in. in wavelength; platy to flaggy splitting; weathers to form slope — 18.5

Total ledge-forming member — 220.9

Sinbad Limestone Member:

7. Dolomitic limestone, similar to unit 5 except bottom few feet consists of contorted laminae within a horizontal set. Unit poorly exposed and may contain clayey siltstone similar to that in unit 6. Unit weathers to form bench — 10.2
6. Clayey siltstone, yellowish-gray (5*Y* 7/2) and grayish-yellow (5*Y* 8/4); common fine-grained accessory white mica; firmly cemented; noncalcareous; stratification concealed; papery splitting; weathers to form bench — 7.3
5. Dolomitic limestone, yellowish-gray (5*Y* 7/2) and pale-olive (10*Y* 6/2); weathers yellowish gray (5*Y* 7/2) and grayish orange (10*YR* 7/4); aphanitic, some sets composed of fine-grained oolites; well cemented; tabular unit of horizontal laminae to thin beds and to a lesser extent of thin planar sets of small-scale cross-laminae, possibly some thin beds of contorted stratification; platy to slabby splitting; weathers to form most prominent ledge and cliff in Moenkopi. Unit contains sparse, indistinct, very small pelecypods(?). Top 5 ft weathers back to form bench — 29.8

Total Sinbad Limestone Member — 47.3

U8. TEMPLE MOUNTAIN—Continued

Moenkopi Formation—Continued

Lower slope-forming member: *Feet*

4. Clayey siltstone to siltstone, yellowish-gray (5*Y* 8/1), minor light-olive-gray (5*Y* 5/2) and grayish-orange (10*YR* 7/4); weathers grayish yellow (5*Y* 8/4); common to abundant limy parts; sparse fine-grained accessory white mica; sparse petroliferous material; stratification poorly exposed, but where seen commonly consists of horizontal laminae and ripple laminae; ripple laminae average ¾ in. in wavelength. Unit weathers to form steep slope. Unit differentiated from one below by yellowish-weathering color, by absence of very light gray layers, and by common thin resistant ledges — 82.1
3. Siltstone and minor claystone, yellowish-gray (5*Y* 8/1); weathers same color and sparse very light gray (*N*8); common limy parts; sparse fine-grained white mica; sparse petroliferous materials; firmly to well cemented; stratification and splitting mostly concealed, but where seen commonly consists of horizontal laminae and sparse small-scale cross-laminae; weathers to form steep slope. Unit poorly exposed in lower one-third — 32.0

Total lower slope-forming member — 114.1

Conglomeratic sandstone unit:

2. Limy conglomeratic sandstone to limy sandy conglomerate, light-olive-gray (5*Y* 6/1); weathers same color; composed of white and gray angular chert granules and pebbles in limy sand matrix. Sand matrix composed of very fine to very coarse well-rounded grains of milky quartz. Some parts of unit appear to be sandy limestone. Unit consists of very thin horizontal beds; slabby splitting; weathers to form small ledge and bench. Unit poorly exposed along line of section but well exposed west of line of section — 4.4
(Note: unconformity at base of unit 2 is suggested by basal conglomerate of Moenkopi and abrupt lithologic change between "Kaibab" and Moenkopi.)

Total conglomeratic sandstone unit — 4.4

Total Moenkopi Formation — 613.6

"Kaibab Limestone" (unmeasured):

1. Dolomitic limestone, light-olive-gray (5*Y* 6/1) and greenish-gray (5*GY* 6/1); weathers yellowish gray (5*Y* 8/1); aphanitic; composed mostly of very coarse sized (1–2 mm) fragments of shells; well cemented; consists of thin horizontal beds; slabby to massive splitting. About 10 ft of unit exposed along creek bottom at base of section. Unit contains sparse accessory grains of a green mineral (apatite?), and 3–5 percent white and gray chert nodules and vuggy crystalline masses of quartz. Contains abundant poorly preserved fossil fragments.

Base of section; base of exposure.

U9. BUCKACRE POINT

[Measured, by J. H. Stewart, June 1953, at point 1.4 miles N. 65° E. of the junction of Poison Springs Box Canyon with the Dirty Devil River. Lat 38°06′ N., long 110°24′ W. Garfield County]

Top of section, not top of exposure.

Chinle Formation (incomplete):

Monitor Butte Member (incomplete): *Feet*

14. Sandstone, yellowish-gray (5*Y* 7/2); weathers same color; fine grained, fair sorted; composed of dense mass of indistinct grains, probably abundant interstitial clay and possibly silica; firmly cemented, calcareous; sparse carbonaceous material; tabular unit of ripple laminae, of thin planar sets of small-scale cross-laminae and of thick trough sets of low-angle cross-laminae, cross-laminae dip only a few degrees and seem slightly wavy; platy to slabby splitting; weathers to form ledge. Unit generally contains a thin set of pebbly sandstone or pebble conglomerate at base as well as in other parts of unit. As much as 60 percent of the pebbly sandstone to pebble conglomerate consists of pebbles and granules. Pebbles and granules are limestone and siltstone. Lower surface of unit fills scours cut about 0.5 ft into underlying unit — 6.0

Total incomplete Monitor Butte Member — 6.0

Mottled strata:

13. Siltstone, grayish-purple (5*P* 4/2) to grayish-red-purple (5*RP* 4/2); weathers same colors; well cemented, noncalcareous; structureless; slabby splitting; fractures into angular fragments; weathers to form conspicuous purple band in cliff — 3.0
12. Siltstone, light-greenish-gray (5*GY* 8/1); weathers same color; silty with sparse well-rounded medium to fine grains; well cemented, noncalcareous; structureless; slabby splitting; weathers to form small light-colored rib in cliff. Unit assigned to Chinle Formation because it contains sparse medium to fine grains. Basal 0.1 ft of unit contains common copper stains — 1.3

Total mottled strata — 4.3

Total incomplete Chinle Formation — 10.3

U9. BUCKACRE POINT—Continued

Moenkopi Formation:

Upper slope-forming member: *Feet*

11. Siltstone, grayish-red (10*R* 4/2), abundant grayish-red-purple (5*RP* 4/2) and very pale green (10*G* 8/2) occurring irregularly near numerous fractures; weathers same colors; common fine-grained white mica; stratification and splitting concealed; weathers into reentrant. Sparse dusky-yellowish-brown (10*YR* 2/2) and pale-reddish-brown (10*R* 5/4) quartz nodules as large as 0.5 in. in diameter and stringers as large as 0.3 in. wide and 2 in. long. More fractures are horizontal than vertical. About 50 percent of top 2 ft of unit is altered to grayish red purple (5*RP* 4/2); top 0.1 ft of unit altered to light greenish gray (5*G* 8/1) and is copper stained. Unit is separated from underlying unit by a slight color change along a fairly sharp wavy seemingly conformable contact...... 6.2
10. Clayey siltstone to siltstone, grayish-red (10*R* 4/2), common thin sets of yellowish-gray (5*Y* 8/1); weathers same colors; firmly cemented, noncalcareous; common fine-grained white mica; stratification mostly concealed, but lower one-fourth commonly ripple laminated (linear rhythmic ripples with wavelength of 1 in. and amplitude of 0.1 in.), whereas rest of unit contains common horizontal laminae and very thin to thick beds or sets; splitting mostly concealed, but some platy and flaggy splitting seen; weathers to form steep smooth slope. Unit forms less resistant upper part of Moenkopi. Yellowish-gray sets are limy. Top 2.5 ft of unit contains numerous fractures along which the rock has been altered to grayish orange (10*YR* 7/4), very pale green (10*G* 8/2), and grayish red purple (5*RP* 4/2). The altered zones are generally about 0.2 in. wide and become slightly wider than this toward top of unit........ 109.8

Total upper slope-forming member..... 116.0

Ledge-forming member:

9. Sandstone, grayish-orange (10*YR* 7/4); weathers same color; very fine grained well sorted, seems to have abundant interstitial silt or clay and abundant interstitial limonite(?); well cemented, calcareous; lenticular unit of thin trough sets of medium-scale cross-laminate; flaggy splitting; weathers to form ledge. The top 18.2 ft of unit 6 and all of units 7, 8, and 9 form a ledgy interval in the Moenkopi............ 2.8
8. Siltstone to sandy siltstone, similar to unit 3. Weathers to form slope. Conspicuous ledge 29.4–36.2 ft above base of unit............ 43.6
7. Sandstone, olive-gray (5*Y* 4/1), yellowish-gray (5*Y* 8/1), and pinkish-gray (5*YR* 8/1); weathers very pale orange (10*YR* 8/2); very fine grained, probably well sorted, seems to have abundant interstitial silt or clay; firmly to well cemented, calcareous; olive-gray parts contain abundant petroliferous material; lenticular unit of thin to thick trough sets of medium- to large-scale low-angle cross-laminae and thin cross-laminae; slabby to massive splitting; weathers to form prominent light-colored ledge. Unit recognized only locally along outcrop. Base of unit fills scours cut about 10 ft into underlying unit.......... 29.0
6. Siltstone to sandy siltstone, similar to unit 3. Weathers to form slopes and benches. Small ledges from 9.6 to 15.6 ft, 68.9 to 71.1 ft, and 81.5 to 87.1 ft above base of unit. Unit from 81.5 to 87.1 ft is yellowish gray (5*Y* 8/1). Ripple marks (linear and rhythmic) occur a few feet above base of unit and have an amplitude of 0.1–0.2 in. and wavelength of 1 in............................ 87.1
5. Sandstone, olive-gray (5*Y* 4/1) and grayish-orange (10*YR* 7/4); weathers grayish orange (10 *YR* 7/4); very fine grained, well sorted; abundant interstitial limonite(?); firmly cemented, calcareous; abundant petroliferous material in olive-gray parts; composed of thin trough sets of dominantly low-angle medium- to small-scale cross-laminae; platy to slabby splitting; weathers to form small ledge. Sparse very coarse grains at base. Base of unit fills scours cut as much as 1 ft into underlying unit 7.6

Total ledge-forming member........... 170.1

Sinbad Limestone Member:

4. Siltstone and limestone. Siltstone, grayish-yellow (5*Y* 8/4), grayish-orange (10*YR* 7/4), and pale-greenish-yellow (10*Y* 8/2); weathers grayish yellow (5*Y* 8/4); fine to coarse silt; abundant fine-grained white mica in a few places; firmly to well cemented, slightly calcareous in parts; horizontally laminated, minor ripple laminae (cuspate? type). Limestone, grayish-orange (10*YR* 7/4) and medium-gray (*N*5); weathers grayish yellow (5*Y* 8/4); dense poorly developed oolites in places; well indurated; probably petroliferous in places; horizontally laminated to thin bedded. Limestone is present from 2.4 to 3.4 ft and from 9.6 to 10 ft above base of unit. Limestone contains disseminated medium grains to granules of limestone in some places. Unit as a whole weathers to form steep slope with small ledges developed on limestone. Unit forms yellowish-gray band throughout area 11.0

Total Sinbad Limestone Member....... 11.0

U9. BUCKACRE POINT—Continued

Moenkopi Formation—Continued

Lower slope-forming member: *Feet*

3. Siltstone to sandy siltstone, grayish-red (10*R* 4/2), sparse pale-red (10*R* 6/2) and yellowish-gray (5*Y* 8/1); weathers grayish red (10*R* 4/2) and pale reddish brown (10*R* 5/4); siltstone contains minor amounts of fine sand; firmly to well cemented, calcareous in part; abundant fine-grained white mica; composed of very thin to thick sets of horizontal and ripple laminae; platy to slabby splitting; weathers to form slope containing small ledges. One very thin set of medium-grained sandstone composed of subrounded clear quartz was seen near middle of unit. Common very thin sets of limy siltstone interbedded with rest of unit ---------- 52.8

Total lower slope-forming member ---------- 52.8

Conglomerate and sandstone unit:

2. Pebble conglomerate to pebbly sandstone (90 percent) and sandstone (10 percent). Pebble conglomerate to pebbly sandstone, light-gray (*N*7) and yellowish-gray (5*Y* 8/1); weathers yellowish gray (5*Y* 8/1); pebbles and minor granules and cobbles of subrounded and minor subangular white and gray chert as large as 0.5 ft set in a sand matrix. Granules, pebbles, and cobbles comprise generally 40–60 percent of the rock. Sand matrix is composed of medium well-sorted subrounded clear quartz grains; no accessory minerals seen. Pebble conglomerate to pebbly sandstone is poorly cemented, calcareous; generally structureless with sparse thin horizontal beds; massive splitting. Sandstone composed of sand similar to sand matrix in rest of unit. Rarely, sandstone contains abundant granules and pebbles of chert. Sandstone occurs as thin to thick lenses, generally less than 100 ft across. Lenses composed of thin horizontal beds and thin trough sets of small-scale cross-laminae. Unit as a whole is tabular and weathers to form pebbly, ledgy slope. Unit contains common petroliferous material. Sand grains commonly have crystal faces due to secondary quartz overgrowths ---------- 29.4

Total conglomerate and sandstone unit ---------- 29.4

Total Moenkopi Formation ---------- 379.3

NOTE.—Unconformity. Abrupt change in lithology at undulating erosion surface containing scours as much as 1 ft deep.

U9. BUCKACRE POINT—Continued

Cutler Formation:

White Rim Sandstone Member (unmeasured):

1. Sandstone, yellowish gray (5*Y* 8/1), white (*N*9), very light gray (*N*8), and grayish-yellow (5*Y* 8/4); weathers yellowish gray (5*Y* 8/1); fine grained with minor very fine and medium sand grains, fair sorted; composed of rounded to subrounded clear quartz, no accessory minerals seen; poorly cemented, calcareous; sparse petroliferous material; composed dominantly of trough sets about 20 ft thick containing large-scale cross-laminae; laminae are contorted in top 2 ft; platy splitting; weathers to form cliff above Dirty Devil River. Numerous fractures striking about N. 15° W. along which sandstone is more resistant and weathers into ridges about ½ in. wide. Only top 10 ft examined in detail. Total exposure about 200–250 ft.

Base of section; not base of exposure.

U10. HORSE CANYON

[Measured, by J. H. Stewart and G. A. Williams, August 1952, in northwest part of Circle Cliffs. Units 1–3 measured along Horse Canyon 1¼ miles up canyon from place where the Long Canyon–The Peaks road crosses Horse Canyon; long 111°11′55″ W., lat 37°56′25″ N. Units 4–8 measured from Horse Canyon, at place ½ mile up creek from where units 1–3 were measured, to promontory to the west; long 111°12′10″ W., lat 37°56′50″ N. to long 111°12′40″ W., lat 37°57′05″ N. Garfield County]

Chinle Formation:

Shinarump Member (unmeasured): *Feet*

8. Sandstone, pale-greenish-yellow (10*Y* 8/23); weathers moderate reddish orange (10*R* 6/6); very coarse grained, poorly sorted; composed of subangular clear quartz and sparse orange and black accessory minerals, common limonite spots; poorly cemented, calcareous; composed of medium- to large-scale cross-laminations; blocky to massive splitting; weathers to form cliff. Unit is conglomeratic, in places containing material as coarse as pebbles; also contains siltstone boulders probably derived from Moenkopi Formation. Contains common fossil wood.

Moenkopi Formation:

Cliff-forming member:

7. Siltstone and claystone, similar to unit 6 except it contains common ripple-laminated parts and locally pseudocross-laminations; forms cliff protected by resistant sandstone of overlying Shinarump Member. Upper 3 ft is dark yellowish orange (10*YR* 6/6) ---------- 73.6

Total cliff-forming member ---------- 73.6

U10. HORSE CANYON—Continued

Moenkopi Formation—Continued

Upper slope-forming member:

Feet

6. Claystone and siltstone, grayish-red (10*R* 4/2) and pale-reddish-brown (10*R* 5/4); weathers to moderate reddish orange (10*R* 6/6) and pale reddish brown (10*R* 5/4); micaceous; firmly cemented, calcareous; very thinly laminated to thin bedded; papery to slabby splitting; weathers to form steep frothy slope. Thin laminae of siltstone are pale greenish yellow (10*Y* 8/2) and form conspicuous color bands 221.4

Total upper slope-forming member 221.4

Ledge-forming member:

5. Siltstone and claystone, pale-reddish-brown (10*R* 5/4) and grayish-orange (10*YR* 7/4); weathers pale reddish brown (10*R* 5/4); firmly cemented, calcareous; predominantly shaly splitting with minor flaggy and slabby splitting. Unit weathers to form ledges and slopes. Unit contains many lenticular siltstone layers that form benches and are current-ripple laminated (common pseudocross-laminations); abundant ripple marks seen. The ledges in unit are not as large or as common as those in the underlying unit 158.6

4. Siltstone and claystone. Siltstone is pale yellowish orange (10*YR* 8/6) and pale reddish brown (10*R* 5/4); weathers same colors; minor very fine grained parts; limonite spots; firmly cemented, calcareous; lenticular ledges, current-ripple lamination with common pseudocross-lamination; shaly to blocky splitting. Weathers to form ledges that are not continuous along outcrop. Claystone is grayish red (10*R* 4/2); weathers same color; micaceous; very thin current-ripple laminae; papery to shaly splitting; weathers to form steep rubbly slope. Basal 5–10 ft of unit is altered to moderate yellow (5*Y* 7/6); color crosses stratification. Unit as a whole forms steep ledgy slope 91.8

Total ledge-forming member 250.4

Sinbad Limestone Member:

(Note: Section transferred along top of unit 3 so that overlying units measured ½ mile north.)

3. Limestone, pale-olive (10*Y* 6/2), grayish-yellow (5*Y* 8/4), and grayish-olive (10*Y* 4/2); weathers dusky yellow (5*Y* 6/4); composed of dense to fine-grained limestone with sparse medium-sized crystals; well cemented; thinly parallel laminated to thinly parallel bedded and sparse thin medium-scale trough and planar sets of high-angle cross-laminations; platy to blocky weathering. Weathers to form steep ledgy slope and cliff. Abundant poorly preserved fossils, mostly pelecypods. Sparse thin to thick sets of moderate-yellow (5*Y* 7/6) laminated siltstone 44.3

Total Sinbad Limestone Member 44.3

Lower slope-forming member:

2. Siltstone and limestone. Siltstone is moderate yellow (5*Y* 7/6) and dark yellowish orange (10*YR* 6/6); weathers same colors; firmly cemented, argillaceous; thinly laminated to parallel laminated, shaly splitting. Limestone is grayish yellow (5*Y* 8/4); weathers grayish orange (10*YR* 7/4); dense; very thin to thin parallel bedding, flaggy to blocky splitting. Limestone beds located from 4.4 to 5.4 ft and from 5.9 to 6.9 ft above base of unit. Entire unit is lenticular; it weathers to form a reentrant and steep rubble-covered slope. It pinches out in some places on the outcrop. Unit is separated from underlying unit by an erosion surface that locally has 5–10 ft of relief 7.9

Total lower slope-forming member 7.9

Basal unit:

1. Silty and sandy limestone, pale-greenish-yellow (10*Y* 8/2); weathers light brown (5*YR* 6/4); dense, dolomitic; firmly cemented; thinly parallel bedded, massive splitting; weathers to form rounded cliff with nodular and pitted surface. Contains abundant chert (estimated 30–40 percent) that is white (*N*9); weathers same color; forms nodular and rounded masses 3–12 in. in diameter and irregular stringy platelike masses. The chert is primarily concentrated along bedding planes 15±

Total basal unit 15±

Total Moenkopi Formation 612.6±

A few feet of limestone exposed in bottom of canyon is probably the top of the "Kaibab Limestone."

U11. MULEY TWIST

[Measured, by J. H. Stewart and G. A. Williams, August 1952, in southeastern Circle Cliffs. Section begins about 1 mile (straight-line distance) up creek (northwestward) from place where Muley Twist road enters Muey Twist Wash. Base of section 200 ft down wash from prominent split in canyon; long 111°1′55″ W.; lat 37°50′30″ N. Garfield County]

Chinle Formation:

Monitor Butte Member (unmeasured):

12. Claystone, greenish-gray (5*GY* 6/1); weathers light greenish gray (5*G* 8/1); poorly cemented, slightly calcareous; bedding concealed. Weathers to form steep frothy slope.

U11. MULEY TWIST—Continued

Moenkopi Formation:

Cliff-forming member: *Feet*

11. Similar to unit below except contains more very thin beds of siltstone than underlying unit. In addition, it contains two prominent siltstone ledges from 0.4 to 4.9 ft and from 43.0 to 46.3 ft above base. Lower siltstone ledge is dominantly pale yellowish orange (10*YR* 8/6); it weathers pale reddish brown (10*R* 5/4) — 53.2

Total cliff-forming member — 53.2

Upper slope-forming member:

10. Claystone and siltstone, interbedded, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers dark reddish brown (10*R* 3/4); firmly cemented; mostly laminated, minor very thin beds; uncommon current ripple marks; shaly and flaggy splitting; weathers to form steep frothy and rubbly slope. Common laminae and very thin beds of grayish-orange (10*Y* 7/4) siltstone that give banded appearance to slope — 146.2
9. Siltstone, moderate-yellowish-brown (10*YR* 5/4) to grayish-orange (10*YR* 7/4); weathers pale yellowish orange (10*YR* 8/6); common mica flakes; firmly cemented, calcareous; common ripple-marked beds; flaggy splitting; weathers to gentle rubble-covered slope. Layers of petroliferous siltstone seen near base — 85.8

Total upper slope-forming member — 232.0

Ledge-forming member:

8. Siltstone, predominantly pale-yellowish-orange (10*YR* 8/6) with minor pale-brown (5*YR* 5/2) and medium-dark-gray (*N*4); weathers grayish orange (10*YR* 7/4); firmly cemented, calcareous; abundant very small limonite spots; predominantly current-ripple laminated, common pseudocross-lamination, and minor very thin to thick bedding; shaly to slabby splitting. Unit weathers to form steep rubble-covered slope with small ledge at top. Top third of unit contains petroliferous medium-dark-gray (*N*4) siltstone — 116.9
7. Siltstone, predominantly pale-yellowish-orange (10*YR* 8/6), minor moderate-orange-pink (10*R* 7/4) and grayish-red (10*R* 4/2); weathers grayish orange (10*R* 7/4) and grayish orange pink (10*R* 8/2); in part sandy (very fine grained); very small limonite spots; firmly cemented, slightly calcareous; predominantly current-ripple laminated with common pseudocross-lamination and minor very thin and thick bedding; shaly to blocky splitting; weathers to form a steep ledgy slope. A 1-ft-thick limestone bed occurs 15 ft above base. Limestone present only locally — 65.4

Total ledge-forming member — 182.3

Basal unit:

6. Sandstone and limestone, pale-yellowish-orange (10 *YR* 8/6), pale-greenish-yellow (10*YR* 8/2) and white (*N*9); weathers white (*N*9) and pale yellowish orange (10*YR* 8/6). Limestone, composed of dense calcite with sparse medium-grained clear quartz. Sandstone, fine grained to very fine grained; composed of clear quartz with sparse mica flakes; some limonite spots and stains; firmly cemented, calcareous. Tabular unit with irregular thin beds of limestone interbedded with sandstone. Unit weathers to form prominent ledge above "Kaibab Limestone." Unit contains abundant bedded chert and chert nodules — 15.6

Total basal unit — 15.6

Total Moenkopi Formation — 483.1

"Kaibab Limestone":

Limestone unit:

5. Limestone, grayish-yellow (5*YR* 8/4), pale-yellowish-orange (10*YR* 8/6); weathers pale yellowish orange (10*YR* 8/6); composed of dense limestone with sparse medium-grained green accessory minerals (apatite?); firmly cemented; very thin beds to very thick parallel beds; flaggy to massive splitting. Forms gentle ledge slope; contains sparse chert nodules at random positions within unit — 54.0

Total limestone unit — 54.0

Flat-bedded sandy limestone to sandstone unit:

4. Limestone and sandstone, pale-yellowish-orange (10*YR* 8/6); weathers same color and dark yellowish brown (10*YR* 4/2). Limestone, composed of dense calcite with sparse to abundant fine-grained clear quartz; firmly to well cemented; contains sparse indistinct molds of fossil fragments. Sandstone, fine-grained, well-sorted; composed of rounded clear quartz and sparse black accessory minerals; some limonite spots and stains; poorly cemented, calcareous. Limestone and sandstone, very thin to very thick bedded; flaggy to massive splitting. Unit weathers to form cliff, minor benches, and reen-

U11. MULEY TWIST—Continued

"Kaibab Limestone"—Continued

Flat-bedded sandy limestone to sandstone unit—Continued *Feet*

trants; top of unit forms prominent bench. All gradations from pure limestone to pure sandstone occur in unit 64.7

3. Sandstone, grayish-yellow (5*Y* 8/4); weathers same color; fine grained, well sorted; composed of rounded clear quartz and sparse orange and black accessory minerals; limonite spots and stains; poorly cemented, calcareous; composed of medium-scale planar and trough sets of cross-laminae; parallel bedding in upper 6 ft; platy and flaggy splitting; weathers to form a cliff 22.0

2. Limestone, grayish-yellow (5*Y* 8/4); weathers grayish yellow (5*Y* 8/4) and grayish orange (10*YR* 7/4); composed of dense calcite and abundant medium to coarse quartz grains; poorly cemented, calcareous; thinly parallel bedded; slabby splitting. Forms reentrant at base of cliff. Contains indistinct cavities that may represent molds of shell fragments 1.5

Total flat-bedded sandy limestone to sandstone unit 88.2

Total "Kaibab Limestone" 142.2

Cutler Formation (incomplete):

White Rim Sandstone Member (incomplete):

1. Sandstone, grayish-orange (10*YR* 7/4); weathers to very pale orange (10*YR* 8/2); fine grained, well sorted; composed of rounded clear quartz and sparse orange accessory minerals; poorly cemented; slightly calcareous; large-scale cross-laminae; forms floor of canyon .... 15.0±

Total incomplete White Rim Sandstone Member .... 15.0±

Total incomplete Cutler Formation .... 15.0±

Base of outcrop.

U13. RANGE CANYON

[Measured, by J. H. Stewart and O. B. Raup, October 1953, near trail on minor promontory between the two forks of Range Canyon near the head of Range Canyon; long 110°05′20″ W., lat 38°07′50″ N. Garfield County]

Top of section; top of local exposure.

Chinle Formation (incomplete):

Moss Back Member (incomplete):

18. Sandstone (95 percent) and conglomeratic sandstone (5 percent). Sandstone is yellow-gray (5*Y* 8/1) and very pale orange (10*YR* 8/2); weathers same colors; fine to medium grained, well sorted; composed of subangular to subrounded clear quartz and uncommon gray accessory mineral; poorly cemented, calcareous; consists of thin to thick trough and planar sets of small- to medium-scale and sparse large-scale cross-laminae. Conglomeratic sandstone is similar to sandstone except that it contains granules and pebbles of rounded quartzite and to a lesser extent, of chert. Commonly the conglomeratic sandstone is medium to coarse grained and contains abundant interstitial silt. All gradations seen, from sandstone containing a few disseminated granules to conglomeratic sandstone containing 30–40 percent pebbles. Conglomerate is present as thin lenses interstratified with rest of unit but generally occurs at the base or in the basal 10 ft of unit. Unit as a whole is tabular and weathers to form a cliff. Unmeasured.

17. Heterogeneous unit of conglomerate and sandstone (60 percent) and siltstone (40 percent). Conglomerate and sandstone is grayish yellow (5*Y* 8/4), minor light greenish gray (5*GY* 8/1); weathers yellowish gray (5Y 8/1). Sandstone is fine to medium grained, well sorted; composed of subangular clear quartz and common black accessory mineral. Sandstone grades to conglomerate containing as much as 60 percent granules and pebbles of rounded to subrounded quartzite and sparse chert. Sandstone and conglomerate is firmly cemented, calcareous; consists of thin trough sets of low-angle medium-scale cross-laminae, some thin irregular lenses. Siltstone is pale green (10*G* 6/2) to greenish gray (5 *GY* 6/1); weathers same colors; firmly cemented, slightly calcareous; structureless. Siltstone occurs in thin lenses interstratified with rest of unit. Unit is highly variable laterally 10.1

Total incomplete Moss Back Member 10.1

Monitor Butte Member:

16. Siltstone, similar to underlying unit except basal 0.3 ft contains about 10 percent rounded fine to coarse frosted clear and milky quartz and minor opaque orange mineral 2.2

15. Siltstone, grayish-blue (5*PB* 5/2), grayish-red-purple (5 *RP* 4/2) in basal foot, abundant light-greenish-gray (5*GY* 8/1) and grayish-red (10*R* 4/2) throughout unit; weathers same colors; well cemented, noncalcareous; structureless; weathers to form a cliff. Basal 0.2 ft of unit is a pinkish-gray-weathering band containing abundant slickensides that form a crisscross pattern 3.7

Total Monitor Butte Member 5.9

Total incomplete Chinle Formation 16.0

U13. RANGE CANYON—Continued

Moenkopi Formation:

Upper slope-forming member: *Feet*

14. Claystone to siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4), sparse yellowish-gray (5*Y* 8/1); weathers pale reddish brown (10*R* 5/4); uncommon fine-grained accessory white mica, firmly cemented, calcareous to slightly calcareous; consists of about 70 percent horizontal laminae, 25 percent structureless material, and 5 percent ripple laminae; dominantly platy splitting; weathers to form rubble-covered slope. Away from line of section unit forms earthy slope. Top 4 ft of unit contains numerous fractures along which rock is altered to very pale green (10*G* 8/2) and grayish red purple (5*RP* 4/2); alteration increases upward, and top 0.3 ft of unit is completely altered — 90.0

Total upper slope-forming member — 90.0

Ledge-forming member:

13. Sandy siltstone to sandstone (85 percent) and siltstone (15 percent). Sandy siltstone to sandstone, pale-red (10*R* 6/2) and grayish-orange-pink (10*R* 8/2); weathers grayish orange (10*YR* 7/4); sandy (very fine grained) siltstone to very fine grained sandstone; firmly cemented, slightly calcareous; composed of horizontal and ripple laminae and sparse thin to very thick trough sets of low-angle medium- to large-scale cross-laminae. Siltstone, similar to siltstone in unit below. Siltstone occurs as thin sets interstratified with rest of unit. Siltstone is commonly absent laterally from line of section. Unit weathers to form a conspicuous ledge. Unit forms top of ledgy interval that includes units 11 to 13; unit above has no ledges — 9.8

12. Siltstone to sandy siltstone, grayish-red (10*R* 4/2), pale-reddish-brown (10*R* 5/4), common grayish-orange (10*YR* 7/4), and sparse pale-red (10*R* 6/2); weathers light brown (5*YR* 6/4); sandy (very fine grained), uncommon very fine grained accessory white mica; consists of very thin to thick sets of horizontal laminae interstratified with very thin to thick sets of ripple laminae; no cross-stratification or structureless siltstone seen; weathers to form steep ledgy slope. About 20 percent of unit has thin to very thick ledges that are generally ripple-laminated (1–2 in. wavelengths) sandy siltstone — 99.1

11. Sandy siltstone, grayish-orange (10*YR* 7/4); weathers very pale orange (10*YR* 8/2); sandy (very fine grained); common fine-grained accessory white mica; firmly cemented, calcareous; consists of thin to very thick trough sets of medium- to large-scale low-angle cross- laminae; weathers to form a conspicuous ledge; basal strata of unit fill channels cut as much as 3 ft into underlying unit — 19.3

U13. RANGE CANYON—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

10. Siltstone, grayish-red (10*R* 4/2), grayish-orange (10*YR* 7/4), and minor greenish-gray (5*GY* 6/1); otherwise similar to unit 7. Unit weathers to form reentrant in cliff. Overlying Moenkopi contains many massive ledges whereas unit below has none — 9.7

Total ledge-forming member — 137.9

Sinbad Limestone Member:

9. Limestone, grayish-orange (10*YR* 7/4); weathers dark yellowish orange (10*YR* 6/6); aphanitic; well cemented; consists of horizontal laminae and thin planar sets of low-angle small-scale cross-laminae; slabby splitting; weathers to form a conspicuous ledge. Unit is persistent to north along outcrop although it seems to thin. No fossils seen — 3.8

8. Siltstone (70 percent) and limestone (30 percent). Siltstone is similar to that in unit below. Limestone is pale yellowish orange (10*YR* 8/6) and grayish orange (10*YR* 7/4); weathers same colors; aphanitic rare medium to very coarse grained oolitic parts; well cemented. Limestone occurs as thin to thick beds interstratified with siltstone and includes thin beds or intraformational limestone conglomerate. Unit weathers to form steep ledgy slope and cliff — 12.9

Total Sinbad Limestone Member — 16.7

Lower slope-forming member:

7. Siltstone, grayish-red (10*R* 4/2), minor very pale orange (10*YR* 8/2); weathers pale reddish brown (10*R* 5/4); commonly sandy (very fine grained); abundant very fine grained accessory white mica; firmly to well cemented, calcareous; consists of very thin to thin horizontal beds and horizontal and ripple laminae; flaggy splitting; weathers to form steep slopes and cliffs. Unit differentiated from one below by difference in color — 34.5

6. Siltstone, light-greenish-gray (5*GY* 8/1), yellowish-gray (5*Y* 8/1), and minor light-olive-gray (5*Y* 6/1); weathers yellowish gray (5*Y* 8/1); abundant very fine grained accessory white mica; firmly to well cemented, slightly calcareous; consists of horizontal laminae, ripple laminae, and very thin to thick horizontal beds; weathers to form steep slope. Unit contains common very fine grained sand in parts and several thin fine grained sandstone sets. This sandstone occurs as thin planar sets of small-

U13. RANGE CANYON—Continued

Moenkopi Formation—Continued

Lower slope-forming member—Continued — *Feet*

scale cross-laminae. One of these sets, from 32.6 to 34.4 ft, contains about 20 percent very coarse grains and granules of altered chert(?). Top of unit is placed at color change from tan below to reddish brown above — 56.9

Total lower slope-forming member — 91.4

Conglomerate and sandstone unit:

5. Sandstone, light-olive-gray (5*Y* 6/1), weathers yellowish gray (5*Y* 8/1); fine to medium grained, well sorted; composed of subrounded frosted clear quartz, no accessory minerals noted; poorly cemented, slightly calcareous; common petroliferous material; stratification poorly developed but seems to consist of very thin to thin lenses in lower 2 ft and contorted laminae in rest of unit (contorted laminae are not easily seen); weathers to form conspicuous ledge in lower 17 ft and bench in rest of unit. Basal 2 ft of unit in line of section contains about 10 percent granules and pebbles, as large as 2 in. in diameter, of medium-light-gray (*N*6) chert. Unit grades into overlying unit. Unit is assigned to the Moenkopi Formation because it contains chert granules and pebbles, because bedding in lower 2 ft is probably fluvial, and because overlying unit has typical Moenkopi bedding — 33.6

Total conglomerate and sandstone unit — 33.6

Total Moenkopi Formation — 369.6

Cutler Formation (incomplete):

White Rim Sandstone Member:

4. Sandstone, light-gray (*N*7), olive-gray (5*Y* 4/1) and light-olive-gray (5*Y* 6/1); weathers very pale orange (10*YR* 8/2); very fine to fine grained, well sorted; composed of subrounded clear quartz and sparse black accessory mineral; poorly cemented, slightly calcareous; abundant petroliferous material; consists of thick to very thick trough to planar sets of large- and medium-scale cross-laminae; weathers to form cliff and steep ledgy slope. Sets average about 5 ft in thickness but are as large as 15 ft thick. Basal 5 ft of unit contains 10–30 percent rounded medium and coarse grains of frosted milky quartz — 158.0

Total White Rim Sandstone Member — 158.0

Organ Rock Tongue:

3. Siltstone to sandy siltstone, very pale orange (10*YR* 8/2) with common grayish-orange (10*YR* 7/4); weathers grayish orange (10*YR* 7/4); sandy (very fine grained), firmly cemented, slightly calcareous; stratification poorly developed but consists of some very thin to thick horizontal beds; weathers to form earthy slope. Contact with underlying unit is based mainly on a sharp color contrast. Unit contains several thin beds of very fine to fine-grained sandstone in top 20 ft. This sandstone has the same colors as the rest of unit and is composed of subangular clear quartz and sparse black accessory mineral. This sandstone may merge laterally into the overlying White Rim Sandstone Member — 78.9

2. Sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; sandy (very fine to fine grained); uncommon medium to fine accessory white and dark mica; firmly cemented, slightly calcareous; very thin to very thick horizontal beds with common horizontal and ripple laminae and sparse thin trough sets of low-angle medium-scale cross-laminae; weathers to form gentle slope. Unit forms red band between light-colored rocks. Basal 25 ft or unit contains common thick to very thick poorly defined beds of silty sandstone. Silty sandstone, pale-red (10*R* 6/2) to grayish-red (5*R* 4/2); very fine to fine grained; composition concealed; poorly cemented, calcareous. Silty sandstone is interstratified with sandy siltstone and may be a westward extension of arkosic sandstone of the Cutler — 82.7

Total Organ Rock Tongue — 161.6

Cedar Mesa Sandstone Member (unmeasured):

1. Sandstone, olive-gray (5*Y* 4/1), light-olive-gray (5*Y* 6/1), sparse grayish-orange (10*YR* 7/4) mottles; weathers very pale orange (10*YR* 8/2) with minor light gray (*N*7); fine to very fine grained, well sorted; composed of subrounded clear quartz, accessory minerals concealed; poorly to firmly cemented, noncalcareous; common grayish-orange (10*YR* 7/4) limonitic nodular inclusions and sparse small nodules of very coarsely crystalline calcite; abundant petroliferous material; stratification poorly developed but some horizontal stratification planes and one set of low-angle cross-laminae were seen. Weathers to form valley bottom. Top of unit placed at color change from gray below to red above. Only top 25 ft of unit examined.

Total incomplete Cutler Formation — 319.6

Base of section; base of local exposure.

U14. SILVER FALLS CREEK

[Measured, by L. C. Craig, G. A. Williams, H. F. Albee, and J. H. Stewart, July 1952, in southwestern Circle Cliffs along main Moody Creek north of Colt Mesa and up spur south of main point between Moody and South Fork Silver Falls Creek; top of section is N. 80° W. from Colt Mesa; long 111°5′ W., lat 37°44′ N. Garfield County]

Top of section; top of good exposure.

Chinle Formation (incomplete):

Shinarump Member (incomplete): *Feet*

19. Sandstone, predominantly very light gray (*N*8) with uncommon grayish-yellow (5*Y* 8/4) and dusky-yellow (5*Y* 6/4); weathers light brown (5*YR* 6/4), some iron staining; grades from very coarse grained to medium grained, but predominantly coarse grained, poorly sorted; composed of angular to subangular clear quartz grains and uncommon black and pink accessory minerals; firmly to poorly cemented, slightly calcareous, abundant interstitial clay; composed of medium-scale trough sets of cross-laminae; predominantly massive and blocky with uncommon shaly to slabby splitting; forms prominent capping cliff. Contains sparse pebbles, some along lamination planes and others disseminated; pebbles composed of pink to gray quartzite, clear quartz, gray chert, and sparse red chert. Slicified tree trunks, circular to elliptical in cross section, and as large as 2 ft in diameter and at least 6–10 ft long occur in unit ---------- 19.5

18. Siltstone, pale-olive (10*Y* 6/2) to greenish-gray (5*GY* 6/1); weathers light gray (*N*7); minor clay-sized particles, well sorted; constituents concealed, possible common finely divided mica; very slightly calcareous; very large scale trough sets of very thin crossbeds and cross-laminae; hoodoo-type weathering; unit forms very steep slope and cliff ---------- 51.3

17. Sandstone, light-olive-gray (5*Y* 6/1); weathers yellowish gray (5*Y* 8/1); fine grained to very fine grained with sparse medium-grained to very coarse grained parts, fair to poor sorted; composed of subrounded clear quartz grains and common white and black accessory minerals, sparse mica; limonite is interstitial and occurs as metallic-looking black stringers; firmly cemented, calcareous; some iron oxide concentrations; common clay pellets and carbonaceous plant fragments. A single thick lenticular bed was seen with asymmetrical ripple lamination and medium-scale trough sets of cross-stratification. Unit is slabby to blocky splitting. Forms prominent lenticular ledge ---------- 16.5

Total incomplete Shinarump Member ---------- 87.3

Total incomplete Chinle Formation ---------- 87.3

U14. SILVER FALLS CREEK—Continued

Moenkopi Formation: *Feet*

NOTE.—Because of the channel cut into the Moenkopi, the top 50 ft of Moenkopi is missing in line of section. About 1 mile northwest of line of section, the top 50 ft of the Moenkopi is present and is composed of reddish-brown siltstone. Of the siltstone, 70 percent is ripple laminated with parallel ripples, and the remaining is structureless. This top 50-ft unit is the cliff-forming member of the Moenkopi.

Upper slope-forming member:

16. Claystone and siltstone, interstratified. Claystone is moderate brown (5*YR* 4/4), silty; composed of quartz grains and abundant biotite flakes; other accessory minerals concealed; firmly cemented, moderately calcareous; hackly weathering. Siltstone is grayish orange (10*YR* 7/4); weathers orange to pink; composed of clear quartz grains; accessory minerals concealed; well cemented, moderately calcareous; siltstone mostly at bottom and top of unit. Tabular unit of very thick structureless beds, basal 5 ft ripple laminated with cuspate ripples. Forms steep slope covered by hackly rubble ---------- 114.4

Total upper slope-forming member ---------- 114.4

Ledge-forming member:

15. Sandstone, pale-pink (5*RP* 8/2); weathers brownish gray (5*YR* 4/1) to moderate brown (5*YR* 4/4); very fine grained, well sorted; composed of clear quartz grains, abundant biotite flakes, and common black accessory minerals; well cemented, slightly calcareous, common limonite and possibly silica cement; tabular unit with very thin bedded, parallel laminated and ripple laminated (cuspate and nonrhythmic) and structureless parts; slabby and flaggy splitting; forms prominent ledge ---------- 5.3

14. Siltstone and claystone, interstratified. Siltstone is grayish orange (10*YR* 7/4), well sorted; composed of clear quartz grains, accessory minerals concealed; limonite spots less than 1 mm in diameter; firmly cemented, slightly calcareous. Claystone is moderate orange pink (5*YR* 8/4), weathers pale reddish brown (10*R* 5/4). Tabular unit consisting of parallel structureless sets and ripple laminated sets (linear asymmetrical ripples). Siltstone is flaggy and slabby splitting whereas claystone is shaly and hackly splitting. Unit forms a shaly slope containing two prominent ledges less than 3 ft thick ---------- 41.6

13. Siltstone, pale-yellowish-orange (10*YR* 8/6); weathers light brown (5*YR* 6/4); well sorted; composed of clear quartz grains, accessory minerals concealed; firmly cemented, calcareous cement; consists of very thin parallel sets of ripple laminae; shaly to flaggy splitting; forms gentle slope ---------- 17.5

U14. SILVER FALLS CREEK—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

12. Sandstone, brownish-black (5*YR* 2/1) to light-brownish-gray (5*YR* 6/1); weathers yellowish gray (5*Y* 8/1); very fine grained and silty with sparse fine-grained parts, well sorted; composed of clear quartz grains, common biotite flakes, and yellowish-brown (limonite?) grains; firmly cemented, calcareous, commonly limonitic; unit saturated with petroliferous material. Tabular unit consisting of alternating sets of medium-scale planar cross-strata and of parallel and ripple laminae (nonrhythmic current-ripples). Predominantly flaggy splitting; weathers to form ledge. Top of unit forms spring horizon ---------------- 21.5
11. Claystone, yellowish-gray (5*Y* 7/2); slightly silty; finely micaceous; parallel laminated. Shaly splitting; forms gentle bench and slope. Interval very poorly exposed -------- 17.4

NOTE.—Section transferred on top of unit 10 so that overlying units measured ½ mile southwest.

10. Sandstone, grayish-orange (10*YR* 7/4); weathers same color; very fine grained and silty, well sorted; composed of clear quartz grains, accessory minerals concealed; firmly cemented, highly calcareous; parallel and ripple laminated with irregular cuspate and linear asymmetric ripples indicating a current direction of S. 80° E.; platy and flaggy splitting. Forms continuous slabby ledge which ½ mile southwest becomes incorporated, by gradual color change, with an underlying red unit ------- 3.7
9. Sandstone, grayish-yellow (5*Y* 8/4); weathers same color; composed of clear quartz grains and abundant fine mica flakes; firmly cemented, highly calcareous; parallel bedded and ripple laminated (ripples trend N. 60° W. with wavelength 0.1 ft and amplitude 0.05 ft); shaly splitting. Unit forms a steep rubble-covered slope. Base of unit is an irregular bleached contact --------------------------------- 23.8
8. Siltstone, light-brown (5*Y* 6/4), pale-reddish-brown (10*R* 5/4), and dark-reddish-brown (10*R* 3/4); well sorted; abundant biotite flakes and interstitial limonite, common black accessory minerals; firmly cemented, calcareous; thinly parallel laminated, cuspate ripple marks; shaly splitting; weathers to form rubble-covered bench. Unit is poorly exposed -------------------------- 5.0
7. Sandstone, pale-red (10*R* 6/2) to grayish-red (10*R* 4/2); very fine grained, well sorted; composed of clear quartz grains and abundant biotite plates, other accessory minerals concealed; firmly cemented, highly calcareous; planar to trough sets of crossbeds, parallel and ripple laminated, cuspate ripples. Forms prominent ledge ----------- 7.3
6. Sandstone, siltstone, and minor claystone, interbedded. Sandstone is pale reddish brown (10*R* 5/4); very fine grained; composed of clear quartz grains, abundant brown (limonite?) grains, and abundant black accessory minerals. Siltstone is pale red (10*R* 6/2). Claystone is dark reddish brown (10*R* 3/4). Siltstone and claystone contain abundant biotite flakes. Strata are firmly to poorly cemented throughout, calcareous; parallel bedded, parallel and ripple laminated. Ripple marks have wavelength as large as 0.1 ft and amplitude of 0.015 ft and are slightly asymmetric. Sand-filled mud cracks as much as 6 in. deep occur at top of unit ---------------------- 21.1
5. Siltstone, grayish-orange (10*YR* 7/4); fair sorted; composed of clear quartz grains, abundant biotite flakes, and common black accessory minerals; firmly cemented, moderately calcareous; bedding indistinct, predominantly ripple laminated; shaly and platy splitting. Interval is poorly exposed in rubbly slope -------------------------- 8.4
4. Sandstone, dusky-brown (5*YR* 2/2) to brownish gray (5*YR* 4/1) and pale-yellowish-brown (10*YR* 6/2); weathers very light gray; fine to very fine grained, silty, well sorted; composed of clear quartz grains and abundant brown (limonite?) grains; firmly cemented, highly calcareous; interstitial black petroliferous material gives rock a dark color; parallel bedded, parallel and ripple laminated with sharp contortions; weathers to form cliff ------------- 6.2
3. Sandstone to siltstone, yellowish-gray (5*Y* 8/1) to pinkish-gray (5*Y* 8/1), sparse pale-red (10*R* 6/1); very fine grained and silty, well sorted; composed of clear quartz grains and sparse black accessory minerals; firmly cemented, calcareous; planar cross-stratified to parallel stratified, ripple laminated with laminae contorted in many places; platy to massive splitting; forms a very steep ledgy slope. At base is local 6-in.-thick bed containing grains (some as large as very coarse) and sparse pebbles (some as large as 1 in. in diameter). Pebbles are composed of chert and locally derived siltstone --------------------------------- 30.0

Total ledge-forming member ----------- 208.8

NOTE.—Section offset on top of unit 2 so that overlying units measured 200 ft to south and across creek.

Basal unit:

2. Limy sandstone (50 percent), siltstone (20 percent), and chert (30 percent). Limy sandstone is grayish yellow (5*Y* 8/4) and dusky yellow (5*Y* 6/4); weathers same

U14. SILVER FALLS CREEK—Continued

Moenkopi Formation—Continued

Basal unit—Continued *Feet*

colors; very fine grained, well sorted; composed of subrounded clear quartz grains. Siltstone is pale greenish yellow (10*Y* 8/2) to pale olive (10*Y* 6/2); weathers same colors; sparse medium-grained accessory white mica. Chert is white (*N*9), dense; occurs as irregularly shaped nodules and small lenses elongated parallel to stratification. Siltstone is present only in lower half of unit, where about 40 percent of rock is chert. Limy sandstone is present only in upper half of unit, where about 20 percent of rock is chert. Stratification of limy sandstone and of siltstone is poorly defined but seems to be horizontally thin bedded in parts, possibly horizontally laminated in parts, and possibly contorted in parts. In places, the unit is entirely conglomerate, in other places including this section, the unit is cherty limy sandstone and siltstone. This unit has been recognized throughout most of the Circle Cliffs area by E. S. Davidson and associates (oral commun., 1954). Davidson believes that this unit could be assigned to either the Kaibab or the Moenkopi, but he tentatively considers it a basal unit of the Moenkopi. Locally near our section, the Sinbad Limestone Member of the Moenkopi overlies this unit, but is less than 2 ft thick where present ---------- 20.4

Total basal unit ---------- 20.4

Total Moenkopi Formation ---------- 343.6

Kaibab Limestone (unmeasured):

1. Dolomite or dolomitic limestone, grayish-yellow (5*Y* 8/4) and pale-yellowish-orange (10*YR* 8/6); weathers same colors; dense; common to abundant green particles (apatite?); horizontally thinly bedded; weathers to form lower part of cliff on side of wash. About 10 percent of unit is white or black chert. Chert occurs in irregular masses elongated along bedding planes. Only 5 ft of unit exposed.

Base of section; base of exposure. Base of section on northwest side of wash.

U18. RICHARDSON AMPHITHEATER

[Measured, by J. H. Stewart and D. A. McManus, July 1954, on southwest-facing cliff at point where Colorado River Canyon widens out into Richardson Amphitheater. Southeastern part of sec. 25 (unsurveyed), T. 23 S., R. 23 E., SLM. Grand County]

Top of section; not top of exposure, Chinle Formation is 295 ft. (including units 15–17) and above unit 17 consists mostly of reddish siltstone.

Chinle Formation (incomplete):

17. Siltstone (60 percent) and sandstone to conglomerate (40 percent). Siltstone, pale-reddish-brown (10*R* 5/4) and sparse light-

U18. RICHARDSON AMPHITHEATER—Continued

Chinle Formation (incomplete)—Continued *Feet*

brown (5*YR* 6/4) and yellowish-gray (5 *Y* 8/1), weathers pale reddish brown (10*R* 5/4); well-cemented, calcareous; horizontally and ripple-laminated, common structureless parts. Sandstone to conglomerate, pale-reddish-brown (10*R* 5/4) and common light-greenish-gray (5*GY* 8/1) mottling, weathers same colors, coarse- to very coarse grained sandstone to granule and pebble conglomerate; poorly sorted; composed of rounded pale-reddish-brown (10*R* 5/4) coarse grains to pebbles of siltstone to limy siltstone in a matrix of calcite. Calcite forms as much as 30 percent of rock in places. Sandstone to conglomerate is poorly to well cemented; composed of very thin horizontal beds and very thin planar and trough sets of small- to medium-scale cross-laminae; slabby to massive splitting. Sandstone to conglomerate is present as thin to very thick cosets interstratified with siltstone. Unit as a whole weathers to form steep slopes and ledges ---------- 50.5

16. Siltstone to silty claystone, moderate yellowish brown (10*YR* 5/4) and minor pale-reddish purple (5 *RP* 6/2), weathers pale red (10*R* 6/2) in lower half and grayish orange (10*YR* 7/4) in upper half; firmly cemented, calcareous; tabular unit, structureless; weathers to form steep slope. Unit forms fairly conspicuous light-colored band on exposure. Unit contains 3 percent medium to very coarse rounded grains. Lower half of unit contains 10 percent pale-red (10*R* 6/2) limestone nodules averaging about 1.5 in. in diameter ---------- 9.2

15. Sandstone, pale-red (10*R* 6/2) and very light gray (*N*8), weathers light brown (5*YR* 6/4), coarse- to very coarse grained, fair-sorted; composed of rounded gray grains and minor clear and milky quartz, (calcite completely fills the area between the grains and comprises about 30–40 percent of the rock); poorly cemented, calcareous; lenticular unit, structureless; weathers to form inconspicuous ledge at base of light-colored interval at base of Chinle ---------- 0.6

Total incomplete Chinle Formation ---------- 60.3

Moenkopi Formation:

Sewemup Member:

14. Siltstone (70 percent) to clayey siltstone (30 percent), pale-reddish brown (10*R* 5/4), grayish-red (10R 4/2) and minor light-brown (5*YR* 6/4), weathers pale reddish brown (10*R* 5/4); abundant fine- to medium-grained accessory white and dark mica; firmly to well-cemented, dominantly noncalcareous; horizontally and ripple-laminated, commonly stratification con-

U18. RICHARDSON AMPHITHEATER—Continued

Moenkopi Formation—Continued

Sewemup Member—Continued *Feet*

cealed; weathers to form steep talus-covered slope containing a few small ledges 173.0

Total of Sewemup Member 173.0

Ali Baba Member:

13. Sandstone (65 percent) and siltstone (35 percent). Sandstone, pale-red (5*R* 6/2), weathers same color and pale reddish brown (10*R* 5/4), very fine to medium-grained, common coarse grains, poorly sorted; composed of subangular to subrounded milky and amber grains, abundant medium to very coarse grained accessory dark and white mica; firmly cemented, calcareous; composed of thin trough and planar sets of small-scale cross-laminae, and very thin to thin horizontal beds, minor ripple laminae. Siltstone, grayish-red (10*R* 4/2) and pale-reddish-brown (10*R* 5/4), weathers same colors; abundant very fine grained accessory dark and white mica; well-cemented, noncalcareous; horizontally laminated to thinly laminated and ripple-laminated. Siltstone is mostly present as a set in basal 15 ft. of unit but is also present as thin sets interstratified with the sandstone in the rest of the unit 45.4
12. Sandstone, pale-red (10*R* 6/2 and 5*R* 6/2), weathers pale reddish brown (10*R* 5/4), very fine to fine-grained, fair-sorted; composition masked, common medium- to very coarse grained accessory dark and white mica; well-cemented, slightly calcareous in parts; composed of thin trough sets of dominantly medium-scale cross-laminae and sparse sets of horizontal laminae; weathers to form conspicuous cliff. Unit contains a few (<5 percent) conglomeratic sandstone lenses in basal part of unit. The conglomeratic sandstone contains granules and pebbles of quartz, feldspar, and gneiss in a medium- to coarse-grained matrix 14.0
11. Siltstone, grayish red (10*R* 4/2) and minor greenish gray (5*GY* 6/1), weathers same colors; abundant fine- to very coarse-grained accessory white and dark mica; well-cemented, noncalcareous; horizontally laminated to very thinly bedded; weathers to form minor reentrant 1.4
10. Conglomeratic sandstone, pale-red (5*R* 6/2) grains with white (*N*9) cement, weathers light brown (5*YR* 6/4); granules and pebbles (25 percent) in a coarse- to very coarse grained matrix, interstices entirely filled by white material which is probably gypsum, poorly sorted; appears to be composed mostly of rounded quartz grains; firmly cemented, probably gypsum cement; lenticular unit containing suggestion of medium-scale cross-laminae; weathers to form vertical cliff 2.9

U18. RICHARDSON AMPHITHEATER—Continued

Moenkopi Formation—Continued

Ali Baba Member—Continued *Feet*

9. Siltstone, pale-reddish-brown (10*R* 5/4) and minor grayish-red (10*R* 4/2), weathers pale reddish brown (10*R* 5/4), otherwise same as siltstone in unit 7. Unit contains several very thin lenses of sandstone the same as that in unit 4 29.3
8. Sandstone, same as sandstone in unit 4 7.7
7. Siltstone (90 percent) and sandstone (10 percent). Siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4), weathers pale reddish brown (10*R* 5/4); common fine- to medium-grained accessory white mica; well-cemented, noncalcareous; horizontally and ripple-laminated; platy splitting. Sandstone, grayish-red (5*R* 4/2), weathers pale reddish brown (10*R* 5/4), very fine grained, and rarely fine- to medium-grained, fair-sorted; composition masked, abundant medium-grained accessory white and dark mica; well-cemented, calcareous; ripple-laminated. Sandstone is present as thin sets, interstratified with rest of unit and is present mostly in basal half. Unit as a whole tabular and weathers to form slope 18.5
6. Sandstone and conglomeratic sandstone to conglomerate. Same as unit 4 3.5
5. Siltstone to very fine grained sandstone, grayish-red (5*R* 4/2) and pale-reddish-brown (10*R* 5/4), weathers pale reddish brown (10*R* 5/4); abundant medium- to coarse-grained accessory white and dark mica; well-cemented, calcareous; horizontally and ripple-laminated; weathers to form steep slope 5.7
4. Sandstone (70 percent) and conglomeratic sandstone to conglomerate (30 percent). Sandstone, pale-red (5*R* 6/2) and sparse pale-reddish-brown (10*R* 5/4), weathers pale reddish brown (10*R* 5/4), fine- to coarse-grained, fair- to poorly sorted; composed of subangular to rounded clear and amber quartz; firmly cemented, calcareous; calcite fills all interstitial spaces; composed of thin to thick trough and planar sets of small- to medium-scale cross-laminae. Conglomeratic sandstone and conglomerate, same as sandstone except contains from 10–55 percent granules and pebbles of quartz, feldspar, gneiss, and schist as large as 2 in. in maximum diameter. Unit as a whole is tabular and weathers to form ledgy slope. Conglomeratic sandstone to conglomerate is present as thin to thick sets and cosets interstratified with the rest of the unit. Basal contact is sharp and basal 1.8 ft. of unit is fine-grained ripple- and cross-laminated sandstone 23.8

Total Ali Baba Member 152.2

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U18. RICHARDSON AMPHITHEATER—Continued

Moenkopi Formation—Continued
Tenderfoot Member: *Feet*
Third unit (first, second, and fourth units are absent):
3. Siltstone, pale-reddish-brown (10*R* 5/4), weathers same, common medium-grained accessory dark-green mica; well-cemented, calcareous; composed of thin to thick horizontal sets containing indistinct horizontal laminae; massive splitting; weathers to form most conspicuous vertical cliff in the Moenkopi Formation. Unit contains about 5 percent fine to very coarse subrounded grains which are either disseminated in the siltstone or concentrated in small masses about 1 in. to 2 in. across. Top 15 ft. of unit does not appear to contain these coarser grains ---- 107.5

NOTE.—Section offset on top of unit so that overlying units were measured about 200 ft. to the north.

2. Sandstone, pale-reddish-brown (10*R* 5/4) and sparse light-greenish-gray (5*G* 8/1), weathers same colors, fine- to medium-grained, poorly sorted; composed of subangular to rounded amber quartz grains and abundant medium- to coarse-grained accessory dark mica; firmly cemented, calcareous; composed of indistinct wavy horizontal laminae; weathers to form vertical cliff continuous with that of the overlying unit. Unit contains granules to pebbles of granite and gneiss, same as those in the underlying unit. The pebbles occur dominantly in the lower foot of the unit. Basal contact of unit placed at color change from pinkish colors of Cutler to brownish colors of Moenkopi. This unit is considered to consist of reworked material from the Cutler Formation ---- 4.2

Total of third unit ---- 111.7

Total of Tenderfoot Member ---- 111.7

Total of Moenkopi Formation ---- 436.9

Cutler Formation (unmeasured):
1. Sandstone to conglomeratic sandstone, grayish-red (5*R* 4/2) and sparse light-greenish-gray (5*GY* 8/1), weathers pale red (5*R* 6/2), fine- to medium-grained, poorly sorted; composed of subangular grains; composition masked; about 5 percent medium to very coarse grained white and dark mica; poorly cemented, noncalcareous; stratification poorly developed but appears to be mostly very thin horizontally bedded or possibly very low angle cross-stratified; weathers to form steep slope with distinctive pinkish color. Unit contains common conglomeratic sandstone to conglomerate parts, containing pebbles to boulders of granite and gneiss.

U18. RICHARDSON AMPHITHEATER—Continued

Base of section; not base of exposure. Base of section is N. 62° E. of southeasternmost tip of promontory of Wingate that lies north-northeast of Richardson Amphitheater and north of the Colorado River. Base of section is N. 21° E. of most prominent peak of Castle Towers.

U20. MOAB CANYON

[Measured, by J. H. Stewart and D. A. McManus, June 1954, up point on southeast side of prominent reentrant in cliffs lying west of The Dugway about 6 miles northwest of Moab, NW. cor. sec. 19, T. 25 S., R. 21 E., SLM. Grand County]

Top of section; not top of exposure
Chinle Formation (incomplete): *Feet*
7. Siltstone to sandstone (50 percent) and siltstone (50 percent). Siltstone to sandstone, light-greenish-gray (5*GY* 8/1) and sparse pale-red (5*R* 6/2); weathers brownish gray (5*YR* 4/1); silt to very fine grained sand; common accessory white mica; firmly cemented, highly calcareous; consists of thin sets of ripple laminae interstratified with rest of unit. Siltstone is grayish red purple (5*RP* 4/2); weathers same color; firmly cemented, slightly calcareous; stratification concealed. Siltstone in basal foot contains interstitial swelling clay. Unit as a whole weathers to form ledgy slope. A thin lens of limestone pebble conglomerate occurs 9.2 ft above base of unit ---- 20.1

Basal sandstone unit:
6. Sandstone, light-greenish-gray (5*GY* 8/1), minor grayish-red (5*R* 4/2) and pale-red-purple (5*RP* 6/2); weathers pinkish gray (5*YR* 8/1); medium to very coarse grained, poorly sorted; abundant interstitial white material (probably clay), composed of subangular to angular milky grains, sparse black accessory minerals; poorly cemented, calcareous; stratification poorly exposed but seems to be dominantly thin to very thick trough sets of small- to medium-scale cross-laminae; weathers to form conspicuous light-colored ledge at base of Chinle Formation. Colors in the unit do not follow stratification but form irregular mottles. Unit becomes silty toward top. Unit contains sparse lenses of gritty and pebbly sandstone near base; granules and pebbles are composed of clear quartz and are as large as ¾ in. in diameter. A few thin seams containing malachite were seen at base of unit ---- 21.4

Total basal sandstone unit ---- 21.4

Total incomplete Chinle Formation ---- 41.5

Moenkopi Formation undifferentiated:
5. Siltstone to sandy siltstone, light-brown (5*YR* 6/4) and common pale-reddish-brown (10*R* 5/4), sparse light-greenish-gray (5*GY* 8/1) mottles and laminae; sandy

U20. MOAB CANYON—Continued

Moenkopi Formation undifferentiated—Continued *Feet*

(very fine grained); firmly cemented, calcareous; consists of thin to thick interstratified sets of horizontal laminae and ripple laminae; weathers to form ledgy slope ---------- 123.5

4. Sandy siltstone, light-brown (5*YR* 6/4), common light-greenish-gray (5*GY* 8/1) mottles and laminae; weathers same colors; sandy (very fine grained); common fine-grained accessory white mica; firmly cemented, calcareous; stratification poorly exposed but strata seem to be horizontally laminated and ripple laminated; massive splitting; weathers to form most conspicuous massive cliff in line of section. Base of unit is sharp and horizontal, and marks the most conspicuous lithologic change within the Moenkopi ---------- 14.5

3. Siltstone, grayish-red (10*R* 4/2), light-brown (5*YR* 6/4) and pale-reddish-brown (10*R* 5/4); weathers grayish red (10*R* 4/2); common fine-grained accessory dark mica; well cemented, calcareous; consists of very thin to thick horizontal sets of ripple laminae, horizontal laminae, and sparse structureless material; papery to slabby splitting; weathers to form steep slope. Unit contains about 5 percent very thin light-greenish-gray (5*G* 8/1) horizontal sets. Unit from 100.2 to 105.7 ft contains common thin trough sets of small-scale low-angle cross-laminae. One thin lens of fine-grained sandstone seen in middle of unit ---------- 184.8

2. Sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; generally composed of about 40 percent very fine to very coarse rounded grains in a silt matrix, poorly sorted; composition concealed; firmly cemented, calcareous; consists of indistinct wavy laminae with a wavelength of about 1–2 in. and an amplitude of about ¼–½ in. Unit weathers to form a slope. Basal contact of unit is sharp. Unit is similar in lithology to the Hoskinnini Member, is tentatively correlated with the Hoskinnini ---------- 0.8

Total Moenkopi Formation undifferentiated ---------- 323.6

Cutler Formation (probably laterally continuous with the Cedar Mesa Sandstone Member) (unmeasured):

1. Sandstone, moderate-reddish-brown (10*R* 4/6) and pale-red (5*R* 6/2); weathers same colors; fine to medium grained, common coarse grains, poorly sorted; composed of subangular to angular grains; composition mostly concealed, abundant medium- to coarse-grained accessory dark and white mica; poorly to firmly cemented, calcareous; consists of thin to very thick trough and planar sets of small- to large-scale cross-laminae; weathers to form cliff. Pale-red parts of unit are coarser grained and form cosets generally about 20 ft thick interstratified with remainder of unit. Only top 30 ft of unit examined.

Base of section; not base of exposure.

U22. KANARRAVILLE

[Measured, by J. H. Stewart and F. G. Poole, October 1955, near Camp Creek about 3 miles south of Kanarraville. Base of section is halfway between Camp Creek and Wayne Canyon on the Hurricane Cliffs. Section continues to east with several offsets, and top of section is about 0.5 mile north of Camp Creek. Sec. 10, T. 38 S., R. 12 W., SLM. Iron County]

Top of section; top of good exposure. Top of section is S. 88° E. from point where U.S. Highway 91 crosses Camp Creek and about 0.5 mile north of Camp Creek.

Chinle Formation (incomplete):

Shinarump Member (incomplete) (unmeasured):

13. Sandstone (95 percent) to conglomerate (5 percent), very pale orange (10*YR* 8/2) and grayish-orange (10*YR* 7/4); weathers same colors. Sandstone, fine to very coarse grained, fair to poorly sorted, composed of angular to subrounded clear and milky quartz and sparse black accessory minerals, common interstitial clay; firmly to poorly cemented, calcareous, some limonite cement; contains common silicified logs; consists of thin trough and planar sets of small- and medium-scale cross-strata and thin to thick horizontal beds. Conglomerate, which grades to conglomeratic sandstone, consists of granules, pebbles, and sparse cobbles of red, white, and gray quartz, quartzite, and chert set in a sandstone matrix. Granules and pebbles are concentrated in thin to thick lenses of conglomerate as well as being disseminated irregularly in the sandstone. Largest cobble seen was 3 in. in maximum diameter. Unit weathers to form cliff in lower part and long dip slope in upper part.

Moenkopi Formation:

Upper red member:

12. Siltstone *type 1* (40 percent) and *type 2* (60 percent). *Type 1* is similar to *type 1* siltstone of unit 11 except it is mostly in thick to very thick horizontal beds. *Type 2* is pale brown (5*YR* 5/2) to pale reddish brown (10*R* 5/4); weathers same colors and light brown (5*YR* 6/4); coarse silt, sparse very fine grain accessory white mica; well cemented, calcareous; consists of horizontal laminae and ripple laminae, stratification difficult to determine; massive splitting. *Type 2* siltstone forms basal one-third of unit and a 10-ft-thick ledge about two-thirds of way up in unit. From a distance *type 2* siltstone appears as smooth bare rock ledges

U22. KANARRAVILLE—Continued

Moenkopi Formation—Continued

Upper red member—Continued — *Feet*

with many rounded knobs. Unit as a whole weathers to form steep slope with ledges on *type 2* siltstone — 73.6

11. Siltstone *type 1* (60 percent) and *type 2* (40 percent). *Type 1*, grayish-red (10*R* 4/2) and sparse light-greenish-gray (5*GY* 8/1), very thin color bands; weathers same colors; fine silt; common very fine grained accessory white mica; well cemented, noncalcareous; horizontally thinly laminated to thin bedded. *Type 2*, pale-brown (5*YR* 5/2) and minor light-brown (5*YR* 6/4); weathers same colors; coarse silt, sandy (very fine grained); common very fine grained white mica; well cemented; calcareous; ripple laminated. One 5-ft-thick lens containing low-angle inclined beds near top of unit. *Type 2* siltstone occurs in sets 0.5–5 ft thick interstratified with *type 1* siltstone. Unit as a whole weathers to form steep slope with small ledges on *type 2* siltstone — 144.1

10. Silty sandstone to sandy siltstone, light-brown (5*YR* 6/4), minor yellowish-gray (5*Y* 8/1) and light-greenish-gray (5*GY* 8/1); weathers same colors; grades from coarse silt to very fine grained sand, well sorted; composed of subrounded clear and amber-stained quartz and abundant black accessory mineral; poorly cemented, slightly calcareous; horizontally laminated in lower half, consists of thin wedge planar sets of medium-scale low-angle cross-laminae in upper half; massive splitting; weathers to form ledge. Unit forms prominent lighter colored, massive ledge as seen from a distance. Base of unit is flat — 31.6

Total upper red member — 249.3

Shnabkaib Member:

9. Siltstone (75 percent) and gypsum to silty gypsum (25 percent). Siltstone, grayish-red (10*R* 4/2) and greenish-gray (5*GY* 6/1); weathers pale reddish-brown (10*R* 5/4) and light-greenish-gray (5*GY* 8/1); common very fine grained accessory white mica; firmly cemented; noncalcareous; mostly horizontally laminated, but a few ripple laminae seen. Gypsum to silty gypsum, similar to that in underlying unit; about 3 percent of unit is composed of white very finely crystalline structureless gypsum occurring in very thin horizontal beds; rest of gypsum contains varying amounts of silt and is horizontally laminated. Unit seems to contain all gradations from siltstone to gypsum, therefore an estimate of the amount of silt in the gypsum is difficult to make. Unit as a whole weathers to form steep slope. Unit distinguished from underlying unit by abundance of greenish-gray layers. Fifty percent of the lower three-fourths of unit is greenish-gray. Upper one-fourth of unit contains less gypsum and is only about 20 percent greenish-gray; it could be included in the overlying upper red member. Subdivision of the interval between the top of the Virgin Limestone Member and the base of the upper red member into members is arbitrary — 416.0

Total Shnabkaib Member — 416.0

NOTE.—Section offset on top of unit 8 so that overlying units were measured 1,000 ft north of underlying units.

Middle red member:

8. Siltstone (80 percent) and gypsum to silty gypsum (20 percent). Siltstone, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), and dark-reddish-brown (10*R* 3/4); weathers pale reddish brown (10*R* 5/4); sparse very fine grained accessory white mica; firmly to well cemented, noncalcareous; consists of laminae ranging in thickness from 0.1 to several millimeters, stratification locally concealed. Gypsum to silty gypsum, white (*N*9), pinkish-gray (5*YR* 8/1), pale-red (10*R* 6/2), and light-greenish-gray (5*GY* 8/1); weathers same colors; fibrous and very finely crystalline; well cemented; occurs as thin laminae to laminae and very thin to thick sets of horizontal laminae interstratified with the siltstone. Highly gypsiferous part of unit forms white and greenish-gray color bands on outcrop. Unit as a whole weathers to form steep slope with a dip slope in lower 30 ft. A thin bed of light-greenish-gray silty limestone 10 ft above base of unit may belong in the Virgin Limestone Member, however it does not seem to be continuous along the exposure — 335.8

Total middle red member — 335.8

Virgin Limestone Member:

7. Limestone and siltstone. Limestone is light gray (*N*7), medium light gray (*N*6), and minor greenish gray (5*GY* 6/1); weathers same colors and very pale orange (10*YR* 8/2); dense; well cemented; very thin to thick horizontally bedded. Limestone contains a few poorly preserved pelecypods. Siltstone is greenish

U22. KANARRAVILLE—Continued

Moenkopi Formation—Continued

Virgin Limestone Member—Continued | Feet

gray (5*GY* 6/1) and brownish gray (5*YR* 4/1); weathers same colors; common very fine accessory white mica; well cemented, calcareous; horizontally thinly laminated to laminated, sparse ripple laminated parts; platy splitting in part. Unit weathers to form ledges on limestone and slopes on siltstone. Top of unit placed at change from gray below to red above. Detailed lithology: 0–9.2 ft, limestone; 9.2–16.1 ft, siltstone; 16.1–37.1 ft limestone; 37.1–68 ft, siltstone; 68–72.6 ft limestone; 72.6–89.4 ft, siltstone; 89.4–94 ft, limestone; 94–115 ft, siltstone 115.0

Total Virgin Limestone Member 115.0

NOTE.—Section offset on top of unit 6—base of Virgin Limestone Member—so that overlying units were measured north of Camp Creek about 2,000 ft northeast of underlying units. Unit 6 was measured up to point about 500 ft south of Camp Creek.

Lower red member:

6. Siltstone (95 percent) and gypsum (5 percent). Siltstone, grayish-red (10*R* 4/2) and minor pale-brown (5*YR* 5/2); weathers pale reddish brown (10*R* 5/4); abundant very fine grained accessory white mica; firmly cemented, noncalcareous; stratification commonly concealed, but where seen is horizontally thinly laminated to laminated. Gypsum, pinkish-gray (5*YR* 8/1), white (*N*9), minor light-greenish-gray (5*GY* 8/1); weathers pinkish gray (5*YR* 8/1) and white (*N*9); very finely crystalline; well indurated; occurs as horizontal laminae interstratified with siltstone, some contorted laminae. Gypsum is most abundant in lower half of unit. Unit contains horizontal sets from 125.8 to 128.3 and 133.1 to 138.1 ft of very pale orange (10*YR* 8/2) ripple-laminated sandstone composed of very fine grains of gypsum 305.1

Total lower red member 305.1

Timpoweap Member:

5. Siltstone (95 percent) and limestone (5 percent). Unit poorly exposed. Siltstone is similar to siltstone in unit 3, except stratification entirely concealed. Limestone, medium-gray (*N*5) and yellowish-gray (5*Y* 8/1); weathers same colors, dense to very finely crystalline; well cemented; horizontally thin to very thin bedded. Limestone occurs as very thin to thick sets interstratified with siltstone. Highest limestone is 6 ft below top of unit. Some limestone contains poorly preserved pelecypods. Unit as a whole weathers to form a steep slope. Top of unit placed at color change from yellows of this unit to reds of overlying unit. Thickness of unit may be in error by as much as 20 percent .... 144±

U22. KANARRAVILLE—Continued

Moenkopi Formation—Continued

Timpoweap Member—Continued | Feet

4. Limestone, light-gray (*N*7) and minor grayish-orange (10*YR* 7/4); weathers same colors; dense, well cemented; horizontally thinly to very thickly bedded; weathers to form ledge. Unit seems to be highly variable in thickness along exposure. Thickness in line of section possibly in error by 10–20 percent owing to local structural complexities and difficulty in estimating dip ...... 29±

3. Siltstone, yellowish-gray (5*Y* 7/2) and grayish-yellow (5*Y* 8/4); weathers same colors; poorly to firmly cemented, calcareous; stratification mostly concealed, but where seen is horizontally laminated; weathers to form steep slope. A thin limestone bed 23 ft above base of unit contains abundant poorly preserved pelecypods. Unit measured in area that has many small faults and folds; thickness, therefore, may be in error by 30–40 percent. About 2,000 ft south of line of section, unit grades laterally into limestone .... 108±

NOTE.—Section offset on top of unit 2 so that overlying units were measured about 1,000 ft north of underlying units.

2. Conglomerate and limestone. Conglomerate, yellowish-gray (5*Y* 8/1) and minor grayish-orange (10*YR* 7/4); weathers same colors; composed of rounded to angular white and minor gray medium grains to cobbles, mostly pebbles, of chert set in a lime matrix; well cemented; structureless, some horizontal bedding planes. Chert cobbles are as large as 9 in. in maximum diameter. Limestone, same fresh and weathered colors as conglomerate except light gray (*N*7) in some parts; dense; well cemented; some beds may be oolitic; structureless in part, horizontally thin bedded in part. Unit as a whole weathers to form cliff. All gradations seen from a conglomerate containing 60 percent pebbles and cobbles to a pure limestone. Basal 95 ft of unit is entirely conglomerate to conglomeratic limestone. Unit from 95 to 139 ft above base is 90 percent limestone and 10 percent conglomerate to conglomeratic limestone. The conglomerate to conglomeratic limestone occurs in thin to very thick horizontal sets interstratified with the limestone. Unit is entirely limestone from 139 to 169 ft. Coarsest conglomerate

U22. KANARRAVILLE—Continued

Moenkopi Formation—Continued

Timpoweap Member—Continued *Feet*

occurs at base of unit. The size of the clasts and amount of conglomerate decrease upward in unit. A few pelecypods occur in top 30 ft of unit ---- 169.0

Total Timpoweap Member ---- 450±

Total Moenkopi Formation ---- 1,871±

Kaibab Limestone:

Beta member:

1. Limestone, light-gray (*N*7) to very light gray (*N*8), and sparse yellowish-gray (5*Y* 8/1); weathers light gray (*N*7), dense, minor medium to coarsely crystalline parts; well cemented; very thin horizontally bedded in lower part and very thin to thin bedded in upper part; weathers to form cliff. Unit is light gray (*N*7) in contrast to grayish orange (10*YR* 7/4) of overlying Timpoweap Member of Moenkopi Formation. As much as 40 percent of unit is irregular gray and white chert nodules as much as a foot in maximum diameter. Chert is sparse in top 20 ft of unit. Lower half of unit has some fossiliferous layers containing crinoid stems, pelecypods, and bryozoa. Estimated thickness of exposed Kaibab Limestone ---- 125

Base of section; base of exposure. Base of section is S. 54° E. from mountain about 5 miles northwest of mouth of Taylor Canyon.

U25. BEARS EARS

[Measured, by J. H. Stewart, May 1953. Lower part measured on northwest side of western part of Maverick Point, sec. 34, T. 36 S., R. 18 E., SLM; upper part measured up west end of Maverick Point at place where road crosses Moenkopi Formation, sec. 3 (unsurveyed), T. 37 S., R. 18 E., SLM. San Juan County]

Top of section; top of good exposure

Chinle Formation (incomplete):

Monitor Butte Member (incomplete):

20. Sandstone, very pale orange (10*YR* 8/2); weathers grayish orange (10*YR* 7/4); fine grained, well sorted; composed of subrounded clear quartz and common black accessory minerals, abundant fine-grained white mica, abundant limonite spots the size of coarse grains; well cemented, calcareous; unit is tabular, consists of thick trough sets of low-angle medium- to large-scale cross-laminae; platy to slabby splitting; weathers to form ledge and the cap on western part of Maverick Point. Unit examined along road.

19. Siltstone, *type 1* (50 percent) and *type 2* (50 percent). *Type 1*, similar to unit 18 except it does not contain grayish purple. *Type 2*, dusky-yellow (5*Y* 6/4); weathers grayish orange (10*YR* 7/4); abundant

U25. BEARS EARS—Continued

Chinle Formation—Continued

Monitor Butte Member—Continued *Feet*

fine-grained white mica; well cemented, noncalcareous; ripple laminated; platy splitting. *Type 1* interstratified with thin to very thin sets of *type 2*. Proportion of *type 1* and *2* varies along outcrop ---- 5.0

18. Siltstone, light-bluish-gray (5*B* 7/1), light-greenish-gray (5*G* 8/1), grayish-purple (5*P* 4/2); weathers same colors; poorly to firmly cemented, noncalcareous; stratification and splitting concealed; weathers to form slope. Thin beds of moderate-yellow (5*Y* 7/6) with minor very light gray (*N*8) well-cemented siltstone at 23.6 and 29.3 ft above base of unit. Poorly exposed in lower 20 ft. Exposures in roadcut ---- 76.7

17. Siltstone, grayish-purple (5*P* 4/2); weathers same color; firmly cemented, noncalcareous; stratification and splitting concealed. West of section a few thin lenticular sets of sandstone, probably Shinarump Member, are present at this horizon ---- 0.3

Total incomplete Monitor Butte Member ---- 82.0

Total incomplete Chinle Formation ---- 82.0

Unconformity. Abrupt change in lithology. No scours or angular discordance seen.

NOTE.—Contact between Chinle and Moenkopi placed at color change from greenish gray of the Chinle to reddish brown of the Moenkopi. In detail, the contact is placed below a purple band characteristic of basal Chinle—where Shinarump is absent—and above a yellowish-gray band that is probably an altered zone at the top of the Moenkopi.

Moenkopi Formation:

Upper slope-forming member:

16. Silty claystone to siltstone, grayish-red (10*R* 4/2), abundant light-greenish-gray (5*GY* 8/1) bands and mottles; weathers pale reddish brown (10*R* 5/4); common very fine grained white mica; firmly cemented, noncalcareous; unit is tabular, horizontally laminated; platy splitting; weathers to form slope. Sparse thin sets of well-cemented (calcareous), horizontally and ripple-laminated siltstone occur interstratified with rest of unit. Top 0.2 ft, which is altered to moderate yellow (5*Y* 7/6), may be Chinle ---- 53.7

Total upper slope-forming member ---- 53.7

Ledge-forming member:

15. Silty sandstone to sandy siltstone, pale-red (10*R* 6/2) and minor light-brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4), very fine grained with minor silt, to silty with minor very fine sand grains; firmly cemented, calcareous; unit is tabu-

U25. BEARS EARS—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

lar, consists of ripple laminae with one thin trough set of medium-scale cross-laminae seen; massive splitting; weathers to form ledge. Common thin clayey siltstone sets form small recesses in ledge ---- 10.9

14. Silty claystone to clayey siltstone, grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); firmly cemented, noncalcareous; unit is tabular, stratification and splitting mostly concealed; platy splitting seen locally; weathers to form slope. Thin sets of well-cemented calcareous horizontally laminated siltstone occur rarely ----- 30.4

13. Sandy siltstone to sandstone, pale-red (10*R* 6/2) and sparse light-brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4); silt with minor very fine sand grains to very fine grained; firmly cemented, calcareous; unit is tabular, consists of ripple laminae and minor thin to thick trough sets of small- to medium-scale cross-laminae; platy and massive splitting; weathers to form rounded ledge ---------------------------- 12.8

12. Sandstone, very pale orange (10*YR* 8/2) and pale-red-purple (5*RP* 6/2), sparse pale-red (10*R* 6/2) and grayish-red (10*R* 4/2); weathers very pale orange (10*YR* 8/2) and pale red purple (5*RP* 6/2) with characteristic overall light and purplish color; fine to very fine grained, well sorted; composed of subrounded clear quartz and orange mineral (10 percent) and abundant green accessory mineral; firmly cemented, calcareous; abundant interstitial hematite locally near base where seen along road, abundant clay galls as large as 0.5 ft in diameter near base; unit is tabular, consists of horizontal thin laminae to laminae and thin to thick trough sets of cross-laminae; massive splitting; weathers to form most prominent ledge in Moenkopi. At two places unit contains irregular set(?) of grayish-red (10*R* 4/2) siltstone several feet high and 5–15 ft long. Base of unit fills channels cut at least 1 ft into underlying unit ----------------- 35.8

11. Silty sandstone, light-brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4); very fine grained with minor silt; common very fine grains of white mica; well cemented, calcareous; unit is tabular, consists of ripple laminae in lower part and thin trough sets of small-scale cross-laminae in upper part; massive splitting; weathers to form cliff along with unit above. Top 0.4 ft of unit is siltstone and weathers to form niche. A thin light-greenish-gray (5*GY* 8/1) band occurs at base of unit ---------------------------- 5.3

10. Clayey siltstone to sandy siltstone, grayish-red (10*R* 4/2) and light-brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4); sandy (very fine grained) in parts; firmly cemented, calcareous in parts, clay binding in parts; unit is tabular, consists of horizontal thin laminae and laminae, and sparse ripple laminae; contains some very thin to very thick horizontal sets of slightly different type of siltstone and sparse light-greenish-gray (5*GY* 8/1) sets; platy to flaggy splitting; weathers to form slope --- 29.0

9. Sandy siltstone to sandstone, pale-red (10*R* 6/2); weathers pale reddish brown (10*R* 6/4); silt with minor very fine sand grains to very fine grained; well cemented, calcareous; unit is tabular, consists dominantly of horizontal thin laminae, minor ripple laminae, and thin trough sets of low-angle, small-scale cross-laminae; massive splitting; weathers along with unit below to form lowest prominent ledge in Moenkopi -- 15.0

8. Sandstone, very pale orange (10*YR* 8/2) and grayish-orange (10*YR* 7/4); weathers grayish orange pink (5*YR* 7/2); medium grained, well sorted; composed of subrounded to rounded clear quartz and sparse black accessory minerals; firmly cemented, calcareous, abundant limonite stains; consists of thin to thick trough sets of small- to medium-scale cross-laminae; blocky splitting; weathers to form basal part of ledge that includes overlying unit. Base of unit fills channels cut as much as 1 ft. locally into underlying unit. Unit seems to pinch out along outcrop on either side of section -------------------------------- 2.5

Total ledge-forming member ----------- 141.7

Lower slope-forming member:

7. Claystone to siltstone, grayish-red (10*R* 4/2); weathers grayish red (10*R* 4/2) and pale reddish brown (10*R* 5/4); abundant very fine grained white mica in parts; firmly cemented, clay binding in parts, calcareous in parts; unit is tabular stratification and splitting concealed; weathers to form rubble-covered slope. Unit is poorly exposed -------------------------------- 23.5

6. Sandstone and siltstone. Sandstone, grayish-orange (10 *YR* 7/4), yellowish-gray (5*Y* 8/1), and minor pale reddish-brown (10*R* 5/4); weathers grayish orange (10*YR* 7/4); fine grained, fair sorted; composed of subrounded to rounded clear quartz and sparse green and black accessory minerals; poorly to firmly cemented, calcareous; composed of thin to very thin trough and planar sets of small-scale cross-laminae and very thin beds; flaggy to slabby splitting. Siltstone, pale reddish brown (10*R* 5/4); weathers same color; micaceous; firmly cemented, noncalcareous; horizontally and

U25. BEARS EARS—Continued

	Feet
Moenkopi Formation—Continued	
Lower slope-forming member—Continued	
ripple laminated, occurs as thin to thick sets interstratified with sandstone; platy splitting. Content of sandstone and siltstone varies along outcrop, but sandstone generally dominates. Unit as a whole is tabular and weathers to form flaggy and slabby ledges at top of cliff of Hoskinnini Member. Unit probably equivalent to basal conglomerate of Moenkopi in the White Canyon area. Basal contact conformable with unit below	3.0
Total lower slope-forming member	26.5
Hoskinnini Member:	
5. Sandstone to siltstone, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), and sparse to abundant light-greenish-gray (5*GY* 8/1) blebs; weathers pale reddish brown (10*R* 5/4); silt and fine- to medium-grained sand, poorly to fair sorted; composed of rounded to well-rounded clear quartz and sparse orange and black accessory minerals, silty parts micaceous; firmly cemented, calcareous; unit is tabular, consists of horizontal sets containing deformed material giving "gneissoid" appearance. Unit is dominantly massive splitting and weathers to form cliff and steep ledgy slope. Sandstone is dominant in lower half and contains interbedded thin to very thin sets of siltstone, whereas siltstone is dominant in upper half. Sandstone grades from sandy siltstone (rounded to well-rounded medium to fine grains in a silt matrix) to siltstone. Unit is unlike the one below because it contains prominent very thin to thick sets that weather into recesses and is dominantly siltstone in some parts. Base of unit is marked by lowest thin reentrant and locally by light-colored band. Base of unit may be horizon of the "crinkly bed" of Baker (1936, p. 39) in Monument Valley	30.3
4. Silty sandstone, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), with common to abundant irregular mottles and beds of yellowish-gray (5*Y* 8/1); weathers pale reddish brown (10*R* 5/4); fine to medium grained, minor silt and very fine grains, poorly to fair sorted; composed of subrounded to rounded fine to medium and sparse coarse frosted grains of clear quartz in silt matrix; firmly cemented; slightly calcareous; unit is tabular, consists of thick to very thick sets probably containing highly deformed material giving a "gneissoid" appearance. Small faults and intricate folds, which developed shortly after deposition of rock, occur rarely. West of section entire interval of Hoskinnini deformed into large-scale folds, locally overturned. Unit has massive splitting and weathers to form cliff with many smooth-surfaced, horizontal ribs. Several feet at bottom is yellowish gray (5*Y* 8/1). Basal few inches contains common very coarse well-rounded frosted clear quartz grains	36.6
Total Hoskinnini Member	66.9
Total Moenkopi Formation	288.8

NOTE.—Section offset, so that overlying units measured about ½ mile southeast of underlying units.

Unconformity. Abrupt change in lithology. The Hoskinnini fills channels cut a few inches to possibly a foot into the underlying Organ Rock.

NOTE.—Contact between Hoskinnini Member of Moenkopi and Organ Rock Tongue of Cutler is placed at lithologic change from siltstone of the Organ Rock to fine-grained sandstone (with abundant well-rounded medium to very coarse grains) of the Hoskinnini. Stratification of Organ Rock is mostly massive and it weathers to form an earthy slope, whereas the Hoskinnini looks "gneissoid" and it weathers to form a cliff. Bottom few feet of Hoskinnini is altered to light greenish gray that forms a conspicuous color band.

	Feet
Cutler Formation (incomplete):	
Organ Rock Tongue:	
3. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; uncommon very fine grained white mica; well cemented, noncalcareous; appears structureless, massive splitting; weathers to form steep earthy slope. Unit contains abundant very thin light-greenish-gray (5*GY* 8/1) horizontal bands, very thin bands along fractures, and irregular mottles. Horizontal bands are the most common and suggest horizontal stratification	145.4
2. Covered. Outcrops of this unit about 1 mile to east and west indicate rock similar to that in overlying unit	104.4
Total Organ Rock Tongue	249.8

Cedar Mesa Sandstone Member (incomplete) (unmeasured):

1. Sandstone, yellow-gray (5*Y* 8/1) and common pale-reddish-brown (10*R* 5/4), fine-grained, well-sorted; composed of subrounded to rounded clear quartz and sparse black accessory minerals; poorly to firmly cemented, calcareous; common medium- to light-gray (*N*5 to *N*7) aphanitic limestone nodules as large as 8 in. in diameter; stratification poorly exposed, but probably dominantly trough sets of small- to large-scale low-angle cross-laminae, possibly sparse horizontal beds and laminae; dominantly

U25. BEARS EARS—Continued

Cutler Formation—Continued

Cedar Mesa Sandstone Member—Continued *Feet*

massive splitting and weathers to form steep bare rock slopes and ledges. Only upper 20 ft of unit examined.

Total incomplete Cutler Formation measured ---------------------------- 249.8

Base of section; not base of exposure.

U26. BRIDGER JACK MESA

[Measured, by J. H. Stewart, O. B. Raup, and A. C. Gorveatt, September 1953, in head of tributary of Lavender Creek and up southwesternmost point of Bridger Jack Mesa, sec. 25 (unsurveyed), T. 32 S., R. 20 E., SLM. San Juan County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Moss Back Member (unmeasured): *Feet*

19. Cliff-forming light-colored sandstone at least 100 ft thick.

Monitor Butte(?) Member:

18. Silty claystone, greenish-gray (5*GY* 6/1), dark-greenish-gray (5*GY* 4/1), and medium-gray (*N*5); firmly cemented, noncalcareous; structureless; weathers to form reentrant. Unit is placed in the Chinle Formation because it contains a basal very thin lenticular sandstone that is medium to very coarse grained, clayey, poorly sorted and composed of subangular clear quartz and common orange accessory mineral. This sandstone has common copper stain and commonly contains pebbles of silty claystone similar to that in rest of unit ---------------------------------- 4.2

Total Monitor Butte(?) Member------ 4.2

Total incomplete Chinle Formation---- 4.2

Moenkopi Formation:

Upper slope-forming member:

17. Silty claystone to clayey siltstone, grayish-red (10*R* 4/2), medium-dark-gray (*N*4), pale-yellowish-green (10*GY* 7/2), and minor grayish-yellow (5*Y* 8/4); grayish red is dominant color in lower few feet of unit; other colors gradually replace grayish red vertically so that top few feet of unit is entirely green, gray, and yellow; weathers same colors; sparse fine-grained accessory white mica; firmly cemented, noncalcareous; no medium to coarse grains were seen; seems to be horizontally very thinly to thinly bedded, although stratification is poorly exposed; weathers to form slope. Unit is placed in the Moenkopi Formation because it seems to grade downward into the Moenkopi and it contains horizontal bedding planes. Except for color, this unit is similar to underlying unit------------ 8.9

16. Silty claystone to siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4) and sparse greenish-gray (5*GY* 6/1); weathers pale reddish brown (10*R* 5/4); common to abundant fine-grained accessory white mica; firmly cemented, noncalcareous with some parts slightly calcareous; stratification poorly exposed but seems to be dominantly horizontally laminated; weathers to form steep rubble-covered slope. Sparse thin resistant siltstone and sandy siltstone sets---------------------- 38.5

U26. BRIDGER JACK MESA—Continued

Moenkopi Formation—Continued

Upper slope-forming member—Continued *Feet*

Total upper slope-forming member----- 47.4

Ledge-forming member:

15. Sandy siltstone, grayish-red (10*R* 4/2), pale-reddish-brown (10*R* 5/4), minor light-brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4); sandy (very fine grained); common medium-grained accessory white mica; firmly cemented, calcareous; ripple laminated with minor horizontal laminae as thin to very thick sets; sandy sets are separated from thin silty sets, locally, by surfaces of erosion (one scour seen is 2 ft deep); about 30 percent of the unit consists of small-scale deformed laminae; unit weathers to form cliff and many ledges. Unit as a whole forms second most prominent ledge in Moenkopi-------- 39.9

14. Sandy siltstone, similar to typical part of unit 10; weathers to form slope---------- 26.5

13. Silty sandstone and minor sandy siltstone, light-brown (5*YR* 6/4); weathers light brown (5*YR* 5/6); very fine grained with minor silt, and minor siltstone with very fine sand grains; uncommon very fine grained accessory white mica; firmly cemented, calcareous; unit is tabular, consists of ripple laminae and minor horizontal laminae; weathers to form most conspicuous cliff in Moenkopi Formation----- 26.9

12. Siltstone to sandy siltstone, similar to typical part of unit 10. One thin set of sandstone consisting of small-scale cross-laminae occurs near middle of unit and is similar to sandstone described in unit 10. Unit weathers to form slope------------------ 33.6

11. Sandstone, yellowish-gray (5*Y* 8/1) and minor pale-red (10*R* 6/2); weathers same colors; very fine grained, well sorted; firmly cemented, slightly calcareous; unit is tabular, consists of horizontal and ripple laminae, indistinct trough sets of low-angle medium-scale cross-laminae and minor small-scale deformed stratification; weathers to form minor ledge. Unit contains sparse fine- to medium-grained sandstone near base. Basal contact is surface of erosion with scours cut as deep as 0.5 ft--- 5.5

Total ledge-forming member----------- 132.4

U26. BRIDGER JACK MESA—Continued

Moenkopi Formation—Continued

Lower slope-forming (?) member: *Feet*

10. Siltstone to sandy siltstone, grayish-red (10*R* 4/2), pale-reddish-brown (10*R* 5/4), and minor very pale orange (10*YR* 8/2); weathers pale reddish brown (10*R* 5/4); sandy (very fine grained) in parts; firmly to well cemented, noncalcareous with minor slightly calcareous parts; unit is tabular, consists of very thin to thin horizontal sets of horizontal and ripple laminae and minor very thin horizontal beds; platy to slabby splitting; weathers to form steep slope. Basal 1 ft of unit contains several resistant sets of very pale orange siltstone that weather to form minor ledge. About 1 percent of unit is fine to very fine grained sandstone. Sandstone, very pale orange (10*YR* 8/2); composed of clear quartz and sparse black accessory minerals; consists of very thin to thin sets of horizontal and ripple laminae interstratified with rest of unit __ 37.1

Total lower slope-forming (?) member __ 37.1

Hoskinnini Member:

9. Siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2), common yellowish-gray (5*Y* 8/1) spots; weathers pale reddish brown (10*R* 5/4); uncommon fine-grained accessory white mica; firmly cemented, slightly calcareous; unit is tabular, consists of thin to thick horizontal sets containing faint horizontal or ripple laminae that seem to be partly distorted and slightly wavy; weathers to form slope. Sparse medium grains seen in bottom few feet. Unit is transitional between the Hoskinnini Member and the lower slope-forming (?) member. It does not contain horizontal or ripple-laminated sets similar to those in the lower slope-forming (?) member nor does it contain common medium to coarse grains that are characteristic of the Hoskinnini. However, the bedding is similar to that in the Hoskinnini. Unit probably correlates with top (unit 24) of Hoskinnini Member at Lockhart Canyon (loc. U32) __ 20.8

8. Siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); firmly cemented, calcareous; stratification similar to unit 6. Top 1.9 ft of unit is silty sandstone similar to silty sandstone described in unit 6. Unit weathers to form smooth ledge __ 10.5

7. Siltstone and sandy siltstone, grayish-red (10*R* 4/2) with minor pale-reddish-brown (10*R* 5/4), yellowish-gray (5*Y* 8/1), and light-greenish-gray (5*GY* 8/1); grays form three distinct color bands in lower half of unit and many indistinct bands and mottles in upper half of unit; unit otherwise similar to underlying unit except it has fewer medium to coarse grains and contains common pure siltstone. A very thin slightly wavy bed at 2.4 ft above base of unit is composed of white (*N*9) fine-grained limestone that is similar to the "crinkly bed" of Baker (1936, p. 39) in Monument Valley. Unit as a whole is tabular and weathers to form slope __ 20.8

6. Silty sandstone to sandy siltstone, pale-reddish brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4) with sparse yellowish-gray (5*Y* 7/2) mottles and one thin band; very fine grained sandstone (with abundant silt) to siltstone (with abundant very fine sand grains); both sandy siltstone and silty sandstone contain 5–20 percent rounded to well-rounded, medium to very coarse grains. Silty sandstone to sandy siltstone is poorly sorted; composition concealed; firmly cemented, slightly calcareous. Unit is tabular, consists of thin to thick horizontal beds or sets containing indistinct wavy laminae that may be either contorted horizontal or ripple laminae; weathers to form two smooth ledges separated by a niche formed on dominantly grayish-red (10*R* 4/2) silty rock __ 59.4

Total Hoskinnini Member __ 111.5

Total Moenkopi Formation __ 328.4

NOTE.—Contact between Organ Rock Tongue of Cutler Formation and Hoskinnini Member of Moenkopi Formation is placed at base of lowest unit containing medium to coarse grains. This slightly wavy contact also marks the top of a conspicuous ledge in the Organ Rock and a color change from reds of the Organ Rock to browns of the Moenkopi. The Hoskinnini directly above the contact contains angular pebbles of siltstone possibly derived from the underlying Organ Rock. Locally the Hoskinnini seems to fill fractures extending several inches down into the Organ Rock.

Cutler Formation (incomplete):

Organ Rock Tongue:

5. Sandstone, pale-red (5*R* 6/2) and minor pale-reddish brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); very fine to fine grained, poorly to fair sorted; composed of angular to subangular clear quartz and minor feldspar, abundant medium- to coarse-grained accessory white and dark mica, other accessory minerals concealed; poorly to firmly cemented, calcareous; unit is tabular, consists of thin trough sets of medium-scale low-angle cross-laminae; weathers to form cliff and most conspicuous ledge in the red-bed sequence. Sandstone

U26. BRIDGER JACK MESA—Continued

Cutler Formation—Continued

Organ Rock Tongue—Continued — Feet

generally contains 2–30 percent irregular white fine to medium grains that may be weathered feldspar and common to abundant silt that occurs interstitially and along laminae planes. Generally one lamina is silty whereas the adjacent one is not. About 8 percent of unit is conglomeratic sandstone with very coarse grains to pebbles of reddish-brown siltstone. A thick set about 30 ft above base and a thin set at top is siltstone similar to underlying unit; lower set is discontinuous along exposure, upper set consists of common thin trough sets of medium-scale cross-laminae and common horizontal laminae — 63.9

4. Siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4) with common light-greenish-gray (5*GY* 8/1) spots; uncommon very fine- to fine-grained accessory white mica; firmly to well cemented, noncalcareous to slightly calcareous; unit is tabular, dominantly structureless with common horizontally laminated parts and one thin coset of trough sets of small- to medium-scale cross-laminae; weathers to form steep rubble-covered slope — 84.6

3. Limy sandstone to silty sandstone, pale-red (10*R* 6/2 and 5*R* 6/2); weathers pale red purple (5*RP* 6/2); unit grades from fine-grained limy sandstone in lower half to very fine grained silty sandstone in upper half, fine-grained part composed of subangular to subrounded clear quartz, accessory minerals concealed; unit contains common grayish-red (10*R* 4/2) claystone in interstices and along stratification planes. Unit is fair sorted; firmly to well cemented, calcareous, horizontally very thinly bedded in lower half grading upward into structureless rock; flaggy splitting in lower half; unit weathers to form steep slope. Unit seems to grade into overlying unit — 14.4

2. Conglomerate, grayish-red (10*R* 4/2) and minor white (*N*9) mottles; weathers grayish red (5*R* 4/2); composed of pebbles and granules and common cobbles set in fine-grained amber-stained quartz matrix; poorly sorted; granules to cobbles composed dominantly of limy sandstone, and, to a lesser extent, of chert, limy sandy siltstone, and probably limestone. Sand matrix forms about 20 percent of rock and contains abundant calcite. Granules to cobbles (as large as 4 in. in diameter) are mostly rounded whereas the sand grains in the matrix are mostly subrounded to rounded. Unit is well cemented, calcareous; structureless; and weathers to form a small ledge. Scours as deep as 3 in. occur along basal contact — 3.3

Total Organ Rock Tongue — 166.2

Cedar Mesa Sandstone Member (incomplete) (unmeasured):

1. Sandstone, very pale orange (10 *YR* 8/2) and light-brown (5*YR* 6/4); weathers same colors; fine to very fine grained, well sorted; composed of subrounded to rounded clear quartz and sparse black accessory minerals; common limonite spots; poorly cemented, calcareous; consists of thin to thick trough sets of medium-scale cross-laminae; platy and massive splitting; weathers to form smooth ledges and cliffs. A thin bed of silty sandstone at 4.4 ft below top is grayish red (10*R* 4/2) with minor light-greenish-gray (5*GY* 8/1) mottles; weathers same colors; very fine grained with minor silt and sparse fine to medium grains; fair sorted; very fine grains are amber-stained quartz; common fine-grained accessory white mica; seems structureless; weathers to form niche. Top 4.5 ft of unit seems structureless; top 10.0 ft of unit contains uncommon light-greenish-gray limestone nodules and stringers. Only top 30 ft of unit examined.

Total incomplete Cutler Formation — 166.2

Base of section, not base of exposure.

U27. COMB WASH

[Measured, by L. C. Craig and T. E. Mullens, June 1951; slightly modified by J. H. Stewart, September 1956. Measured on Comb Ridge about 2.5 miles north of Snake Canyon, long 109°39′ W., lat 37°19′ N. San Juan County]

Top of section; not top of exposure

Chinle Formation (incomplete): — Feet

Petrified Forest and Monitor Butte Members undifferentiated (incomplete):

13. Claystone, silty to fine sandy, light-greenish-gray (5*GY* 8/1) to light-gray (*N*7). Contains common fossilized logs replaced by calcite and minor silica. Unit weathers to form rounded badland hills with hard frothy surface — 54.8

12. Claystone, medium-light-gray (*N*6), silty. Weathers to form distinct grayish-red band with soft frothy slope — 4.2

11. Claystone, sandy and silty; very light gray (*N*8) to medium-light-gray (*N*6); sand as coarse as fine-grain size; hackly fracture. Weathers to form rounded badland hills with steep hard frothy surface that is white at base and light gray at top — 53.1

U27. COMB WASH—Continued

Chinle Formation—Continued

Petrified Forest and Monitor Butte Members undifferentiated—Continued *Feet*

10. Interval poorly exposed. Claystone, silty and sandy (fine grained), grayish red (5*R* 4/2); weathers to form high hard frothy surface covered with nodules of gray sandy limestone as large as 3 in. in diameter. Top contact of unit is poorly exposed, but marks a sharp color break — 41.0

Total incomplete Petrified Forest and Monitor Butte Members undifferentiated (incomplete) — 153.1

Mottled strata:

9. Sandstone, white to light-greenish-gray (5*GY* 8/1) with blackish-red (5*R* 2/2), pale-reddish-brown (10*R* 5/4), grayish-purple (5*P* 4/2), and dark-yellowish-orange (10*YR* 6/6 mottling in upper two-thirds; fine- to very fine-grained, well sorted except for interstitial clay; composed of subangular to subrounded clear quartz, uncommon orange, black, and green accessory minerals; common white interstitial clay; slightly calcareous, firmly cemented; unit forms two subparallel lenticular beds as much as 10 ft thick. Lower bed contains gently dipping festooned laminations of fluvial origin, whereas upper bed is structureless. Lower bed forms a local ledge and upper bed forms a massive rounded ledge. Unit is lenticular and extends 300–500 ft along Chinle-Moenkopi contact — 13.9

Total mottled strata — 13.9

Total incomplete Chinle Formation — 167.0

Moenkopi Formation:

Upper slope-forming member:

8. Sandstone (80 percent), siltstone (15 percent) and claystone (5 percent). Sandstone and siltstone, light-brown (5*YR* 6/4 to 5*YR* 6/5), light-gray mottling seen near contact with Chinle Formation. Unit is similar to underlying unit but differs in percentage of sandstone, siltstone, and claystone. Unit weathers to form minor hogbacks with flaky clay surface in places. Upper surface of unit is beveled by Chinle Formation — 29.2

7. Sandstone (40 percent), siltstone (30 percent) and claystone (30 percent). Sandstone and siltstone, light-brown (5*YR* 6/4, silty to very fine grained sand; composed of subangular clear quartz and common white, green, and orange accessory minerals, finely micaceous; moderately calcareous, poorly cemented; possible ripple lamination seen. Claystone, grayish-red (5*R* 4/2 to 10*R* 4/2); finely micaceous; very fissile, parallel beds 3–10 ft thick. Unit poorly exposed, weathers to form earthy and shaly slope with discontinuous green-mottled sandstone giving unit a horizontal banding — 80.0

Total upper slope-forming member — 109.2

Ledge-forming and lower slope-forming members: (Upper 43.7 ft of unit 6 contains more sandstone than lower 48 ft; therefore, the upper part is correlated with the ledge-forming member and the lower part with the lower slope-forming member.)

6. Sandstone (70± percent) and interbedded claystone (30± percent). Sandstone, light-brown (5*YR* 6/4 to 5*YR* 5/6), pale-green mottling completely discolors some thin beds; very fine to medium grained, fair sorted; composed of subangular to subrounded clear and amber-stained quartz, finely micaceous (white and green) along laminae; highly calcareous; consists of beds 5–15 ft thick containing some indistinct ripple laminae. Claystone, grayish-red (5*R* 4/2 to 10*R* 4/2), some local pale-green mottling; abundant fine mica; noncalcareous; very fissile; consists of beds 6 in. to 3 ft thick; shaly splitting. Unit as a whole is poorly exposed; weathers to form earthy and shaly slope — 91.7

5. Sandstone, very light gray (*N*8) and yellowish-gray (5*Y* 8/1), minor light-greenish-gray (5*GY* 8/1); weathers same colors; very fine to medium grained, sparse coarse grains, fair to poorly sorted; composed of subangular to well-rounded clear quartz and sparse black and green accessory mineral; well cemented, calcareous; consists of very thin wedge and tabular planar sets and possibly a few trough sets of low-angle small-scale cross-laminae, minor parallel ripple marks; weathers to form conspicuous light-colored ledge — 1.6

Total ledge-forming and lower slope-forming members — 93.3

Hoskinnini Member:

4. Siltstone to sandstone, light-brown (5*YR* 5/6) and pale-reddish-brown (10*R* 5/4), minor light-greenish-gray (5*GY* 8/1) thin bands and mottles; weathers same colors; unit has all combinations of fine silt to coarse sand grains, however most of unit is sandy siltstone to silty sandstone containing poorly sorted very fine sand grains. Sand fraction composed of subrounded to well-rounded clear and amber-stained quartz and sparse orange and green accessory minerals and contains common dark-green accessory white mica. Unit is firmly cemented, slightly to highly calcareous. Stratifica-

U27. COMB WASH—Continued

Moenkopi Formation—Continued
Hoskinnini Member—Continued — Feet

tion is indistinct, but probably mostly structureless with some intervals of wavy horizontal laminae. Unit weathers to forms gentle slope — 19.9

3. Sandstone, moderate-reddish-orange (10*R* 6/6), pale-reddish-brown (10*R* 5/4), and grayish-orange-pink (10*R* 8/2); light-greenish-gray (5*GY* 8/1) mottling; very fine to very coarse grained, poorly sorted; composed of subangular to well-rounded clear quartz (in part amber stained), uncommon gray black, and orange acccessory minerals; moderate to highly calcareous, firm to hard cement; parallel bedded (1- to 5-ft-thick beds), structureless to faintly contorted subparallel laminations. Unit contains two light-greenish-gray (5*GY* 8/1) forming sets from 3.4 to 4.2 ft below top of unit and in top 0.5 ft of unit. Lower 0.8-ft-thick ledge may be equivalent to the "crinkly bed" of Baker (1936) in Monument Valley. Basal contact with De Chelly Sandstone Member of Cutler Formation is sharp and is probably a beveled surface. Top contact is poorly exposed but based on abrupt change in lithology — 32.1

Total Hoskininni Member — 52.0

Total Moenkopi Formation — 254.5

Cutler Formation (incomplete):
De Chelly Sandstone Member:

2. Sandstone, moderate-reddish-orange (10*R* 6/6 to 10*R* 5/6), pale-green mottling as streaks, bands, and spots, fine to very fine grained; composed of subangular amber-stained clear quartz, common to abundant black and white accessory minerals, uncommon greenish-gray mica flakes along laminae; slightly calcareous, firmly cemented; top and bottom quarters of unit are massive and contain faintly parallel laminated in beds 2–10 ft thick, whereas middle half of unit has compound and inclined cross-lamination in beds ½–4 ft thick; middle unit locally weathers to rounded massive cliff. Middle half of unit is probably eolian, whereas remainder of unit is probably water laid — 53.0

Total De Chelly Sandstone Member — 53.0

Transition unit between De Chelly Sandstone Member and Organ Rock Tongue:

1. Sandstone, interbedded moderate-reddish-brown (10*R* 4/6) and dark-reddish-brown (10*R* 3/4); abundant pale-green mottling as streaks, bands, and ½–1 in. spots, very fine to fine grained, composed of angular to subangular clear and amber-stained quartz, uncommon black accessory minerals, very fine white mica; noncalcareous to slightly calcareous, firmly cemented; parallel bedded, faint subparallel laminations; weathers to form ledgy cliff, darker colored parts are less resistant — 37.2

U27. COMB WASH—Continued

Cutler Formation—Continued
Transition unit—Continued — Feet

Total transition unit between De Chelly Sandstone Member and Organ Rock Tongue — 37.2

Total incomplete Cutler Formation — 90.2

Base of section; not base of exposure.

U28. COTTONWOOD CREEK

[Measured, by J. H. Stewart and O. B. Raup, September 1953, about 1 mile north of Notch Canyon on tributary that enters Notch Canyon ¾ mile west of its junction with Cottonwood Creek. Secs. 33 and 34 (unsurveyed) T. 34 S., R. 20 E., SLM. San Juan County]

Top of section; top of local exposure.

Chinle Formation (incomplete):

Moss Back Member: not described; thickness not measured. An estimated 40 ft of Moss Back Member is exposed below top of cuesta.

Monitor Butte Member: — Feet

17. Covered — 49.5

16. Siltstone (80 percent) and claystone (20 percent), greenish-gray (5*GY* 6/1), medium-light-gray (*N*6), mottled grayish-red-purple (5*RP* 4/2), and common pale-yellowish-orange (10*YR* 8/6); weathers light gray (*N*7); siltstone well to firmly cemented, noncalcareous; stratification concealed; fractures into angular fragments; claystone poorly cemented, noncalcareous; stratification concealed. Claystone is confined to upper 20 ft of unit. Unit as a whole weathers to form slope — 48.5

Total Monitor Butte Member — 98.0

Shinarump Member:

15. Sandstone, very pale orange (10*YR* 8/2), grayish-orange (10*YR* 7/4) and pale-yellowish-orange (10*YR* 8/6); weathers grayish orange (10*YR* 7/4); medium to coarse grained; commonly contains about 10 percent interstitial clay, fair sorted; composed of subangular to subrounded clear and milky quartz, sparse black accessory mineral; poorly cemented, calcareous; abundant limonite spots and stains; stratification poorly exposed, but probably mostly thin trough sets of small- and minor medium-scale cross-laminae; massive splitting; weathers to form ledge. Basal 0.2 ft contains sparse to common granules and pebbles as large as 1½ in. in maximum diameter that are composed of quartz and chert — 10.9

Total Shinarump Member — 10.9

Total incomplete Chinle Formation — 108.9

U28. COTTONWOOD CREEK—Continued

	Feet
Moenkopi Formation:	
NOTE.—Members of the Moenkopi in this section are not well defined; hence, their contacts are only tentative.	
Upper slope-forming member:	
14. Silty claystone, grayish-red (10*R* 4/2); weathers same color; common very fine grained accessory white mica; firmly cemented, noncalcareous; structureless; weathers to form steep slope. Top 0.6 ft is altered to greenish gray (5 *GY* 6/1) and pale yellowish orange (10*YR* 8/6)	6.0
Total upper slope-forming member	6.0
Ledge-forming member:	
13. Sandstone to sandy siltstone, pale-red (5*R* 6/2 and 10*R* 6/2) and minor grayish-orange (10*YR* 7/4) to very pale orange (10*YR* 8/2); weathers pale reddish brown (10*R* 5/4) and light brown (5*YR* 6/4); fine-grained sandstone in lower 4 ft grading upward into very fine grained sandy siltstone, fair sorted. Fine-grained sandstone is composed of subrounded milky quartz and sparse orange accessory mineral. Basal 4 ft and top 1 ft of unit consist of thin trough sets of high-angle medium-angle medium-scale cross-laminae, whereas rest of unit is horizontally thinly laminated to laminated. Unit as a whole is firmly cemented and calcareous, and weathers to form ledge	14.0
12. Siltstone (50 percent) and sandy siltstone (50 percent). Siltstone, grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); common fine-grained white mica; firmly cemented, noncalcareous, commonly clayey; stratification poorly exposed, but seems to be mostly structureless with common horizontal laminae. Sandy siltstone, light-brown (5*YR* 6/4), pale-reddish-brown (10*R* 5/4), and yellowish-gray (5*Y* 8/1); weathers pale reddish brown (10*R* 5/4); sandy (very fine grained), abundant fine- to medium-grained accessory biotite and muscovite; well cemented, calcareous; parallel-type ripple laminations; platy to flaggy splitting. Sandy siltstone occurs as thin to thick sets interstratified with siltstone; unit as a whole weathers to form steep slope	20.2
11. Sandstone, pale-red (5*R* 6/2) and common very pale orange (10*YR* 8/2) and pale-reddish-brown (10*R* 5/4) in upper 5.5 ft; weathers pale reddish brown (10*R* 5/4); very fine grained with sparse fine-grained parts, upper 5.5 ft is silty, fair sorted; fine-grained parts composed of subrounded milky quartz and abundant orange accessory minerals; firmly cemented, calcareous, abundant limonite spots and stains; horizontally thinly laminated to laminated; lower 16.3 ft has about 5 percent thin trough sets of small- to medium-scale low-angle cross-laminae and upper 5.5 ft about 50 percent thin trough sets of medium-scale cross-laminae; platy and massive splitting, weathers to form steep slope and ledge	21.8
10. Siltstone (70 percent) and sandy siltstone (30 percent), similar to unit 8. Sandy siltstone grades to very fine grained sandstone	16.8
9. Silty sandstone, pale-red (10*R* 6/2) and abundant grayish-orange (10*YR* 7/4) and very pale orange (10*YR* 8/2); very fine grained and minor silt, well sorted; firmly cemented, slightly calcareous; horizontally thinly laminated to laminated; platy and massive splitting; weathers to form steep ledgy slope. Top 12 ft of unit contains common thin sets of ripple-laminated siltstone and sandy siltstone. A small channel was seen about 8 ft below top of unit	38.5
Total ledge-forming member	111.3
Lower slope-forming member:	
8. Siltstone (80 percent) and sandy siltstone (20 percent). Siltstone, grayish-red (10*R* 4/2); weathers same color; common to abundant fine- to medium-grained accessory white mica; firmly cemented, slightly calcareous; structureless with common horizontal and ripple laminae. Sandy siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); weathers same colors; sandy (very fine grained); grades rarely into very fine grained sandstone containing sparse fine to medium grains; well cemented, calcareous; parallel-type ripple laminations; platy splitting. Unit from 40.2 to 40.9 ft is medium-scale cross-laminated. Unit as a whole weathers to form slope	61.8
Total lower slope-forming member	61.8
Hoskinnini Member:	
7. Siltstone (75 percent) and sandy siltstone (25 percent). Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; firmly cemented, noncalcareous to slightly calcareous; structureless. Sandy siltstone, grayish-orange (10*YR* 7/4) and very pale orange (10*YR* 8/2) with minor pale-reddish-brown (10*R* 5/4); weathers same colors; silt with as much as 50 percent fine to coarse grains, poorly sorted; fine to coarse grains are composed of rounded milky quartz. Sandy limestone is firmly	

U28. COTTONWOOD CREEK—Continued

Moenkopi Formation—Continued

Hoskinnini Member—Continued — Feet

cemented, slightly calcareous; structureless and thin bedded. Sandy siltstone occurs as two thin light-colored beds in lower half of unit and as a light-colored bed in top 1 ft of unit; it also occurs sparsely throughout rest of unit. Unit is placed in the Hoskinnini Member because (1) it contains sandy siltstone similar to typical Hoskinnini, (2) it has no ripple laminae characteristic of the overlying part of the Moenkopi, and (3) it contains rounded and cigar-shaped light-colored mottles that are typical of the Hoskinnini — 37.7

6. Sandy siltstone to sandstone. Thin beds of yellowish-gray (5*Y* 8/1) and light-greenish-gray (5*GY* 8/1) sandy siltstone to sandstone containing small-scale wavy parting planes occur at base and top of unit. These thin beds are separated by a thin bed of pale-reddish-brown (10*R* 5/4) sandy siltstone. Texture of unit is similar to that of underlying unit except uppermost bed contains sparse medium-grained sandstone. Unit weathers to form small ledge. This unit may be correlative with the "crinkly bed" of Baker (1936, p. 39) in Monument Valley — 1.8

5. Sandy siltstone (70-80 percent) to silty sandstone, pale-reddish-brown (10*R* 5/4), common grayish-orange (10*YR* 7/4) round to cigar-shaped spots elongated horizontally; weathers pale reddish brown (10*YR* 5/4); basal 1.8 ft is yellowish gray (5*Y* 8/1). Unit ranges from a very fine- to medium-grained sandstone containing minor silt to a siltstone containing minor very fine to medium grains. Rocks are poorly sorted. Very fine to medium grains are composed of rounded to well-rounded amber, milky, gray, and orange minerals. Rock is firmly cemented, calcareous; consists of thin horizontal beds or sets that contain indistinct wavy laminae separated by silty seams; contains sparse small-scale deformed bedding. Unit weathers to form steep ledgy slope — 48.9

Total Hoskinnini Member — 88.4

Total Moenkopi Formation — 267.5

Cutler Formation (incomplete):

Organ Rock Tongue:

4. Siltstone to sandy siltstone, grayish-red (10*R* 4/2) to pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); several very thin yellowish-gray (5*Y* 8/1) color bands; uncommon accessory white mica; well cemented, slightly calcareous;

U28. COTTONWOOD CREEK—Continued

Cutler Formation—Continued

Organ Rock Tongue—Continued — Feet

structureless and minor thin to thick horizontal beds; weathers to form steep slope. Sandy parts are very fine grained — 235.0

Total Organ Rock Tongue — 235.0

Cedar Mesa Sandstone Member (incomplete):

Transition unit:

3. Sandstone, very pale orange (10*YR* 8/2), yellowish-gray (5*Y* 8/1) and minor pale-reddish-brown (10*R* 5/4) and pale-red (10*R* 6/2); weathers grayish orange (10*YR* 7/4), minor pale reddish brown (10*R* 5/4); very fine to fine grained, fair sorted; composed of subrounded clear and amber-stained quartz and sparse black accessory minerals; poorly to firmly cemented, highly calcareous, common to abundant limonite spots; consists of thin to thick horizontal beds and minor thin trough and possibly planar sets of medium-scale cross-laminae; contains two thin horizontal beds of reddish-brown silty sandstone in upper half; contains cross-stratification only in lower half; weathers to form cliff and steep ledgy slope — 58.6

2. Unit mostly covered. Outcrop in lower 3 ft is sandstone that is pale reddish brown (10*R* 5/4); weathers same color; very fine to fine grained, fair sorted; composed of subrounded amber quartz and sparse black accessory minerals; poorly to firmly cemented, calcareous; structureless. Unit as a whole weathers to form rubble-covered slope on east side of wash. Nature of weathering and outcrop in lower 3 ft suggests that entire unit may be reddish-brown sandy siltstone and siltstone characteristic of the transitional unit at the top of the Cedar Mesa Sandstone Member — 14.6

Total transition unit — 73.2

1. (Unmeasured.) Sandstone, very pale orange (10*YR* 8/2) and yellowish-gray (5*Y* 8/1); weathers very light gray (*N*8); fine to very fine grained, fair sorted; composed of subrounded clear quartz and sparse black accessory minerals; poorly to firmly cemented, highly calcareous; stratification concealed; weathers to form smooth dip slope.

Total incomplete Cedar Mesa Sandstone Member — 73.2

Total incomplete Cutler Formation — 308.2

Base of section, base of good exposure. Base of section in creek bottom between hogbacks formed of Cedar Mesa Sandstone Member and Moss Back Member.

U29. HITE

[Measured, by J. H. Stewart, November 1952, beginning about 1/4 mile upstream from easternmost swing of Colorado River at The Horn and following a steep ledgy gully to promontory on the north. Promontory 1 3/4 miles south-southeast of Hite, Utah. Long 110°25′40″ W., lat 37°47′05″ N. San Juan County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Moss Back Member: *Feet*

21. Sandstone, predominantly pale-red (10*R* 6/2) and minor pinkish-gray (5*YR* 8/1) and yellowish-gray (5*Y* 8/1); weathers moderate brown (5*YR* 4/4) and brownish black (5*YR* 2/1); fine to medium grained, well sorted; composed of subrounded clear quartz and sparse white, orange, and black accessory minerals; locally sparse thin conglomeratic beds contain quartz, claystone, and siltstone granules and pebbles; firmly cemented, calcareous, limonite stains as spots 0.25–0.5 mm in size; composed of thin trough sets of small- and medium-scale cross-laminae, uncommon parallel laminae; platy to blocky and massive splitting; weathers to form most prominent cliff and bench in Chinle Formation. Top 8.8 ft weathers back to form a bench and is very poorly exposed ---------- 48.0
20. Sandstone, pale-red-purple (5*RP* 6/2) and light-brownish-gray (5*YR* 6/1); weathers same colors; very fine grained, common clay minerals, fair sorting; angularity and composition mostly concealed; bottom 4 ft well cemented and highly calcareous, and contains abundant reddish-brown, greenish-gray, and yellow-brown siltstone granules and pebbles; firmly cemented, noncalcareous; unit is tabular, but varies in thickness; thin to thick trough sets of medium-scale low-angle cross-laminae; platy splitting; weathers to form cliff. Base of Moss Back channels as much as 3 ft into underlying Monitor Butte Member ---------- 13.0

Total Moss Back Member ---------- 61.0

Monitor Butte Member:

19. Silty claystone to clayey sandstone, light-greenish-gray (5*GY* 8/1) to greenish-gray (*GY* 6/1) and minor grayish-red (10*R* 5/2); composed of silty clay to very fine grained sand with abundant clay; common fine-grained white mica; firmly to well cemented, argillaceous; stratification mostly concealed; weathers to form steep frothy slope. Sparse interbedded thin sets of ripple-laminated sandstone that is light greenish gray (5*GY* 8/1) and grayish red (10*R* 4/2); weathers same colors; very fine grained, well sorted; well cemented, highly calcareous; platy splitting ---------- 91.1

U29. HITE—Continued

Chinle Formation—Continued

Monitor Butte Member—Continued *Feet*

18. Sandstone and conglomeratic sandstone, light-greenish-gray (5*GY* 8/1) and yellowish-gray (5*Y* 8/1); weathers same colors and pale yellowish brown (10*YR* 6/2); fine to very fine grained; top 5 ft well sorted; bottom 4 ft fair to poorly sorted and contains medium grains and abundant coarse to very coarse grains, granules, and pebbles; composed of subrounded clear quartz and common orange and black accessory minerals, (granules and pebbles are composed of limestone and limey siltstone); firmly cemented, highly calcareous; unit is tabular, consists of thin trough sets of small- to medium-scale cross-laminae, sparse parallel laminae to thin beds; platy to slabby splitting; weathers to form minor ledge that is fairly persistent along outcrop ---------- 9.0
17. Silty claystone to clayey sandstone and sandstone. Silty claystone to clayey sandstone is light greenish gray (5*GY* 8/1) to greenish gray (5*GY* 6/1), red purple (5*RP* 4/2) from 82.0 to 86.0 ft above base of unit; weathers predominantly light greenish gray (5*GY* 8/1); ranges from silt with abundant clay to very fine grained sand with abundant silt and clay, fair sorting; sand grains are composed of subangular clear quartz and common orange and black accessory minerals, common fine-grained white mica; poorly to well cemented, moderately to highly calcareous; stratification mostly concealed, but sparse laminae seen; splitting mostly concealed, but where seen is highly fractured with common slickensided surfaces. Silty claystone is confined to bottom 30–40 ft of unit. Along outcrop, bottom 3–20 ft is variegated with grayish purple (5*P* 4/2), grayish yellow (5*Y* 8/1), and grayish red (10*R* 4/2) with common dark-yellowish-orange (10*YR* 6/6) stain along fracture surfaces; and contains sparse limestone nodules as much as 5 in. in diameter. Sandstone, light-greenish-gray (5*GY* 8/1) and pale-yellowish-brown (10*YR* 6/2); weathers predominantly light greenish gray (5*GY* 8/1) and dark yellowish brown (10*YR* 4/2); very fine grained, fair to well sorted; composed of subangular clear quartz and sparse black accessory minerals; well cemented, calcareous; ripple laminated, common parallel laminae, and probably some thin trough and planar sets of medium-scale low-angle cross-laminae; platy to slabby splitting. Sandstone is characteristically contorted and slumped as a result of

U29. HITE—Continued

Chinle Formation—Continued

Monitor Butte Member—Continued *Feet*

penecontemporaneous(?) deformation. Unit as a whole weathers to form steep rubble-covered slope containing small irregular ledges ---- 87.0

Total Monitor Butte Member ---- 187.1

Total incomplete Chinle Formation ---- 248.1

Contact between Moenkopi and Chinle is sharp and marks a change from red rocks below to green rocks above. Strata above the contact contain swelling clays, whereas those below do not.

Moenkopi Formation:

Upper slope-forming member:

16. Siltstone, grayish-red (10*R* 4/2); weathers same color; common fine-grained mica; firmly cemented, slightly calcareous; unit is tabular, consists of parallel laminae; platy splitting; weathers to form steep slope. Sparse laminae and very thin sets of laminae of grayish-yellow (5*Y* 8/4), calcareous, sandy siltstone are interstratified with the siltstone ---- 39.2
15. Siltstone (80 percent) and sandy siltstone (20 percent). Siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers same colors; common fine-grained white mica; firmly cemented, noncalcareous; predominantly parallel laminated with minor ripple laminae; platy splitting. Sandy siltstone, grayish-orange (10*R* 7/4) and minor pale-red (10*R* 6/2); weathers grayish orange (10*YR* 7/4) and pale reddish brown (10*R* 5/4); composed of silt with abundant very fine sand grains; well cemented, calcareous; predominantly ripple laminated, sparse thin trough sets of medium-scale cross-laminae; platy to blocky splitting. Cross-laminated sets confined to pale-red very thick cosets from 8.8 to 10.8 ft, 18.5 to 21.5 ft, 35.8 to 37.8 ft and 60.1 to 65.8 ft above base of unit. These cross-laminated cosets grade laterally into ripple-laminated sets. Entire unit is tabular and weathers to form a gentle to steep slope with small ledges in the cross-laminated cosets ---- 118.4
14. Sandy siltstone, similar to that in unit 9 ---- 3.8

Total upper slope-forming member ---- 161.4

Ledge-forming member:

13. Sandy siltstone, pale-red (10*R* 6/2); weathers light brown (5*YR* 6/4). Similar to unit 6. Bottom 1.6 ft is a thin set of high-angle cross-laminae. Grades into overlying unit. The interval from the base of Moenkopi to the top of unit 13 weathers to form a cliff or a steep rubble-covered slope with prominent ledges, whereas the interval from the top of unit 13 to the top of the Moenkopi weathers to form a gentle to steep slope with small ledges ---- 9.2

U29. HITE—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

12. Clayey siltstone, similar to that in unit 5. Contains 20 percent pale-reddish-brown (10*R* 5/4) ripple-laminated thin siltstone sets. One poorly exposed channel about 3 ft deep seen ---- 5.9
11. Sandy siltstone, similar to that in unit 9 ---- 7.4
10. Sandy siltstone, similar to unit 8. Grades into overlying unit. Weathers to form small ledge ---- 8.5
9. Sandy siltstone and clayey siltstone. Sandy siltstone, pale-red (10*R* 6/2) to grayish-red (10*R* 4/2); weathers same colors; composed of silt with abundant very fine sand grains; firmly cemented, calcareous; ripple laminated, cuspate and parallel current ripples; uncommon pseudocross-laminations; platy splitting. Current ripples have 3-in. wavelength and ⅜-in. amplitude. Clayey siltstone similar to that in unit 5 occurs from 10.6 to 12.3 ft and 25.4 to 29.2 ft above base of unit ---- 29.2
8. Sandy siltstone, pale-red (10*R* 6/2) and light-brown (5*YR* 6/4); weathers same colors. Similar to unit 6, except it consists predominantly of horizontal laminae with minor ripple laminae. Grades into overlying unit. Weathers to form minor ledge. Basal contact is an erosional surface ---- 10.2
7. Sandy siltstone (30 percent) and clayey siltstone (70 percent). Sandy siltstone, light-brown (5*YR* 6/4) and grayish-yellow (5*Y* 8/4); weathers light brown (5*YR* 6/4); abundant very fine sand grains, common to abundant fine-grained white mica; firmly to well cemented, calcareous; ripple laminated and sparse horizontal laminated parts; flaggy to blocky splitting. Clayey siltstone, similar to that in unit 5. Very thin to thick horizontally sets of sandy siltstone interbedded with clayey siltstone. Weathers to form steep slope with small ledges ---- 13.6
6. Sandy siltstone, light-brown (5*YR* 6/4); weathers same color; silt with abundant very fine sand grains; well cemented, calcareous; unit is tabular, consists of ripple laminae; massive splitting; weathers to form small ledge ---- 4.4
5. Sandy siltstone to sandstone (60 percent) and clayey siltstone (40 percent). Sandy siltstone to sandstone, very pale orange (10*YR* 8/2) and grayish-orange (10*YR* 7/4); weathers pale reddish brown (10*R* 5/4); abundant very fine sand grains to very fine grained sand, sparse medium to

U29. HITE—Continued

	Feet
Moenkopi Formation—Continued	
Ledge-forming member—Continued	
coarse grains, fair sorting; composed of subangular to subrounded clear quartz, accessory minerals concealed; firmly cemented with sparse well-cemented parts, calcareous, abundant limonite stains; very thin horizontal beds and sparse horizontal laminae; flaggy to slabby splitting. Clayey siltstone, grayish-red (10*R* 4/2); weathers same color; common fine-grained white mica; firmly cemented, noncalcareous; horizontal laminae; platy splitting. Very thin to thick and sparse very thick sets of sandy siltstone to sandstone interbedded with very thin to very thick sets of clayey siltstone. Weathers to form gentle slope with small ledges and cliffs	22.8
4. Sandstone and siltstone. Sandstone, grayish-orange (10*YR* 7/4); weathers pale red (10*R* 6/2); fine to medium grained, sparse coarse to very coarse grains, fair sorting; composed of subangular clear quartz and sparse black accessory minerals; firmly cemented, slightly calcareous; very thin horizontal beds and abundant thin planar sets of small-scale cross-laminae; flaggy and slabby splitting. Siltstone, predominantly light greenish gray (5*GY* 8/1) to greenish gray (5*GY* 6/1) with minor pale reddish brown (10*R* 5/4); firmly cemented, noncalcareous; very thin parallel beds; flaggy splitting. Siltstone occurs in basal 1 ft and 5.5 to 5.9 ft above base of unit. Weathers to form small ledge	9.1
Total ledge-forming member	120.3
Conglomerate and sandstone unit:	
3. Conglomeratic sandstone, grayish-yellow (5*Y* 8/4) and grayish-orange (10*YR* 7/4); weathers grayish orange (10*YR* 7/4); predominantly medium grained with abundant fine, coarse, and very coarse grains and granules, and pebbles and sparse cobbles, poorly sorted; sand grains composed of subrounded clear quartz and uncommon gray and black accessory minerals, granules through cobbles composed of angular to subangular white chert. Rock is well cemented, calcareous; unit is tabular, but varies in thickness; structureless; massive splitting; weathers to form slightly overhanging rounded ledge. Basal contact is sharp and has local relief of about 3 ft	6.0
Total conglomerate and sandstone unit	6.0
Total Moenkopi Formation	287.7

U29. HITE—Continued

	Feet
Cutler Formation (incomplete):	
White Rim Sandstone Member:	
2. Sandstone, not examined in detail because of inaccessibility. Unit weathers yellowish gray (5*Y* 8/1) and forms a conspicuous light-colored band in section. Weathers to form cliff	3.0±
Total White Rim Sandstone Member	3.0±
Organ Rock Tongue (incomplete) (unmeasured):	
1. Siltstone, not examined in detail because of inaccessibility. Unit weathers to form pale-reddish-brown (10*R* 5/4) steep rubble-covered slope and cliff above the Colorado River flood plain. Estimated 60 ft of Organ Rock exposed in line of section.	
Total incomplete Cutler Formation	3.0±
Base of section, base of exposure.	

U30a. JACOBS CHAIR

[Measured, by J. H. Stewart and G. A. Williams, October 1952, beginning 500 ft down creek from place where Jacobs Chair road crosses White Canyon. Line of section N. 78° W. Long 110°14′25″ W., lat 37°42′35″ N. San Juan County]

	Feet
Top of section, not top of exposure.	
Moenkopi Formation (incomplete):	
Hoskinnini Member (incomplete):	
13. Sandstone, grayish-orange (10*YR* 7/4); weathers same color; fine grained with abundant medium to coarse grains, poorly sorted; composed of subrounded clear quartz and abundant green and black accessory minerals; firmly cemented, calcareous; unit is tabular, consists of very thick horizontal beds; massive splitting; weathers to form conspicuous white band at base of cliff. Equivalent to unit 1 in Jacobs Chair section (loc. U30b)	4.0
Total incomplete Hoskinnini Member	4.0
Total incomplete Moenkopi Formation	4.0
Cutler Formation (incomplete):	
Organ Rock Tongue:	
12. Siltstone, similar to unit 4. Unit is tabular, consists of thin to thick horizontal beds. Weathers to form cliff with minor reentrants along some bedding planes	7.4
11. Siltstone, similar to unit 9. Contains beds similar to those in unit 4 from 11.1 to 11.5 ft and 15.4 to 16.2 ft above base. Unit is grayish red (10*R* 4/2) along stratification planes. Unit is tabular, consists of thick to very thick horizontal beds. Unit above 16.2 ft locally weathers to form rounded cliff	44.2
10. Siltstone, similar to unit 4. Weathers to form steep rubble-covered slope	3.1

U30a. JACOBS CHAIR—Continued

Cutler Formation—Continued

Organ Rock Tongue—Continued *Feet*

9. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; abundant medium-grained white mica; firmly cemented, calcareous; stratification poorly exposed, but where seen is predominantly very thick bedded; predominantly massive splitting, minor platy splitting; weathers to form steep rubble-covered slope with minor ledges ---------- 15.2
8. Siltstone, similar to unit 4, weathers to form rubble-covered slope---------- 4.0
7. Siltstone pale-reddish-brown (10*R* 5/4); basal 0.4 ft grayish yellow (5*Y* 8/4); weathers same colors; clayey along lamination planes; common to abundant fine-grained white mica; firmly cemented, calcareous; unit is tabular, consists of horizontal laminae; platy splitting; weathers to form minor ledge---------- 5.5
6. Siltstone, similar to unit 4, weathers to form rubble-covered slope---------- 29.3
5. Sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; abundant very fine sand grains; common medium-grained white mica; firmly cemented, calcareous; unit is tabular and structureless; massive splitting; weathers to form minor rounded ledge ---------- 7.2
4. Siltstone, grayish-red (10*R* 4/2); sparse yellowish-gray (5*Y* 7/2) thin beds; weathers same colors; common very fine sand grains; common very fine grained white mica; firmly cemented, argillaceous; bedding concealed; probably mostly massive splitting; fractures into angular pebble-sized fragments; weathers to form gently sloping bench. Unit poorly exposed in basal 19 ft-- 23.3

Total Organ Rock Tongue---------- 139.2

Cedar Mesa Sandstone Member (incomplete):

3. Sandstone, similar to unit 1, except it has thick to very thick trough sets of medium-scale cross-laminae in basal 18.8 ft. Stratification concealed in rest of unit. Unit does not contain red argillaceous parts as in unit 1. Top 3.6 ft weathers to form rough ledge ---------- 22.4
2. Sandstone, grayish-red (10*R* 4/2); top 0.8 ft pale yellowish orange (10*YR* 8/6); weathers same colors; very fine grained, silty, poorly sorted; firmly cemented, argillaceous; unit is tabular; stratification obscured; massive splitting; weathers to form prominent reentrant and minor bench----- 9.6
1. Sandstone, pale-yellowish-orange (10*YR* 8/6) and grayish-orange (10*YR* 7/4); weathers very pale orange (10*YR* 8/2); fine grained, well sorted; composed of subrounded clear quartz and sparse black accessory minerals; poorly cemented, calcareous, abundant limonite spots and stains; lower half of unit has thick trough and planar sets of medium- and large-scale high-angle cross-strata, whereas upper half of unit has predominantly thick to very thick horizontal beds and medium-scale cross strata; blocky to massive splitting; weathers to form ledgy cliff. Unit from 19 to 20 ft and 54 to 54.9 ft above base is pale-reddish-brown (10*R* 5/4) fine to very fine grained sandstone that grades laterally and vertically into the major sandstone type; these red sandstones weather more easily and form benches. Total thickness of unit not exposed 67.2

Total incomplete Cedar Mesa Sandstone Member ---------- 99.2

Total incomplete Cutler Formation----- 23.84

Base of section; base of exposure.

U30b. JACOBS CHAIR

[Measured, by J. H. Stewart and G. A. Williams, October 1952, at place where Jacobs Chair road crosses cliff of Hoskinnini Member, northeast of White Canyon, long 110°13'00" W., lat 37°43'15" N. San Juan County]

Top of section, not top of exposure.

Chinle Formation (incomplete) (unmeasured): *Feet*

22. Siltstone, medium-dark-gray (*N*4); weathers very light gray (*N*8); common very fine sand grains; firmly cemented, argillaceous; unit is tabular; bedding concealed; shaly splitting; weathers to form steep rubble-covered slope. Locally, unit contains medium- to very coarse-grained iron-stained sandstone layers as much as 0.4 ft thick.

Moenkopi Formation:

Upper slope-forming member:

21. Siltstone (90 percent) and sandy siltstone (10 percent). Siltstone, predominantly pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); stratification concealed; otherwise similar to unit 10. Sandy siltstone, yellowish-gray (5*Y* 8/1), similar to siltstone in unit 20. Sandy siltstone is interstratified with siltstone. Unit as a whole weathers to form rubble-covered gentle slope and on distant outcrop it forms a lighter colored smooth slope. Top 1 ft is iron stained ---------- 23.1
20. Siltstone (90 percent) and sandy siltstone (10 percent). Siltstone similar to that in unit 10. Sandy siltstone, pale-red (10*R* 6/2) and yellowish-gray (5*Y* 8/1); weathers grayish orange (10*YR* 7/4) and pale reddish brown (10*R* 5/4); abundant very fine sand grains, common to abundant very fine

U30b. JACOBS CHAIR—Continued

Upper slope-forming member—Continued *Feet*

grained white mica; firmly cemented, calcareous; unit is tabular; horizontally and ripple laminated, sparse thick trough sets of medium-scale cross-laminations; platy to slabby splitting. Thin to thick sets of sandy siltstone are interstratified with siltstone. Sandy siltstone is confined to lower half and upper 8 ft of unit. Weathers to form steep rubble-covered slope. Parts of unit poorly exposed ---- 61.8

Total upper slope-forming member ---- 84.9

Ledge-forming member:

19. Sandy siltstone, very pale orange (10*YR* 8/2) and pale-red (10*R* 6/2); weathers grayish orange (10*YR* 7/4); abundant very fine sand grains; abundant orange and black accessory minerals, sparse very fine grained white mica; firmly cemented, calcareous; horizontally and ripple laminated and sparse thin trough sets of medium-scale low-angle cross-laminations; massive splitting; weathers to form small ledge ---- 3.8
18. Siltstone (30 percent) and sandy siltstone (70 percent). Siltstone similar to that in unit 10. Sandy siltstone, pale-red (10*R* 6/2) and pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); abundant very fine sand grains; abundant orange and black accessory minerals, common very fine grained white mica; firmly cemented, calcareous; horizontally and ripple laminated, one example of small-scale slumping seen; blocky to massive splitting. Thick to very thick sets of sandy siltstone are interbedded with siltstone. Unit as a whole weathers to form reentrant below overlying unit ---- 7.0
17. Sandy siltstone, pale-red (10*R* 6/2); weathers pale reddish brown (10*R* 5/4); no ripple laminations seen; upper 6.5 ft of unit has platy splitting and weathers back from rest of interval; otherwise similar to unit 14 ---- 28.1
16. Sandstone (60 percent) and siltstone (40 percent), similar to unit 10 except for higher percentage of sandstone and common mud cracks. Weathers to form steep slope and reentrant below base of overlying unit ---- 15.4
15. Siltstone (50 percent) and sandy siltstone (50 percent). Siltstone similar to that in unit 10. Sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; abundant very fine sand grains, abundant very fine grained mica; firmly cemented, calcareous; ripple laminated, cuspate ripples (averaging 2½ in. across and ¼ in. deep), thin to thick sets interbedded with siltstone; platy splitting. Unit weathers to form rubble-covered gentle slope. Unit is poorly exposed ---- 9.3

U30b. JACOBS CHAIR—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

14. Sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; abundant very fine sand grains, uncommon very fine grained white mica; firmly cemented, calcareous; unit is tabular, consists predominantly of horizontal ripple laminae and minor thick trough sets of medium-scale cross-laminae; massive splitting; weathers to form prominent ledge. Basal contact is a surface of erosion ---- 16.6
13. Siltstone (80 percent) and sandstone (20 percent), similar to unit 10 except for smaller content of sandstone and more abundant uniform sets of siltstone and sandstone ---- 5.8
12. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; common very fine sand grains, sparse fine- to medium-grained white mica; contains sparse intraformational conglomerate composed of rounded granules and pebbles of calcareous lighter colored siltstone; firmly to well cemented, calcareous; unit is tabular, consists of thin sets of ripple and horizontal laminae; slabby to blocky splitting; weathers to form steep rubble-covered slope and cliff ---- 7.3
11. Sandstone (90 percent) and siltstone (10 percent), similar to unit 10 except for thick sets of sandstone interbedded with thin sets of siltstone; weathers to form small overhanging ledge ---- 3.8
10. Siltstone (70 percent) and sandstone (30 precent). Siltstone, grayish-red (10*R* 4/2); weathers same color; common very fine grained white mica; firmly cemented, argillaceous; horizontally and ripple laminated; shaly splitting. Sandstone, very pale orange (10*YR* 8/2); weathers grayish orange (10*YR* 7/4); medium to fine grained with minor coarse grains, fair sorting; composed of subrounded clear quartz and sparse black accessory minerals; firmly cemented, calcareous, limonite stains; horizontally and ripple laminated and contains thin horizontal beds; flaggy to slabby splitting. Sandstone is interbedded with siltstone and concentrated in several 2-ft-thick intervals. Unit as a whole is tabular and weathers to form steep rubble-covered slope with small ledges ---- 49.5
9. Conglomeratic sandstone, yellowish-gray (5*Y* 8/1), light-olive-gray (5*Y* 6/1), and olive-black (5*Y* 2/1); weathers grayish orange (10*YR* 7/4); medium to fine grained, contains common medium to very coarse grains, granules, and pebbles as much as 2½ in. in diameter (pebbles are angular to subangular and composed predominantly of

U30b. JACOBS CHAIR—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

chert), poorly sorted; composed of subangular to subrounded clear quartz and sparse black accessory minerals; firmly to poorly cemented; calcareous; unit is tabular, consists of thin sets of horizontal laminae and trough sets of small-scale low-angle cross-laminae; slabby splitting; weathers to form prominent ledge. Pebbles comprise 20–30 percent of rock and are commonly concentrated along bedding planes ---- 9.2

Total ledge-forming member ---- 155.8

Lower slope-forming member (not well defined; therefore, contacts in doubt):

8. Sandstone and siltstone interbedded, grayish-red (10*R* 4/2); uncommon very thin beds of grayish-yellow (5*Y* 8/4) sandstone; weathers same colors; about equal portions of siltstone and very fine grained sandstone; firmly cemented, argillaceous. Sandstone is argillaceous and contains abundant poorly sorted medium to coarse grains. Unit is tabular and consists of very thin horizontal beds. Unit as a whole is flaggy splitting and weathers to form reentrant in line of section ---- 6.3

7. Sandstone, grayish-orange (10*YR* 7/4); weathers same color; very fine to fine grained with sparse medium grains, fair sorting; composed of subrounded clear quartz and sparse orange and green accessory minerals, sparse fine-grained white mica; well cemented, calcareous; unit is tabular, consists of very thin horizontal beds; some ripple marks on bedding planes; a 2-in.-thick pale-reddish-brown (10*R* 5/4) siltstone bed in middle of unit is very thinly laminated ---- 2.1

6. Siltstone, grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); common fine to very fine grained white mica; firmly cemented, argillaceous and slightly calcareous; stratification concealed; unit is tabular, probably mostly massive splitting, fractures into angular fragments; weathers to form rubble-covered steep slope. Unit is poorly exposed ---- 10.5

5. Sandstone, grayish-orange (10*YR* 7/4); weathers same color; medium grained with abundant coarse to very coarse grains, common granules and pebbles, poorly sorted; composed of subangular clear and milky quartz and common orange and black accessory minerals, quartzite and sandstone pebbles; firmly cemented, calcareous; unit is lenticular, structureless; slabby splitting, weathers to form small ledge. Locally unit contains interbedded very thin beds of sandstone and dark-reddish-brown (10*R* 3/4) siltstone. Lower surface of unit is very slightly irregular ---- 0.7

Total lower slope-forming member ---- 19.6

Hoskinnini Member:

4. Siltstone and sandstone, grayish-red (10*R* 4/2) mottled with pale-reddish-brown (10*R* 5/4); upper 7 ft yellowish gray (5*Y* 8/1) and mottled olive gray (5*Y* 4/1) by petroliferous material; silt to fine-grained sand with common medium to coarse grains, poorly sorted; firmly cemented, slightly calcareous. Sandstone composed of subrounded clear quartz and sparse black accessory minerals. Unit is tabular, but contorted by movement in unit below; composed of thin to thick horizontal beds of brecciated rock that has "gneissoid" pattern similar to that in units 2 and 3; massive splitting; weathers to form smooth cliff. Unit was uplifted over contorted zone in unit below, but shows less contortion ---- 29.6

3. Sandstone, grayish-red (10*R* 4/2), yellowish-gray (5*Y* 8/1), and olive-black (5*Y* 2/1); weathers pale reddish brown (10*Y* 5/4) and grayish orange (10*YR* 7/4); yellowish-gray bands 2.6–3 ft and 4.4–4.9 ft above base; petroliferous parts lighter colored; fine grained, common medium to coarse grains in lower part, poorly sorted; composed of subrounded clear quartz and sparse black accessory minerals, firmly to well cemented, calcareous; upper 14.3 ft highly petroliferous; unit is tabular, but varies greatly in thickness due to contorted strata; composed of thick to very thick horizontal beds containing brecciated sandstone that has a "gneissoid" pattern; massive splitting; weathers to form cliff continuous with cliff below. Unit is locally contorted into folds 100 ft across and 20 ft high. Unit locally is about 40 ft thick and contains grayish-red (10*R* 4/2) sandy siltstone and minor yellowish-gray (10*Y* 8/1) fine-grained sandstone in upper part ---- 22.4

2. Sandstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2), some grayish-yellow (10*Y* 5/4); very fine grained, common medium grains, fair sorting; composed of subrounded clear quartz and sparse orange and black accessory minerals, common fine-grained white mica; well cemented, calcareous; thin to thick horizontal beds containing brecciated sandstone having a "gneissoid" appearance; massive splitting; weathers to form prominent cliff ---- 45.9

1. Sandstone, grayish-red (10*R* 4/2), minor yellowish-gray mottling (5*Y* 8/1); weathers same colors; fine grained, abundant

U30b. JACOBS CHAIR—Continued

Moenkopi Formation—Continued

Hoskinnini Member—Continued *Feet*

medium to coarse grains, poorly sorted; composed of subrounded clear and milky quartz and common green accessory minerals; firmly cemented, calcareous; unit is tabular, but varies in thickness; composed of thin to thick horizontal beds of brecciated "gneissoid-patterned" sandstone; massive splitting; weathers to form prominent white band at base of cliff. Equivalent to unit 13 in Jacobs Chair section (loc. U30a) ---- 4.2

Total Hoskinnini Member ---- 102.1

Total Moenkopi Formation ---- 362.4

Base of section, not base of exposure.

U32. LOCKHART CANYON

[Measured, by J. H. Stewart and G. A. Williams, September 1953, beginning 2 miles up Lockhart Canyon from Colorado River and continuing eastward up to westernmost projection of a prominent point, sec. 23 and middle of west side of sec. 24, T. 28 S., R. 20 E., SLM. San Juan County]

Top of section; not top of exposure.

Chinle Formation (unmeasured):

Moss Back Member: *Feet*

33. A 35-ft-thick cliff-forming, light-colored sandstone.

Moenkopi Formation:

Upper part:

32. Clayey siltstone to sandy siltstone, grayish-red (10*R* 4/2) and common light-brown (5*YR* 6/4); top 2 ft light greenish gray (5*GY* 8/1), sparse greenish-gray (5*GY* 6/1) very thin bands in rest of unit; weathers pale reddish brown (10*R* 5/4); sandy (very fine grained), common very fine grained accessory white mica; firmly cemented, calcareous; unit is tabular, stratification poorly exposed, but where seen is horizontally laminated; platy splitting; weathers to form steep earthy slope ---- 47.5
31. Siltstone to sandy siltstone, similar to unit 25 except for being dominantly light brown (5*YR* 6/4) and at least 50 percent ripple laminated. Unit contains several discontinuous thick resistant sandy siltstone sets and one thin set of contorted strata at 56 ft above base. Unit weathers to form steep slope with common ledges ---- 65.3
30. Siltstone, grayish-red (10*R* 4/2) and minor light-greenish-gray (5*G* 8/1); weathers same colors; abundant fine-grained accessory dark and white mica; well cemented, calcareous; contorted stratification consisting of small- and large-scale folds, many of which are recumbent; weathers to form reentrant below overlying unit. Unit is distinctive on outcrop because it contains large light-colored circular masses averaging about 2 ft in diameter ---- 8.7

U32. LOCKHART CANYON—Continued

Moenkopi Formation—Continued

Upper part—Continued *Feet*

29. Siltstone to sandy siltstone, light-brown (5*YR* 6/4) and sparse light-greenish-gray (5*GY* 8/1); weathers same colors; sandy (very fine grained), lower 21.2 ft sandier than rest of unit, uncommon fine-grained accessory white and dark mica; firmly cemented, calcareous; horizontally laminated in lower 17 ft, structureless from 17 to 21.2 ft, and ripple and horizontally laminated in rest of unit. Weathers to form gentle slope ---- 26.6
28. Sandstone, light-brown (5*YR* 6/4) and sparse light-greenish-gray (5*GY* 8/1); weathers same colors; very fine grained, well sorted; composed of subrounded amber quartz and uncommon black accessory mineral; poorly cemented, calcareous; unit is lenticular, consists of ripple and horizontal laminae and possibly some medium-scale cross-laminae and cuspate ripples; top 1 ft has contorted bedding. Unit weathers to form ledge and grades out laterally or pinches out 200 ft west of section line ---- 8.2
27. Siltstone to sandy siltstone, similar to unit 25. Unit is horizontally bedded with one wavy bed containing blebs of very coarsely crystalline barite and very sparse pyrite at 35.2 ft above base. Unit weathers to form steep slope ---- 55.8
26. Sandy siltstone, pale-reddish-brown 10*R* 5/4), sparse light-brown (5*YR* 6/4) and light-greenish-gray (5*G* 8/1); weathers light brown (5*YR* 6/4); sandy (very fine grained), abundant fine- to medium-grained accessory white mica; well cemented, slightly calcareous; unit is tabular, consists of ripple laminae; slabby to massive splitting; weathers to form ledge ---- 6.0
25. Siltstone to sandy siltstone, grayish-red (10*R* 4/2), common light-brown (5*YR* 6/4), thin to very thin bands of light-greenish-gray (5*G* 8/1); weathers light brown (5*YR* 6/4); sandy (very fine grained), common to abundant fine- to medium-grained white and dark mica; firmly to well cemented, slightly calcareous to noncalcareous; consists of horizontal laminae and common very thin to thin beds and ripple laminae (parallel type with wavelength of 1 in.); a thin resistant bed of ripple laminations at 11.0 ft above base, one thin horizontal set of contorted laminae seen; platy to slabby splitting; weathers to form steep slope ---- 53.5

Total upper part of Moenkopi Formation ---- 271.6

U32. LOCKHART CANYON—Continued

Moenkopi Formation—Continued

Hoskinnini Member: *Feet*

24. Siltstone, grayish-red (10*R* 4/2) and light-brown (5*YR* 5/6); weathers light brown (5*YR* 5/6); lower 10 ft contains 1 percent well-rounded medium sand grains; abundant fine-grained accessory white mica; firmly cemented, slightly calcareous; unit is tabular, stratification poorly exposed, but where seen consists mostly of thin horizontal beds; upper one-third of unit contains thin sets of slightly wavy horizontal laminae. Unit is platy spliting in part; weathers to form steep ledgy slope. Unit is placed in the Hoskinnini Member because (1) it has typical Hoskinnini stratification in the upper one-third, (2) it contains sparse medium sand grains typical of the Hoskinnini, and (3) it does not contain the typical horizontal- and ripple-laminated siltstone of the overlying part of the Moenkopi. Top of unit marks a color change from reddish browns of the Hoskinnini to light browns of the Moenkopi and also marks a change from wavy horizontal laminae of the Hoskinnini to horizontally laminated and ripple-laminated platy siltstone of the Moenkopi. Unit probably correlates with topmost unit, or units, of the Hoskinnini at North Sixshooter Peak and Bridger Jack Mesa sections 37.8
23. Silty sandstone to sandy siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); very fine grained, top 2 ft of unit contains about 30 percent medium to coarse rounded grains; uncommon fine-grained accessory white and dark mica; firmly cemented, slightly calcareous; unit is tabular, stratification poorly defined, but seems to be mostly wavy horizontal laminae; several indistinct thin trough sets of medium-scale low-angle cross-laminae seen in middle of unit. Weathers to form steep ledgy slope. Sandy top 2 ft of unit may correlate with a similar bed near the top of the Hoskinnini at North Sixshooter Peak and Bridger Jack Mesa sections 38.9
22. Silty sandstone, grayish-red (10*R* 4/2) and minor light-greenish-gray (5*GY* 8/1); weathers grayish red (10*R* 4/2), otherwise similar to unit below except for containing about 35 percent medium to coarse grains and having medium-scale waviness to the stratification. Unit is equivalent to the wavy bed at the North Sixshooter, Bridger Jack, and Cottonwood Creek sections, and probably correlates with the "crinkly bed" of Baker (1936) in Monument Valley 1.5
21. Silty sandstone to sandy siltstone, light-brown (5*YR* 6/4) and uncommon grayish-red (10*R* 4/2), common light-greenish-gray (5*G* 8/1) spots and mottles; weathers light brown (5*YR* 6/4); grades from silty very fine grained sandstone to siltstone containing abundant very fine to medium grains and 2 percent coarse to very coarse grains, poorly sorted; composed of subrounded amber-stained quartz, accessory minerals concealed except for fine- to medium-grained white and dark mica; firmly cemented, calcareous; unit is tabular, consists of wavy horizontal laminae; weathers to form horizontal ledges about 2–4 ft thick and smooth-surfaced ledgy cliff 36.6

Total Hoskinnini Member 114.8

Total Moenkopi Formation 386.4

Cutler Formation:

Organ Rock Tongue and Cedar Mesa Sandstone Member undifferentiated:

20. Sandstone (80 percent) and siltstone to sandy siltstone (20 percent). Sandstone, grayish-red (5*R* 4/2) and minor pale-red (5*R* 6/2), common light-greenish-gray (5*GY* 8/1) mottling; fine to coarse grained, poorly sorted; composed of subangular clear, milky, and amber quartz and minor feldspar, uncommon medium- to coarse-grained accessory white and dark mica, some conglomeratic sandstone with pebbles and granules of light-brown (5*YR* 6/4) siltstone. Sandstone is poorly cemented, calcareous; consists of thin to very thick trough sets of small- to large-scale cross-laminae and minor horizontal laminae. Siltstone to sandy siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2), sandy (very fine grained); abundant very fine grained accessory white mica; firmly cemented, calcareous; horizontally laminated to thinly bedded, individual beds thicken and thin along exposure; occurs in 2- to 20-ft-thick cosets near base and and in 2- to 10-ft-thick cosets in rest of unit; cosets commonly contain thick horizontal sets of silty sandstone that seems to to be midway in composition and texture between siltstone to sandy siltstone and sandstone. The sandstone sets and cosets interfinger with the siltstone and sandy siltstone and fill channels cut into the latter. Unit as a whole is tabular and weathers to form "hoodoo" cliff. Unit is approximately equivalent to the Organ Rock Tongue of the Cutler Formation 237.6
19. Sandstone, similar to unit 6 except for being structureless. Unit is lenticular, and locally along outcrop is light greenish gray (5*GY* 8/1). Unit is the highest Cedar Mesa-like sandstone bed and is probably near the

U32. LOCKHART CANYON—Continued

Cutler Formation—Continued

Organ Rock Tongue etc.—Continued *Feet*

stratigraphic position of the top of the Cedar Mesa Sandstone Member to the south ---------- 1.0

18. Silty sandstone, similar to that in unit 13. Weathers to form gentle slope---------- 6.4
17. Sandstone, similar to unit 12. Weathers to form ledge and bench---------- 26.4
16. Sandstone, similar to unit 6 except it contains only 2 percent medium to coarse grains; stratification poorly defined, but probably consists mostly of thin to thick horizontal cosets containing thin trough sets of small- and medium-scale cross- laminae and horizintal laminae. Weathers to form small ledge and bench---------- 10.8
15. Silty sandstone, similar to that in unit 13. Weathers to form cliff---------- 8.4
14. Sandstone, similar to unit 12 except stratification is less well defined and consists of thin trough sets of medium-scale low-angle cross-laminae and horizontal laminae. Weathers to form rounded cliff---------- 25.1
13. Silty sandstone (80 percent) and sandstone (20 percent). Silty sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained, abundant fine- to coarse-grained accessory white and dark mica; firmly cemented, calcareous; horizontally and ripple laminated. Sandstone, similar to unit 6; occurs as several 5- to 10-ft-thick cosets interstratified with rest of unit. Basal 10 ft of unit contains a very thick lens of sandstone similar to underlying unit except that it forms a prominent ledge. Unit as a whole weathers to form ledges and small benches---------- 57.2
12. Sandstone, grayish-red (5*R* 4/2) to grayish-red-purple (5*RP* 4/2); weathers same colors; fine to coarse grained, poorly sorted; composed of angular to subangular clear and milky quartz and minor feldspar, uncommon coarse-grained accessory dark mica; one thick set contains 2 percent angular granules of feldspar; poorly cemented, calcareous; unit is tabular, consists of thin to thick trough sets of medium-scale low-angle cross-laminae, minor horizontal laminae, and contorted laminae; weathers to form ledge---------- 21.9
11. Sandstone (75 percent) and siltstone (25 percent). Sandstone, pale-reddish-brown (10*R* 5/4) and pale-red (10*R* 6/2); weathers same colors; fine to medium grained, fair sorted; composed of subangular to subrounded clear and milky quartz and minor feldspar, sparse medium-grained white mica; poorly cemented, highly calcareous; consists of very thin to thin horizontal beds and thin to thick beds of thin trough sets of small-scale cross-laminae. Siltstone, grayish-red (10*R* 4/2); weathers same color; abundant very fine grained accessory white mica; firmly cemented, calcareous; horizontally laminated. Siltstone dominantly in upper 8 ft of unit. Unit as a whole is tabular and weathers to form a bench---------- 31.0
10. Sandstone, similar to unit 6 except it contains only 2 percent medium to coarse grains; weathers to form cliff in lower half and bench in upper half. This unit marks top of light-brown sandstone that forms cliffs in lower part of Cutler---------- 12.0
9. Heterogeneous unit; 80 percent sandy siltstone to silty sandstone, pale-reddish-brown (10*R* 5/4), grayish-red (10*R* 4/2), light-brown (5*YR* 6/4), and common pale-red-purple (5*RP* 6/2); weathers pale reddish brown (10*R* 5/4); very fine grained; uncommon medium-grained accessory white mica; firmly cemented, calcareous; consists of thin to thick horizontal beds and laminae and minor channel-filling lenses. Unit also contains thin to thick channel-filling lenses of medium to coarse sandstone similar to that in units 6 and 3. Weathers to form cliff---------- 62.5
8. Sandstone, pale-reddish-brown (10*R* 5/4) in lower half and light-brown (5*YR* 6/4) in upper half; weathers same colors; otherwise similar to unit 6 except that it is dominantly horizontally laminated with minor thin trough sets of medium-scale cross-laminae and common medium-scale contorted bedding. Weathers to form cliff. This unit lenses out about 300 ft west of section line---------- 15.7
7. Silty sandstone, grayish-red (5*R* 4/2), pale-red (5*R* 6/2), and pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); very fine grained with minor fine sand grains and silt, fair sorted; composed of subangular milky and clear quartz and minor feldspar, uncommon fine-grained accessory white mica; poorly cemented, highly calcareous; dominantly structureless, but contains some thin to very thin beds with sparse wavy layers; weathers to form cliff---------- 18.3
6. Sandstone, light-brown (5*YR* 6/4), and commonly pale-reddish-brown (10*R* 5/4), pale-red (5*R* 6/2), and yellowish-gray (5*Y* 8/1); very fine to fine grained with 5–10 percent subangular opaque and reddish-brown medium to coarse grains, fair sorted, composed of subrounded amber quartz and sparse black accessory minerals, uncommon medium-grained accessory white mica; poorly cemented, highly calcareous; unit is tabular, consists of thin to very thick trough and planar sets of medium-scale low-angle cross-laminae; weathers to form cliff with bench in top 10 ft. Unit contains 3

U32. LOCKHART CANYON—Continued

Cutler Formation—Continued

Organ Rock Tongue etc.—Continued *Feet*

percent thin lenses of pale-reddish-brown (10*R* 5/4) sandy siltstone to very fine grained silty sandstone 115.2

5. Siltstone to silty sandstone, pale-reddish-brown (10*R* 5/4), grayish-red (5*R* 4/2), common light-greenish-gray (5*GY* 8/1); weathers pale reddish brown (10*R* 5/4); very fine grained, abundant fine-grained accessory white and dark mica; firmly cemented, calcareous; unit is tabular, consists of thin sets of ripple laminae and horizontal laminae, and thin to thick horizontal beds; platy with minor slabby splitting; weathers to form bench in lower part and reentrant below overlying unit in upper part. Unit contains 5 percent thin cosets of grayish-red fine- to medium-grained sandstone that is composed of subangular reddish-stained quartz and minor feldspar and abundant medium- to coarse-grained white and dark mica and consists of thin trough sets of small-scale cross-laminae 26.6

4. Sandstone, light-brown (5*YR* 6/4); weathers same color; very fine to fine grained with common medium grains, fair sorted; composed of subrounded amber quartz, abundant black accessory minerals, and uncommon fine- to medium-grained accessory white mica; poorly cemented, highly calcareous; unit is tabular, consists of thin to very thick trough sets of small- to large-scale low- and high-angle cross-laminae. Weathers to form cliff 51.7

3. Sandstone (60 percent) and siltstone (40 percent). Sandstone, grayish-red (5*R* 4/2) and minor light-greenish-gray (5*GY* 8/1); fine to medium grained, fair sorted; composed of subangular amber and clear quartz and minor feldspar, abundant coarse-grained biotite and muscovite; poorly cemented, calcareous; lower part of unit is horizontally thin bedded and upper part of unit is structureless. Siltstone, grayish-red (10*R* 4/2); weathers same color; abundant accessory fine-grained muscovite; firmly cemented, noncalcareous; occurs as a very thick structureless bed in middle of unit. Unit as a whole is tabular and weathers to form a conspicuous reentrant beneath overlying unit 18.0

Total Organ Rock Tongue and Cedar Mesa Sandstone Member undifferentiated 745.8

Total Cutler Formation 745.8

Rico Formation (incomplete):

2. Limestone, medium-light-gray (*N*6); weathers same color; dense, well cemented; unit is tabular, consists of indistinct very thin to thin horizontal beds; weathers to form conspicuous bench in vicinity of Lockhart Draw 6.7

1. (Unmeasured.) Sandstone, light-brown (5*YR* 6/4), light-greenish-gray (5*GY* 8/1), and pale-red (5*R* 6/2) in top 10 ft; weathers same colors; very fine grained, well sorted; composed of subrounded amber and clear quartz and common black accessory minerals; poorly cemented, calcareous; consists of thin to very thick trough sets of medium- to large-scale cross-laminae with indistinct thin horizontal beds in top 10 ft; weathers to form cliff.

Total incomplete Rico Formation 6.7

Base of section; not base of exposure.

U33. MILK RANCH POINT

[Measured, by J. H. Stewart and A. C. Gorveatt, August 1953, across southward-extending ridge directly west of Comb Ridge at head of Comb Wash and continuing up Comb Ridge. Center of section is 1.5 miles east of the crest of Milk Ranch Point. Sec. 35 (unsurveyed), T. 36 S., R. 20 E., SLM. San Juan County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Monitor Butte Member (incomplete): *Feet*

11. Clayey sandstone, pale-olive (10*Y* 6/2) and greenish-gray (5*GY* 6/1); weathers light greenish gray (5*GY* 8/1) and greenish gray (5*GY* 6/1); fine to very fine grained with sparse medium grains and about 20 percent clay, poorly sorted; composed of subangular milky mineral and 3–10 percent amber, orange, and green minerals, common medium- to coarse-grained accessory dark-green mica; common to abundant clay pellets and irregular pebble-size masses and slightly swelling clays; poorly cemented, noncalcareous, clay binding; stratification concealed; weathers to form steep rubble-covered slope with frothy surface where exposed. Upper 13 ft of unit contains more clay than rest of unit and grades into sandy claystone. Contact between the Chinle and Moenkopi Formations is placed at a change from red silty claystone of the Moenkopi to greenish-gray swelling claystone of the Chinle 65.5

Total incomplete Monitor Butte Member 65.5

Total incomplete Chinle Formation 65.5

Moenkopi Formation:

Upper slope-forming member:

10. Silty claystone to siltstone, grayish-red (10*R* 4/2) and pale-reddish-brown (10*R* 5/4); weathers same colors; silty claystone dominant type; micaceous; firmly cemented, silt-

U33. MILK RANCH POINT—Continued

Moenkopi Formation—Continued

Upper slope-forming member—Continued *Feet*

stone is calcareous and silty claystone is noncalcareous; stratification poorly exposed, but where seen is horizontally laminated with minor ripple laminae; weathers to form steep rubble-covered slope 100.6

Total upper slope-forming member 100.6

Ledge-forming member:

9. Sandstone, pale-red (10*R* 6/2) and minor light-greenish-gray (5*GY* 8/1); weathers pale reddish brown (10*R* 5/4) and very pale orange (10*YR* 8/2); very fine grained, fair sorted; composed of subangular milky mineral (probably dominantly quartz) and abundant orange and green accessory minerals; firmly cemented, highly calcareous; unit is tabular, consists of horizontal laminae and minor indistinct trough sets of medium-scale low-angle cross-laminae; platy and massive splitting; weathers to form uppermost of two conspicuous ledges in Moenkopi. A grayish-red (10*R* 4/2) ripple-laminated siltstone occurs as a thin set near base and as a thick set near top of unit. Unit may correlate with a pale-red sandstone in the middle of the Moenkopi in the Bears Ears section 29.3

8. Silty claystone to clayey siltstone (70 percent) and siltstone (30 percent), similar to unit 6 except siltstone is confined to a 6-ft-thick interval in middle of unit and a 4-ft-thick interval at top of unit; no sandstone seen 32.4

7. Sandy siltstone to sandstone, light-brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4); ranges from siltstone with minor very fine sand grains to very fine grained sandstone, abundant medium-grained white and dark accessory mica; firmly cemented, highly calcareous; unit is tabular, consists of horizontal laminae and minor ripple laminae; weathers to form lowermost of two conspicuous ledges in Moenkopi 16.7

Total ledge-forming member 78.4

Lower slope-forming member:

6. Silty claystone to clayey siltstone (70 percent) and siltstone (30 percent). Silty claystone to clayey siltstone, grayish-red (10*R* 4/2), sparse greenish-gray (5*GY* 6/1) bands a few millimeters thick; weathers same colors and pale reddish brown (10*R* 5/4); contains very fine grained accessory white mica; firmly cemented, noncalcareous; stratification and splitting concealed. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; common sandy (very fine grained) parts, common very fine grained accessory white mica; firmly to well cemented, calcareous; horizontally and ripple laminated in very thin to thin sets interstratified with rest of unit. Unit contains 3 percent interbedded thin sets of very pale orange (10*YR* 8/2) and light-greenish-gray (5*GY* 8/1) sandstone that is fine to very fine grained, well sorted; composed of subrounded clear quartz and sparse orange and black accessory minerals; firmly cemented, calcareous; horizontally and ripple laminated, minor very thin to thin planar sets of small-scale cross-laminae. Unit as a whole is tabular and weathers to form steep slope 58.8

Total lower slope-forming member 58.8

Hoskinnini Member:

5. Silty sandstone (50 percent) to siltstone (50 percent). Unit contains common light-greenish-gray (5*GY* 8/1) very thin to thin bands. Silty sandstone is similar to that in unit below but occurs as thin to thick horizontal beds interstratified with siltstone. Siltstone is grayish red (10*R* 4/2) and pale reddish brown (10*R* 5/4); weathers same colors; common very fine grained accessory white mica; firmly cemented, calcareous; seems structureless. Unit as a whole is tabular and weathers to form steep slope along with overlying units. Unit contains two thin beds of silty sandstone with crinkly or wavy bedding at 1.5 and 3.6 ft above base—the lower one may be equivalent to the "crinkly bed" of Baker (1936) in Monument Valley, Utah. Unit is placed in the Hoskinnini Member because it contains well-rounded medium to coarse grains and has bedding typical of the Hoskinnini. Top of unit placed at base of lowest horizontally and ripple-laminated set of the lower slope-forming member 26.2

4. Silty sandstone, moderate-reddish-orange (10*R* 6/6) and minor pale-reddish-brown (10*R* 5/4); weathers pale reddish brown; light-greenish-gray (5*GY* 8/1) thin bed at base and top of unit and common spots and irregular mottles in rest of unit; fine to very fine grained with minor silt and common 5–10 percent medium to very coarse grains, poorly sorted; composed of subrounded to rounded amber quartz, accessory minerals concealed; firmly cemented, calcareous; unit is tabular, consists of thin horizontal sets with wavy laminae and possibly some ripple laminae; contains sparse small-scale penecontemporaneous faults and sparse large-scale wavy

U33. MILK RANCH POINT—Continued

	Feet
Moenkopi Formation—Continued	
Hoskinnini Member—Continued	
beds seen nearby; massive splitting; weathers to form cliff	67.2
Total Hoskinnini Member	93.4
Total Moenkopi Formation	331.0
Cutler Formation (incomplete):	
Organ Rock Tongue:	
3. Siltstone, grayish-red (10*R* 4/2) and minor pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); sparse greenish-gray (5*GY* 6/1) very thin bands; commonly sandy (very fine grained), grades rarely into very fine grained sandstone; firmly cemented, calcareous; stratification poorly exposed and defined, but where seen commonly contains very thin horizontal beds and abundant horizontal bedding planes; weathers to form steep earthy slope. A 1.1-ft-thick bed of light-greenish-gray (5*GY* 8/1) limy sandstone 27.6 ft above base of unit is fine grained, well sorted; composed of subrounded clear quartz and uncommon black and orange accessory minerals; well cemented, highly calcareous; structureless. This limy sandstone may correlate with uppermost bed of the Cedar Mesa Sandstone Member in the Comb Wash section, although here it does not overlie purple rock as at Comb Wash	309.3
Total Organ Rock Tongue	309.3
Cedar Mesa Sandstone Member (incomplete):	
Transition unit:	
2. Sandstone and sandy siltstone. Sandstone, pale-reddish-brown (10*R* 5/4) with uncommon very pale orange (10*YR* 8/2), basal coset very pale orange (10*YR* 8/2) and moderate orange-pink (5*YR* 8/4); weathers same colors; very fine to fine grained, well sorted; composed of subrounded clear quartz and sparse black accessory minerals; poorly to firmly cemented, calcareous; mostly horizontally laminated to very thin bedded with minor thin to thick trough sets of small- to medium-scale cross-laminae; basal coset entirely cross-laminated, percentage of cross-stratification decreases upward; few laminae are wavy and deformed, sparse deformation by small-scale faults. Sandstone occurs as thin to very thick horizontal sets or cosets interbedded with siltstone; upward it becomes siltier and grades into sandy siltstone similar to that in the Organ Rock; sandstone occurs from 1.8–12.7 ft, 26.1–32.1 ft, 37.1–85.1 ft, 89.4–92.2 ft, and as thin sets forming about 50 percent of interval 92.2–107.3 ft above base of unit. Sandy siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers same colors; sandy (very fine grained); micaceous; firmly cemented, calcareous; horizontally thinly laminated to laminated; platy to slabby splitting. Unit as whole weathers to form poorly exposed ridge-and-valley topography in canyon between Cedar Mesa dip slope and steep slope of Organ Rock. Top of transistion unit placed at highest yellowish-gray (5*Y* 8/1) sandstone set	107.3
Total transition unit	107.3
1. (Unmeasured.) Sandstone, very pale orange (10*YR* 8/2) and minor pale-reddish-brown (10*R* 5/4); weathers same colors; fine to very fine grained, well sorted; composed of subrounded clear quartz and sparse black accessory minerals; poorly cemented, calcareous; consists of thick to very thick trough sets of medium- to large-scale cross-laminae; platy and massive spliting; weathers to form bare rock dip slopes and cliffs. Unit contains sparse pale-reddish-brown very fine grained sandstone layers that are a few feet to at least 10 ft thick and are horizontally laminated to thinly bedded; these layers are more common in upper 100 ft of Cedar Mesa.	
Total incomplete Cedar Mesa Sandstone Member	107.3
Total incomplete Cutler Formation	416.6

Base of section; not base of exposure.

U34. MONITOR BUTTE

[Measured, by L. C. Craig and P. J. Katich, June 1951, on northeast side of Monitor Butte, long 110°26′ W., lat 37°13′ N. San Juan County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Shinarump Member (incomplete) (unmeasured):

35. Conglomeratic sandstone, pale-yellowish-orange to yellowish-gray; medium grained and coarser; composed of subangular to subrounded clear quartz and sparse black accessory minerals; pebbles—mostly white and rose to pink quartz and white and dark chert—less than 1 in. and mostly ½–¼ in. in diameter, are disseminated in sand matrix as well as concentrated in lenses; festoon cross-lamination sets 1–10 ft thick; common channels with plant fragments and intraformational clay pebbles at base of unit. Unit forms massive ledge.

Moenkopi Formation:

Upper slope-forming member:

34. Claystone to siltstone, dusky-red (5*R* 3/4) and pale-green (5*G* 7/2); contains abundant fine and very fine sand grains; con-

U34. MONITOR BUTTE—Continued

Moenkopi Formation—Continued

Upper slope-forming member—Continued — *Feet*

tains intraformational conglomerate lenses composed of clay pebbles as large as ⅜ in. in diameter; poorly defined horizontal bedding and horizontal laminations; weathers to form cliff beneath Shinarump Member of Chinle Formation — 9.5

33. Claystone, siltstone, sandstone, and gypsum, interbedded. Claystone, dark-reddish-brown (10*R* 3/4); contains sparse fine sand grains; noncalcareous; slightly fissile. Siltstone, moderate-reddish-brown (10*R* 4/6); contains abundant very fine quartz grains; poorly defined ripple marks; slightly fissile; hackly weathering. Sandstone, light-green to moderate-reddish-brown, fine to very fine grained, contains sparse red and black accessory minerals; ripple laminated with well-defined ripple marks. Gypsum, white and intermixed with pale-green claystone; gypsum beds mainly in lower 50 ft of unit. Unit weathers to form horizontally banded talus-covered steep slope — 161.0

32. Limestone, greenish-gray (5*GY* 6/1); weathers dark greenish gray (5*GY* 4/1); dense to moderately crystalline; contains common well-rounded fine quartz sand grains; no bedding seen; poorly exposed; unit contributes large amount of angular lime fragments to talus slope — 0.4

Total upper slope-forming member — 170.9

Ledge-forming member:

31. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; fine grained; contains abundant well-rounded medium quartz grains, common black accessory minerals, white mica flakes along lamination planes; well indurated, noncalcareous; ripple laminated (1/32–⅜ in. amplitude); weathers to form rounded to platy ledge — 19.5

30. Sandstone, light-green; fine to medium grained; composed of perfectly rounded quartz grains, common orange and red chert, common very fine black accessory minerals; abundant green clay blebs; abundant gypsum seams; friable to firmly cemented, noncalcareous; structureless — 3.4

29. Sandstone, pale-reddish-brown (10*R* 5/4), abundant pale-green mottling in spots and bands; weathers same colors; fine grained, silty; contains sparse black and white accessory minerals, very fine white mica along laminations; firmly cemented, calcareous binding; horizontally bedded (1- to 4-ft-thick beds) and ripple laminated; silty fissile partings in upper part of unit; weathers to form rounded to platy ledge — 48.4

28. Siltstone, pale-reddish-brown (10*R* 5/4); contains abundant very fine quartz sand grains and common very fine white mica; noncalcareous; ripple bedded and ripple laminated; fissile; weathers to form shaly slope — 2.5

U34. MONITOR BUTTE—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued — *Feet*

27. Sandstone, grayish-orange-pink (5*YR* 7/2); very fine grained; contains sparse black accessory minerals; very calcareous; top surface ripple marked; forms persistent parting plane — 0.1

26. Sandstone, pale-red (10*R* 6/2); weathers same color; very fine to fine grained; contains abundant fine white mica flakes and common black accessory minerals; firmly cemented, slightly calcareous; horizontally bedded (1- to 3-ft-thick beds) and horizontally to ripple laminated (1/16–¼ in. amplitude), micaceous along laminations, pseudocrossbedding; very fissile at top; weathers to form lowest large prominent smooth ledge — 18.8

Total ledge-forming member — 92.7

Lower slope-forming member:

25. Siltstone, moderate-brown (5*YR* 4/4); weathers light brown (5*YR* 6/6); contains white gypsum in veins, vugs, and concretions as large as 1 ft in diameter; firmly cemented, slightly calcareous; structureless, minor parallel ripple laminae; weathers to form slope — 46.8

Total lower slope-forming member — 46.8

Hoskinnini Member:

24. Silty sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained; horizontally bedded, indistinct wavy laminae; weathers to form slope — 22.4

23. Gypsum, white; weathers white and moderate reddish brown (10*R* 4/6); medium to finely crystalline; contains sparse red and black chert grains; bedding concealed; poorly exposed; forms ledge where exposed. T. E. Mullens (oral commun., 1955) suggests that this gypsum unit probably correlates with the "crinkly bed" of Baker (1936) in Monument Valley — 3.2

22. Sandstone, pale-green (10*G* 7/2); fine to very fine grained; contains abundant well-rounded coarse frosted clear quartz grains, common coarse red chert grains, and common very fine black accessory minerals; firmly cemented, very calcareous; poorly exposed lenticular bed with no structure or lamination seen — 0.7

21. Sandstone, pale-reddish-brown (10*R* 5/4), abundant pale-green mottling in bands, streaks, and spots; weathers same colors; very fine grained, silty; contains abundant well-rounded medium quartz grains, sparse to common well-rounded coarse quartz

U34. MONITOR BUTTE—Continued

Moenkopi Formation—Continued

Hoskinnini Member—Continued *Feet*

grains, sparse white mica; firmly cemented, very calcareous; secondary gypsum occurs as veinlets and vug fillings; contains many thin layers of sandy siltstone; some silty sandstone with sparse well-rounded medium quartz grains at top of unit. Unit weathers to form shaly steep slope banded by mottling and by persistent sandstone ledges 39.0

20. Sandstone, pale-reddish-brown (10*R* 5/4), pale-green mottling in bands, streaks, and spots; fine to very fine grained, abundant silt in matrix, and common silty partings; contains abundant well-rounded coarse frosted and amber quartz grains, sparse coarse rounded black grains, sparse very fine black accessory minerals; firmly cemented, very calcareous; ranges from structureless at base to laminated (1/6- to 1/8-in.-thick laminae) at top. Unit is gradational with underlying unit 14.0

19. Sandstone, very light gray (*N*8); weathers same color; fine to very fine grained, contains abundant perfectly rounded very coarse frosted quartz and red chert grains, sparse very fine black accessory minerals; friable to firmly cemented, slightly calcareous; secondary gypsum as veins and vugs; bedding concealed; forms rounded ledge. Unit is gradational with overlying unit. Lower contact is wavy 11.0

Total Hoskinnini Member 90.3

Total Moenkopi Formation 400.7

Cutler Formation (incomplete):

Organ Rock Tongue:

18. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained, abundant silt; contains common fine white mica flakes; well indurated, slightly calcareous; structureless; weathers to form ledgy high-angle slope 51.6

17. Sandstone, pale-reddish-brown (10*R* 5/4) to moderate-reddish-brown (10*R* 4/6); very fine grained, silty; contains common fine white mica; well indurated, slightly calcareous; bedding mostly concealed, but where seen is ripple laminated (1/6- to 1/4-in.-thick laminae). Unit forms rounded slope covered by thin talus debris. Unit grades upward to slightly fissile silty sandstone 24.0

16. Limestone pellet conglomerate, pale-brown (5*YR* 5/2); weathers moderate red (5*R* 5/4), gradational to pale-red (5*R* 6/2) sandstone along strike; contains subrounded limestone pellets as large as 3/4 in. in diameter, contains some highly calcareous very fine grained sandstone; well indurated; unit is lenticular 2.5

U34. MONITOR BUTTE—Continued

Cutler Formation—Continued

Organ Rock Tongue—Continued *Feet*

15. Sandstone and siltstone, pale-reddish-brown (10*R* 5/4), mottled pale-green in bands and spots; siltstone, very sandy; contains very fine grained mica; calcareous cement; bedding concealed; sandstone occurs in lenticular beds; hackly weathering; forms horizontally banded shaly slope 25.6

14. Sandstone, moderate-reddish-orange (10*R* 6/6); weathers same color; very fine grained, slightly silty; contains scattered fine to medium quartz grains and white mica, sparse black mica, common very fine black accessory minerals; weak to firm cement, calcareous; bedding not seen; irregular rounded concretionary weathering. Unit grades into reddish-brown sandstone along strike 12.8

13. Sandstone, light-greenish-gray (5*GY* 8/1); weathers same color; very fine grained; contains abundant very fine grains of red and orange chert, black accessory minerals; minor to abundant calcareous cement; sandstone grades into fine conglomerate composed of subrounded limestone pebbles. Unit is cross-laminated to horizontally laminated, lenticular and weathers to form prominent rounded light-colored ledge 4.4

12. Sandstone and siltstone. Siltstone, dark- to moderate-reddish-brown (10*R* 3/4 to 10*R* 4/6); weathers same colors; contains abundant very fine sand grains; very fine mica; well indurated, very slightly calcareous. Siltstone grades into very fine grained sandstone that contains abundant very fine grained mica. Unit is well indurated, slightly calcareous; no lamination seen. Horizontally banded appearance due to lenticular sandstone ledges; a 2-ft-thick bed at 38 ft and a 3-ft-thick bed at 50 ft above base of unit form prominent dual ledges. Common 20–30 ft wide lenses of light-green limestone. Limestone contains pale-green mottling in streaks and spots; weathers pale red (10*R* 6/2). Unit contains considerable limestone rubble on surface. Unit is hackly weathering; top 30 ft contains rounded concretionary structures 94.0

11. Sandstone, moderate-reddish-orange (10*R* 6/6); weathers same color; very fine to fine grained; contains common white mica and very fine black accessory minerals; friable to firm cement, slightly calcareous; massive with poorly defined lamination at top; splits into large angular blocks; weathers to form prominent ledge which has vertical joints at base and which is slightly rounded at top 6.6

10. Siltstone and sandstone, pale-red-brown (10*R* 5/4); pale-green mottling (5*G* 7/2 and 10*G* 6/2) in streaks, blotches, and irregu-

U34. MONITOR BUTTE—Continued

Cutler Formation—Continued

Organ Rock Tongue—Continued *Feet*

lar spots; weathers same colors. Siltstone contains abundant very fine sand grains and very fine grained white mica and is well indurated, slightly calcareous. Siltstone grades into silty very fine grained sandstone that is well indurated and weakly calcareous. Unit has horizontal banded appearance owing to thin beds (0.2–0.4 ft) and lenticular ledges; weathers to form badland hills. Abundant pale-green (5*G* 7/2) very fine grained sandstone dikes that terminate at top of unit — 135.0

NOTE.—Section offset on unit 9 so that overlying units measured 3,000 ft south of underlying units.

9. Sandstone, moderate-reddish-brown (10*R* 4/6); very persistent pale-green (5*G* 7/2) 0.4-ft-thick mottled band at base of unit; weathers same colors; very fine grained, silty; contains abundant fine white mica; well indurated, slightly calcareous; structureless; hackly splitting (debris forms small angular blocks); weathers to form lenticular ledge — 7.2
8. Siltstone, dark-reddish-brown (10*R* 3/4); weathers moderate reddish brown (10*R* 4/6); contains abundant very fine quartz sand grains and common very fine white mica; noncalcareous to slightly calcareous; hackly splitting. Unit contains a lenticular 0.1- to 0.2-ft-thick very light gray (*N*8) limestone bed near base. Unit as a whole weathers to form shaly steep slope — 22.0
7. Sandstone, moderate-reddish-brown (10*R* 4/6); weathers same color; composed of subrounded to well-rounded fine sand grains, slightly silty; contains common white mica and sparse black accessory minerals; friable to well cemented, calcareous binding; common light-green calcareous concretions. Unit is lenticular, structureless, and massive; weathers to subrounded blocks 8 in. to 1 ft in diameter that form cap of extensive dip slope — 2.0
6. Sandstone, dark-reddish-brown (10*R* 3/4); weathers moderate reddish brown (10*R* 4/6); very fine grained, silty; noncalcareous; finely laminated (1/8- to 3/8-in.-thick laminae); slightly fissile; forms lenticular layer between overlying and underlying units — 3.0
5. Sandstone, moderate-reddish-brown (10*R* 4/6); weathers same color; subrounded to well-rounded fine grains, slightly silty; common white mica and sparse black accessory minerals; friable to well cemented, calcareous binding; common light-green calcareous concretions. Unit is lenticular, structureless, and massive; weathers to subrounded blocks 8 in. to 1 ft in diameter — 1.9
4. Sandstone, pale-reddish-brown (10*R* 5/4) to moderate-reddish-brown (10*R* 4/6); pronounced white mottled band 18 ft above base of unit; very fine grained, silty, poorly sorted; contains common fine-grained quartz, common fine to medium white mica, and sparse black accessory minerals; well indurated, slightly calcareous; grades from silty to clean sandstone that occurs as lenticular 1½- to 2½-ft-thick ledges 7, 18, 28, and 43 ft above base of unit; weathers to form an alternating ledge and shale slope — 50.4
3. Sandstone, moderate-reddish-brown (10*R* 4/6); abundant white mottling in streaks and irregular spots; weathers same colors; very fine to fine grained; composed of subangular to well-rounded quartz grains, common fine and medium white mica, sparse black accessory minerals; friable to firmly cemented, calcareous cement; structureless; weathers to large rounded nodules; weathers to form persistent ledge — 1.5
2. Sandstone, dark-reddish-brown (10*R* 3/4); weathers same color; very fine grained and silty, poorly sorted; contains abundant angular to well-rounded fine to medium quartz grains and common fine white mica; slightly calcareous; unit in lenticular becoming thicker locally away from section line; structureless; hackly weathering, weathers to form rounded low-angle slope — 3.4

Total Organ Rock Tongue — 447.9

Cedar Mesa Sandstone Member (incomplete) (unmeasured):

1. Limestone, medium-light-gray (*N*6); weathers same color; dense, very sandy; grades laterally into moderate-reddish-brown (10*R* 4/6) very fine grained calcareous sandstone that has abundant light- and pale-green mottling. Unit is highest limestone bed. Contact with Organ Rock is well defined.

Total incomplete Cutler Formation — 447.9

Base of section; not base of exposure.

U35. NORTH SIXSHOOTER PEAK

[Measured, by J. H. Stewart and G. W. Weir, May 1953, on north side of North Sixshooter Peak in secs. 30 and 31, T. 30 S., R. 21 E., SLM. San Juan County]

Top of section; not top of exposure.

Chinle Formation (incomplete): *Feet*

Moss Back Member:

21. Sandstone, similar to unit 20 except for abundant cross-stratification at top that consists of trough sets of medium-scale low-angle cross-laminae; green claystone parting at base — 23.8

U35. NORTH SIXSHOOTER PEAK—Continued

Chinle Formation—Continued

Moss Back Member—Continued — Feet

20. Sandstone, yellowish-gray (5*Y* 8/1); weathers light brown (5*YR* 5/6); fine to medium grained, fair sorted; composed of clear quartz and feldspar(?), fine white mica, white to yellowish-gray clay grains (perhaps representing decomposed feldspar), and abundant black and orange accessory minerals; well cemented; stratification poorly exposed, but probably mostly horizontally stratified; massive splitting; weathers to form cliff — 18.0

19. Silty claystone (50 percent) and sandstone (50 percent). Claystone, pale-olive (10*Y* 6/2); weathers same color; thinly laminated; papery splitting that forms small chips. Sandstone, yellowish gray (5*Y* 7/2); weathers light brown (5*YR* 6/4); fine grained, silty, fair sorted; well cemented; ripple marked; occurs as lenticular layers in claystone; platy splitting. Unit as a whole forms prominent notch in cliff. Unit defines prominent local diastem — 1.0

18. Conglomeratic sandstone, pale-greenish-yellow (10*Y* 8/2); weathers light brown (5*YR* 6/4); fine to coarse grained with granules and pebbles, poorly sorted; composed of subangular to subrounded grains of milky, bluish-gray, and clear quartz, clear plagioclase(?), and greenish-gray and yellowish-orange clay (perhaps representing, in part, decomposed feldspar), and subangular to well-rounded granules and pebbles as large as 1½ in. in diameter (average ⅜ in. diameter) of milky quartz, orange, gray, and black chert, greenish-brown limy siltstone, and light-gray thinly laminated siltstone; firmly cemented, calcareous(?), with some clay binding; trough sets of medium- and small-scale low- to high-angle cross-lamination throughout unit; platy to massive splitting. Unit weathers to form rough steep ledge, and breaks up into large blocks 10 ft or more in diameter that are mainly concentrated within 75 ft of the Moss Back–Moenkopi contact. Some siltstone and sandstone pebbles and cobbles, as large as 5 in. in diameter, were probably derived from the Moenkopi. Carbonaceous material is not conspicuous on the outcrop, but its presence is indicated by some scattered dark spots partly replaced by calcite and by impressions on talus blocks — 10.0

Total Moss Back Member — 52.8

Total incomplete Chinle Formation — 52.8

NOTE.—Contact between the Moenkopi and Moss Back is placed at the base of a conglomeratic sandstone that rests on poorly exposed pale-reddish-brown and light-brown siltstone of the Moenkopi. The contact commonly is concealed by slump blocks of Moss Back and slope wash from higher units. If the reddish-brown silty material identified as Moenkopi directly below the conglomeratic sandstone is slope wash from higher formations (Chinle and Wingate), the actual Moss Back-Moenkopi contact may be as much as 10 ft below the contact selected here. Section offset so that underlying units were measured about 1,000 ft east of unit 18.

Moenkopi Formation:

Upper part:

NOTE.—Later work in this area indicates that upper three members in the Moenkopi can be recognized, although their contacts are poorly defined: basal 100± ft is lower slope-forming member, middle 103± ft is ledge-forming member, and top 92± ft is upper slope-forming member.

17. Siltstone to clayey siltstone, pale-reddish-brown (10*R* 5/4) and light-brown (5*YR* 6/4); abundant thin bands of light-greenish-gray (5*GY* 8/1) from 55.5 to 104.5 ft and locally elsewhere in unit; weathers same colors; contains abundant fine-grained white mica; horizontally and ripple laminated; platy splitting with minor flaggy and slabby splitting; weathers to form rubble-covered steep slope with few thin ledges. Unit differentiated from one below by its light-greenish-gray bands and fewer resistant ledges — 164.0

16. Siltstone to sandy siltstone, pale-reddish-brown (10*R* 5/4) and light brown (5*YR* 6/4); weathers pale reddish brown (10*R* 5/4); sandy (very fine grained) in parts; contains abundant fine-grained white mica; firmly to well cemented, calcareous; consists of thin to thick horizontal sets of ripple laminae with minor contortions, sparse current lineations, and common cuspate ripples; platy splitting with minor flaggy to massive splitting; weathers to form steep slope, covered by large platy fragments, containing many thin to thick ledges — 130.7

Total upper part of Moenkopi Formation — 294.7

Hoskinnini Member:

15. Sandy siltstone, pale-reddish-brown (10*R* 5/4) and moderate-brown (5*YR* 4/4); weathers pale reddish brown (10*R* 5/4); sandy (very fine grained); firmly cemented, calcareous; unit is tabular, stratification poorly exposed, but where seen contains common thin horizontal beds; common platy splitting; weathers to form slope. Unit seems to be a transition between the Hoskinnini Member and over-

U35. NORTH SIXSHOOTER PEAK—Continued

Moenkopi Formation—Continued
Hoskinnini Member—Continued *Feet*

lying part of the Moenkopi. It contains no medium and coarse grains or peculiar stratification characteristic of the Hoskinnini and no ripple laminae characteristic of the overlying part of the Moenkopi. The basal strata of the overlying part of the Moenkopi contain a thin persistent ledge that marks the first occurrence upward of typical Moenkopi ripple laminae. Unit probably correlates with unit 24 in the Lockhart Canyon section ---------- 25.9

14. Silty sandstone to sandy siltstone, similar to unit 11. Unit is one thick tabular set and weathers to form persistent ledge. Unit probably correlates with the highest thin sandy intervals in the Hoskinnini at Cottonwood Creek, Bridger Jack Mesa, and Lockhart Canyon sections ---------- 2.6
13. Siltstone, pale-reddish-brown (10*R* 5/4) and sparse light-greenish-gray (5*GY* 8/1) bands; weathers same colors; firmly cemented, slightly calcareous; unit is tabular, stratification mostly concealed (top 4 ft has stratification similar to unit 11); weathers to form rubble-covered steep slope with a cliff in top 4 ft. Unit is poorly exposed ---------- 25.7
12. Silty sandstone, grayish-red (10*R* 4/2) with thin bands of light-greenish-gray (5*GY* 8/1) at top and bottom; weathers pale reddish brown (10*R* 5/4); medium grained, poorly sorted; firmly cemented, calcareous; stratification poorly exposed, unit is tabular with small-scale waviness or "crinkliness"; weathers to wavy indistinct ledge. Lower 0.8 ft of unit is composed of rhombohedral crystals of calcite set in a silt matrix; the basal 0.1 ft contains calcite crystals the size of granules and common orange chert nodules averaging about 3/8 in. in diameter; otherwise composition similar to underlying unit. Unit undoubtedly correlates with similar wavy beds in Cottonwood Creek, Bridger Jack Mesa, and Lockhart Canyon sections, and probably correlates with the "crinkly bed" of Baker (1936) in Monument Valley ---------- 1.7
11. Silty sandstone to sandy siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; silt to fine sand grains in various proportions with about 5 percent medium and coarse sand grains, poorly sorted; composed of subrounded very fine to fine amber quartz grains; contains abundant medium-grained accessory white mica; firmly cemented, slightly calcareous; unit is tabular, consists of thin to thick horizontal sets; stratification within sets is only rarely exposed, but where seen consists of laminae, bounded by films of red silt or clay, that seem to be mostly horizontal, but are commonly wavy and generally lens out within a few inches; these wavy laminae in some places may be ripple laminae. Unit weathers to form thin to thick smooth rounded ledge with small slope in places ---------- 54.9

Total Hoskinnini Member ---------- 110.8

Total Moenkopi Formation ---------- 405.4

NOTE.—Contact between Organ Rock Tongue of Cutler Formation and Hoskinnini Member of Moenkopi Formation is placed at a color change where light brown (5*YR* 5/6) of the Hoskinnini begins to predominate over pale red (5*R* 6/2) characteristic of the Organ Rock. Hoskinnini is also characterized by common well-rounded medium and coarse sand grains set in a silty and sandy matrix.

Cutler Formation (incomplete):
Organ Rock Tongue:

10. Sandstone (60 percent) and sandy siltstone (40 percent), interstratified. Sandstone is similar to that in unit 3 and sandy siltstone is similar to that in unit 4. Very thick cosets of sandstone interstratified with cosets of sandy siltstone. Percentage of sandstone and sandy siltstone changes along strike; unit contains granule conglomerate to pebbly sandstone layers at 16.6–19.6 ft, 25.1–27.6 ft, and 36.0–37.7 ft, above base. These layers are composed of granules to cobbles of light-brown siltstone set in a sand matrix similar to sandstone in rest of unit; the pebbly conglomerate 25.1 ft above base of unit forms a prominent ledge that is overlain by a prominent bench ---------- 38.7
9. Pebbly sandstone, pale-red (5*R* 6/2); weathers light brown (5*YR* 6/4); medium to coarse grained, poorly sorted; composed of subangular to subrounded grains of clear quartz and milky feldspar, and granules, pebbles, and cobbles of limy siltstone and granules and pebbles of graphic granite, granite, and hornfels (or felsite?); firmly cemented, highly calcareous; consists of some medium-scale low-angle cross-lamination and some structureless rock; slabby splitting; weathers to form small ledge ---------- 3.0
8. Sandstone (50 percent) and sandy siltstone (50 percent), interstratified. Sandstone similar to that in unit 3 and sandy siltstone similar to that in unit 4. Lithology changes along outcrop. Weathers to form steep slope containing small ledges ---------- 24.7
7. Sandstone, similar to that in unit 3 except that it contains fewer sets of medium- and coarse-grained sandstone sets ---------- 18.7
6. Sandy siltstone, similar to that in unit 4 ---------- 20.6

U35. NORTH SIXSHOOTER PEAK—Continued

Cutler Formation—Continued

Organ Rock Tongue—Continued

	Feet
5. Sandstone, similar to that in unit 3 except for abundant intraformational conglomeratic sandstone in lower 6 ft. Conglomeratic sandstone contains granules to cobbles of reddish-brown siltstone and sandstone; reddish-brown siltstone granules sparse to common in upper 13.7 ft of unit. Weathers to form a small rounded ledge	19.7
4. Sandy siltstone, pale-reddish-brown (10*R* 5/4); common thin yellowish-gray bands; weathers same colors; sandy (very fine grained); contains abundant fine-grained dark-green mica; firmly cemented, noncalcareous; laminated and thinly to thickly horizontally bedded, possibly ripple laminated in part; platy to slabby splitting; weathers to form steep slope with cliff locally developed at top of unit	17.3
3. Sandstone, pale-red (5*R* 6/2); weathers same color; fine grained, well sorted; composed of subangular clear quartz and feldspar(?) with abundant dark-green mica and common white mica; firmly cemented, calcareous; consists of trough sets of medium- and large-scale low-angle cross-laminae; platy to massive splitting; weathers to form small smooth rounded ledge. Unit contains several sets of pale-yellowish-orange (10*YR* 8/6) medium- to coarse-grained, poorly to fair-sorted sandstone; composed of subangular to subrounded clear quartz and feldspar and abundant black accessory minerals; poorly cemented, calcareous; stratification and splitting similar to rest of unit	13.6
2. Sandstone (80 percent) and conglomeratic sandstone (20 percent), moderate-reddish-brown (10*R* 4/6) and grayish-red (10*R* 4/2); weathers same colors; fine to medium grained, also medium to very coarse grained, coarser grained rock characterized by irregularly distributed clay pellets averaging ½ in. in diameter. Sandstone and conglomeratic sandstone is fair sorted and also poorly sorted; composed of subrounded and angular amber-stained quartz, feldspar, and common black accessory minerals; firmly cemented, calcareous and clay binding; consists of trough sets of large- to medium-scale low-angle cross-laminae (some ledges seem disconformable to regional dip, but may be low rolling contorted bedding); massive to platy splitting; weathers to form an irregular bench with ledges. Lithology of unit is highly variable	32.8
Total Organ Rock Tongue	189.1

U35. NORTH SIXSHOOTER PEAK—Continued

Cutler Formation—Continued

Cedar Mesa Sandstone Member (incomplete) (unmeasured):

	Feet
1. Sandstone, grayish-orange (10*YR* 7/4) and light-brown (5*YR* 6/4 and 5*YR* 5/6); weathers grayish orange (10*YR* 7/4); medium grained, well sorted; composed of subrounded clear quartz and abundant green and black accessory minerals; poorly cemented, calcareous; stratification poorly exposed, but where seen contains large-scale low-angle cross-laminae and some contorted strata; slabby splitting; forms bench and low rounded ledge. Top 3 ft of unit forms structureless capping ledge. Only top 10 ft of unit exposed.	
Total incomplete Cutler Formation	189.1

Base of section; base of local exposure.

U36. PONCHO HOUSE

[Measured, by L. C. Craig, T. E. Mullens, G. A. Williams, and P. J. Katich, June 1951, on Comb Ridge about 2 miles south of place where Chinle Wash crosses Comb Ridge; long 109°45′ W., lat 37°8′ N., and long 109°45′ W., lat 37°7′ N. San Juan County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Monitor Butte Member:

	Feet
81. Silty claystone, light-greenish-gray (5*GY* 8/1); contains numerous gypsum flakes in lower part and numerous irregularly oriented logs that are replaced by sand, calcite, and iron oxide; weathers to hackly and highly frothy surface that forms steep cuesta and dip slope	158.5
80. Silty claystone, medium-light-gray (*N*6) with faint red and purple bands; weathers to hackly and frothy surface. About 300 ft south of section line a sandstone occurs near top of unit that is medium-gray, lenticular, much contorted, fills channels, and contains plant impressions and some ripple lamination. Laterally member is contorted and thicker than along line of section	22.9
Total Monitor Butte Member	181.4
Total incomplete Chinle Formation	181.4

NOTE.—From ¼ to ¾ mile south of line of section a prominent sandstone lens of the Shinarump Member occurs at the base of the Chinle. The lens has a maximum thickness of 30–40 ft, a remarkably flat basal surface, and an irregular top surface. This sandstone is light greenish gray (5*GY* 8/1) to yellowish gray (5*Y* 8/1) and very pale orange (10*YR* 7/4); fine to medium grained, coarser at base; composed of subangular grains of clear quartz with common to abundant black, orange, and white accessory minerals; consists of numerous festoon sets, less than 1 ft thick, of small-scale cross-laminations.

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U36. PONCHO HOUSE—Continued

Moenkopi Formation:

Upper part: *Feet*

79. Claystone and sandstone, similar to unit 77 except for less sandstone and fine banding. Lithology not examined in detail because unit forms inaccessible cliff along line of section. Entire unit is cut out by channel at base of Chinle 300 ft south of section line. Channel fill consists of strata of the Monitor Butte Member of Chinle ---- 23.0
78. Sandstone, pale-red (10*R* 6/2) and light-greenish-gray (5*GY* 8/1) with white mottling and banding; very fine to fine grained; composed of subangular clear quartz and common gray to black accessory minerals; locally contains small-scale cross-laminated sets; weathers with rounded "hoodoo" shapes ---- 11.5
77. Claystone (50 percent) and sandstone (50 percent). Claystone, pale- to dark-reddish-brown (10*R* 5/4 to 10*R* 3/4); silty; highly micaceous; seems to be finely ripple laminated. Sandstone, light-greenish-gray (5*GY* 8/1) to white (*N*9) and moderate-reddish-orange (10*R* 6/6); fine to medium grained; composed of subangular clear quartz; thin bedded (2 in. to 2 ft thick), ripple marked and structureless: platy to massive splitting ---- 42.3
76. Sandstone, white (*N*9) to pale-reddish-brown (10*R* 5/4); very fine to medium grained, poorly sorted; composed of subangular clear quartz and uncommon pink and black accessory minerals; unit is a local cross-laminated lens that weathers irregularly depending on lime and silt content. Unit contains some indistinct fine lamination ---- 14.1
75. Claystone and minor sandstone. Claystone is pale reddish brown (10*R* 5/4); very silty to slightly sandy (fine grained); highly micaceous with thin parallel lamination (fissile) in upper part and hackly in lower part. Sandstone is light greenish gray (5*GY* 8/1); very fine to medium grained, poorly sorted; occurs as thin parallel beds ---- 23.5

Total upper part of Moenkopi Formation ---- 114.4

Hoskinnini Member:

74. Sandstone, irregularly banded and mottled pale-reddish-brown (10*R* 5/4), light-greenish-gray (5*GY* 8/1), and yellowish-gray (5*Y* 8/1); very fine to very coarse grained, poorly sorted; composed of subangular to well-rounded clear quartz and common orange and black accessory minerals; firm to hard cement, moderately calcareous; faint very irregular subparallel laminations with contorted beds at top having relief of 10 ft in 50 ft. Basal contact is sharp and is marked by channels cut as deep as 1 ft into underlying unit ---- 51.7

Total Hoskinnini Member ---- 51.7

Total Moenkopi Formation ---- 166.1

Cutler Formation (incomplete):

De Chelly Sandstone Member:

73. Sandstone, moderate-reddish-orange (10*R* 5/6 to 10*R* 6/6); fine to medium grained, fair sorted; composed of subangular to subrounded clear and slightly amber stained quartz grains with common white and abundant black accessory minerals; firm to weak slightly calcareous cement; unit is a coset consisting of sets 5–15 ft thick and many subsets; contains compound cross-lamination ---- 182.8
72. Sandstone, moderate-reddish-orange (10*R* 5/6), upper one-half pale-reddish-brown (10*R* 5/4); very fine to medium grained, fair sorted; composed of subangular to subrounded clear and amber-stained quartz grains, common white accessory minerals (other accessory minerals are concealed); contains indistinct parallel bedding. Top 1 ft of unit is locally clayey and micaceous. Unit forms a massive and structureless nonresistant ledge marking local spring line. Three hundred yards lateral to line of section cross-laminated material occupies position of unit ---- 36.1
71. Sandstone, moderate-reddish-orange (10*R* 6/6); fine to very fine grained with some laminar concentrations of subrounded to well-rounded medium grains; composed of subangular clear and amber-stained quartz grains, common white accessory minerals, other accessory minerals concealed, uncommon white to pale-green mica; contains some worm markings (?); forms massive coset (stratum) of compound large-scale cross-laminated sets 5–25 ft thick and thin subsets ---- 61.1
70. Sandstone, moderate-reddish-orange (10*R* 5/6); very fine to fine grained; composed of clear and amber-stained quartz with common white accessory minerals; forms an indistinct massive and structureless unit that occurs as a continuous thick sandstone at the base of the De Chelly Sandstone Member ---- 14.1

Total De Chelly Sandstone Member ---- 294.1

U36. PONCHO HOUSE—Continued

	Feet
Cutler Formation—Continued	
Transition unit:	
69. Sandstone, alternating moderate-reddish-orange (10*R* 5/6) and pale-reddish-brown (10*R* 4/4); very fine grained and silty; composed of clear and amber-stained quartz with common greenish-gray to colorless mica; consists of beds 2–5 ft thick that are faintly parallel laminated. Unit becomes more massive upward, forms shaly dip slopes with some hackly- to earthy-weathering ledges	42.3
68. Sandstone, moderate-reddish-orange (10*R* 5/6) to pale-reddish-brown (10*R* 4/4) with minor thin light-gray streaks; very fine grained, fair sorted; composed of subangular amber-stained quartz grains, contains common mica flakes in lower half and uncommon mica flakes in upper half; consists of faint parallel thin laminae; weathers to form nonresistant shaly slope	19.8
67. Sandstone, moderate-reddish-orange (10*R* 5/6); very fine grained, fair-sorted; composed of subangular amber-stained quartz, accessory minerals concealed; noncalcareous; worm borings abundant in upper part; some possible laminations; weathers to form a single structureless massive bed	4.0
Total transition unit	66.1
Organ Rock Tongue:	
66. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; fine to very fine grained; contains common fine-grained white mica and sparse black accessory minerals; well indurated, noncalcareous; horizontally laminated (⅛–½ in. thick) and ripple laminated in beds as much as 6 in. thick	6.0
65. Sandstone and siltstone, interbedded. Siltstone, moderate-reddish-brown (10*R* 4/6); weathers same color; contains abundant very fine quartz grains and scattered mica flakes; calcareous cement. Sandstone, very fine grained with abundant silt and scattered fine quartz grains, poorly sorted; calcareous cement. Sandstone forms ledges that weather into angular blocks; siltstone forms interledge slopes	34.4
64. Siltstone, moderate-reddish-brown (10*R* 4/6); weathers same color; contains abundant very fine quartz grains and abundant fine to very fine white mica; calcareous cement; unit is mostly covered by a 6-in.-thick mantle of weathered silt and is conspicuous by the absence of sandstone ledges	41.6
63. Sandstone, pale-reddish-brown (10*R* 5/4); weathers moderate reddish brown (10*R* 4/6); very fine grained with abundant silt, poorly sorted; contains common fine quartz grains and common fine white mica; calcareous cement. Sandstone forms horizontal lenticular ledges that weather into angular blocks; silty sandstone forms interledges 1–3 ft thick that weather to shaly slopes	27.1
62. Sandstone, moderate-reddish-orange (10*R* 6/6); weathers moderate reddish brown (10*R* 4/6); very fine grained and slightly silty; contains common fine quartz grains and common fine white mica; well indurated, slightly calcareous; occurs as a very persistent lenticular bed; massive splitting; weathers to desert-varnished boulders 8–12 ft in diameter and forms most persistent ledge in Organ Rock	19.0
61. Siltstone and very fine grained sandstone, pale-reddish-brown (10*R* 5/4) to moderate-reddish-brown (10*R* 4/6); abundant pale-green mottling in bands; weathers same colors. Siltstone contains abundant very fine quartz grains and abundant very fine mica; calcareous cement. Sandstone contains abundant silt, common fine quartz grains, and abundant fine and very fine white mica; calcareous cement. Sandstone and siltstone intergrade; sandstone forms horizontal lenticular rounded to highly fractured ledges 1–2 in. thick and siltstone forms intervening hard steep shaly slopes. Unit contains an altered igneous dike that weathers to a pale-green chloritic sand and silt; igneous alteration may account for some green mottling in unit	182.0
60. Sandstone, pale-red (10*R* 6/2) to pale-reddish-brown (10*R* 5/4); very fine grained; contains sparse to comon fine to very fine mica; firm calcareous cement; unit occurs as an irregular tabular bed; horizontal and ripple laminated with minor cross-laminated lenses; contains poorly defined 1/32- to ¼-in. crescent current ripple marks; weathers to form jagged irregular ledge	6.3
59. Siltstone, pale-red-brown (10*R* 5/4); weathers same color; contains abundant very fine quartz grains and clay, poorly sorted; common fine to very fine chloritic mica; calcareous cement; bedding mostly cancealed, but where seen contains faint horizontal banding owing to slightly sandy and (or) slightly calcareous layers; unit is mostly covered by a 6-in.-thick mantle of weathered material that forms a rounded shaly slope	78.0
58. Sandstone, moderate-reddish-orange (10*R* 6/6); weathers same color; very fine grained with abundant silt, poorly	

U36. PONCHO HOUSE—Continued

Cutler Formation—Continued

Organ Rock Tongue—Continued *Feet*

sorted; contains common fine quartz grains and abundant fine to very fine mica; calcareous cement; bedding mostly concealed; slightly fissile on weathered surface; forms shaly slope — 9.0

57. Sandstone, moderate-reddish-brown (10*R* 4/6) to pale-reddish-brown (10*R* 5/4); very fine grained; contains abundant fine to medium mica and sparse black accessory minerals; firm calcareous cement; unit occurs as a massive bed that is poorly exposed in creek — 2.4

56. Covered by detritus in streambed — 18.0

55. Sandstone, pale-red (10*R* 6/2); weathers pale reddish brown (10*R* 5/4); very fine grained; contains common fine to medium mica and sparse red and black accessory minerals; firm calcareous cement; horizontal laminations (1/16–1/8 in. thick) that are crudely rippled locally; slabby splitting; weathers to form ridge cap on west side of creek along section line — 0.5

54. Siltstone, dark-reddish-brown (10*R* 3/4); weathers moderate reddish brown (10*R* 4/6); very abundant pale-green (5*G* 7/2) mottling in bands, blotches, and diagonal streaks; contains abundant very fine quartz grains and common fine to very fine mica; slightly calcareous; bedding concealed — 36.4

53. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained with abundant silt; very calcareous; unit occurs as a tabular bed; structureless with some possible laminae; forms very persistent concretionlike ledge — 2.3

52. Siltstone, moderate-reddish-brown (10*R* 4/6); contains very fine quartz grains and abundant clay, common fine to very fine mica; slightly calcareous; horizontal bedding; sandy layers give unit a horizontal banded appearance; weathers to form steep shaly slope — 26.6

51. Sandstone, pale-reddish-brown (10*R* 5/4); very fine grained; contains abundant very fine to medium mica and sparse black accessory minerals; well indurated, slightly calcareous; unit occurs as a lenticular bed with very irregular laminations and some sets of festoon cross-lamination; blocky splitting; forms an irregular ledge that extends 1/4 mile — 3.2

50. Siltstone, moderate-reddish-brown (10*R* 4/6); weathers same color; contains abundant clay and abundant very fine quartz grains; well indurated, slight calcareous cement; bedding mostly concealed, but where seen is horizontally bedded; light-colored sandy layers give unit a horizontal banded appearance — 15.6

Total Organ Rock Tongue — 508.4

NOTE. Section of Organ Rock was measured about 1 mile south of section of Cedar Mesa; offset on sandstone ledge at top of the Cedar Mesa Sandstone Member.

Cedar Mesa Sandstone Member:

49. Sandstone, very pale orange (10*YR* 8/2); weathers pale greenish yellow (10*Y* 8/2); abundant pale-green mottling (5*G* 7/2); a faint purple to grayish-red zone, about 2–3 in. thick, is directly above unit; very fine to fine grained with abundant silt, poor sorting; well indurated, noncalcareous; bedding and lamination concealed; weathers to a faint light-colored line along strike — 1.1

48. Siltstone, moderate-reddish-orange (10*R* 6/6); weathers same color; contains abundant very fine quartz grains; well indurated, weak calcareous cement; bedding mostly concealed, but where seen is thinly laminated (paper thin) and fissile; forms shaly-covered slope — 13.5

47. Sandstone, pale-reddish-brown (10*R* 5/4); weathers dark red (10*R* 3/4); fine to very fine grained with abundant silt, poorly sorted; calcareous cement; occurs as a crudely stratified bed that extends only 100 ft on either side of section; blocky splitting; weathers to form slight ledge — 0.4

46. Sandstone, pale-red (5*R* 6/2), fine to very fine grained with abundant silt, poorly sorted; calcareous cement; bedding and lamination concealed; forms covered slope — 2.9

45. Sandstone, grayish-red (5*R* 4/2); weathers same color; very fine grained; contains sparse red and black accessory minerals; firm calcareous cement; consists of horizontal laminations, 1/16–3/8 in. thick; forms purplish platy ledge — 0.3

44. Sandstone, grayish-yellow-green (5*GY* 7/2); weathers same color; fine to very fine grained; contains sparse very fine red and black accessory minerals and minor very fine grained mica; firm calcareous cement; consists of horizontal laminations, 1/16–1/8 in. thick; forms conspicuous white band — 1.2

43. Siltstone, moderate-reddish-orange (10*R* 6/6); weathers same color; contains common fine to very fine quartz grains; calcareous cement; bedding concealed — 7.8

U36. PONCHO HOUSE—Continued

Cutler Formation—Continued

Cedar Mesa Sandstone Member—Continued

	Feet
42. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; contains abundant fine to very fine well-rounded grains; calcareous cement; no bedding seen; splits into angular fragments; weathers to form persistent minor ledge	0.2
41. Siltstone, moderate-reddish-orange (10*R* 6/6); weathers same color; contains abundant fine to very fine rounded quartz grains; weakly cemented, calcareous; bedding concealed; unit forms break between two ledges	1.5
40. Limestone, pale-red (5*R* 6/2); weathers pale red (10*R* 6/2); abundant pale-green mottling; dense, scattered fine sand grains; horizontal bedding (1–3 in. thick) and horizontal lamination (1/32–1/16 in. thick); weathers to thin irregular plates; unit forms minor hogback	1.4
39. Siltstone, moderate-reddish-orange (10*R* 6/6); weathers same color; some pale-green mottling in bands and spots; contains scattered very fine sand grains. Unit is banded by pale-green silty sandstone beds and dark-reddish-brown fissile claystone layers as much as 4 in. thick	211.5
38. Gypsum, white; weathers pale red (10*R* 6/2), very sandy; contains well-rounded fine to very fine quartz grains and red and black accessory minerals; unit is very poorly exposed	1.0
37. Covered interval. Chert rubble concentrated at this position in section. Pebble- to boulder-size rubble at base of interval consists of angular light-gray (*N*7) and light-bluish-gray (5*B* 7/1) chert fragments as large as 1 ft in length with the average size of 1½–2 in	31.6
36. Siltstone to very fine grained sandstone, variegated similar to unit below; conspicuous 2-ft thick layer of moderate reddish orange (10*R* 6/6) at 43 ft, grayish red to light gray in top 2 ft; consists of clean very fine grained sandstone that grades into siltstone; weak calcareous cement; horizontally bedded (0.3–20 ft thick) and faintly laminated	91.1
35. Siltstone to very fine grained sandstone, variegated grayish-red (5*R* 4/2), pale-red (10*R* 6/2), moderate-orange-pink (10*R* 7/4), and light-gray (*N*7), rock types occur in alternating horizontal bands that intergrade along strike; weak calcareous cement; weathers to form steep slope	41.9
34. Gypsum, similar to unit 32	3.0
33. Siltstone, moderate-reddish-orange (10*R* 6/6); pale-green (5*G* 7/2) mottling in spots and streaks; contains abundant rounded to subrounded fine to very fine quartz grains; weak calcareous cement; forms poorly exposed shaly slope	13.8
32. Gypsum, light-gray (*N*7); weathers same color; impure, abundant fine to very fine quartz grains and scattered red and black accessory minerals; unit is tabular, consists of faint laminated bed; forms irregular ledge	2.7
31. Sandstone, white and pale-reddish-brown (10*R* 5/4); weathers moderate reddish orange (10*R* 6/6); fine to very fine grained, contains rounded to subrounded quartz grains and sparse red and black accessory minerals; highly gypsiferous; weak to firm calcareous cement; cross-bedded and horizontally bedded; some interbedded gypsum seen; poorly exposed; weathers to form residual gypsum slope	65.0
30. Sandstone, grayish-purple (5*P* 4/2), grayish-red (5*R* 4/2, 10*R* 4/2), pale-green (5*G* 7/2), and moderate-red-brown (10*R* 4/6); weathers same colors; contains abundant very fine quartz grains; highly gypsiferous; bedding concealed; unit weathers to form poorly exposed shaly slope	5.0
29. Sandstone, white; weathers light brown (5*YR* 6/4); fine to very fine grained; contains subrounded to well-rounded quartz grains and common red and black accessory minerals; highly gypsiferous; weak calcareous cement; bedding concealed; weathers to form residual gypsum slope	4.8
28. Sandstone, moderate-reddish-orange (10*R* 6/6); weathers same color; very fine grained with abundant silt, poorly sorted; contains abundant fine-grained quartz; highly gypsiferous; weak calcareous cement; occurs as irregular horizontal masses with ⅛–⅜-in. laminae; splits into platy angular blocks; weathers to form ledge	3.0
27. Siltstone, dark-reddish-brown (10*R* 3/4), pale-reddish-brown (10*R* 5/4), and moderate-reddish-orange (10*R* 6/6); pale-green mottling in bands and irregular streaks; contains common well-rounded fine and very fine quartz grains; highly gypsiferous; weak calcareous cement; unit weathers to form poorly exposed slope	14.4
26. Limestone, moderate-light-gray (*N*6); weathers light gray (*N*7); dense with scattered well-rounded fine quartz grains; bedding concealed; splits into angular fragments 3 in. long; weathers to form very persistent ledge that caps hogback. Unit is the most persistant limestone ledge seen in section	1.1

U36. PONCHO HOUSE—Continued

Cutler Formation—Continued

Cedar Mesa Sandstone Member—Continued *Feet*

25. Sandstone, light-brown (5*YR* 6/4); weathers moderate reddish orange (10*R* 6/6); pale-green and white mottling at top of unit; fine grained; composed of rounded to subrounded clear quartz, sparse black accessory minerals, and common white mica; highly gypsiferous; firmly cemented, noncalcareous; consists of festoon cross-laminations; weathers to form rounded ledge covered by highly gypsiferous colluvium — 37.6
24. Siltstone to sandstone, pale-reddish-orange (10*R* 6/6); weathers same color; greenish-gray mottling at top of unit; fine to very fine grained and silty; contains subrounded to rounded quartz grains and common black accessory minerals; highly gypsiferous; weak calcareous cement; bedding concealed; weathers to form poorly exposed slope — 22.5
23. Sandstone, pale-red (5*R* 6/2); weathers pale red (10*R* 6/2); fine grained with abundant silt, poorly sorted; composed of subrounded to rounded clear and amber quartz, accessory minerals absent; highly gypsiferous; firm calcareous cement; laminae and very thin beds mostly concealed; weathers to form faintly purple ledge — 0.6
22. Sandstone, pale-reddish-brown (10*R* 5/4) to moderate-reddish-orange (10*R* 6/6); fine grained, well sorted; composed of subrounded to rounded amber and clear quartz and sparse black accessory minerals; highly gypsiferous; well cemented, slightly calcareous; festoon cross-laminated with 1/16- to 1/8-in.-thick laminae that extend 3 in. to 4 ft along exposure; weathers to form prominent ledge — 21.5
21. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; contains abundant fine and very fine quartz grains; highly gypsiferous, gypsum occurs in small interstitial vug fillings and seams; calcareous cement; horizontally laminated (1/16–1/8 in. thick) to horizontally thick bedded; unit is poorly exposed and weathers to form base of overlying ledge — 5.1
20. Gypsum, pale-green (5*G* 7/2) and grayish-red (5*R* 4/2); weathers to moderate reddish orange; impure with abundant silt and clay; contains abundant fine and very fine quartz grains and red and black accessory minerals; unit consists mainly of gypsum with lenticular lens of sandstone and claystone; weathers to form massive ledge — 11.0
19. Claystone to siltstone, grayish-red (5*R* 4/2) and pale-green (5*G* 7/2); green predominates near top and grayish red near base of unit; highly gypsiferous, gypsum occurs as granules, seams, and selenite crystals; a 1-ft-thick white pure gypsum bed occurs 11 ft above base of unit; unit weathers to form very poorly exposed slope — 23.0
18. Covered (probably uppermost part of underlying sandstone unit) — 10.3
17. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained with abundant silt; contains scattered fine quartz and mica grains; highly gypsiferous; strong calcareous cement; unit is a tabular bed with lamination concealed; weathers to form massive ledge with pitted surface. Unit locally covered by talus about 6 in. thick — 20.0
16. Siltstone, grayish-red (5*R* 4/2); weathers same color; white and pale-green mottling and bands; poorly sorted; contains abundant very fine quartz grains and abundant very fine mica; highly gypsiferous; sand and gypsum most abundant at top of unit; well indurated, weakly calcareous; unit is a tabular bed with some lamination; weathers to form poorly exposed shaly slope — 13.0
15. Sandstone, moderate-reddish-orange (10*R* 6/6); weathers same color; white banding at base of unit and common white mottling near top; lithologically similar to unit below; some crossbedding seen where unit is exposed; weathers to form rounded ledge — 30.0
14. Sandstone, light-gray (*N*7); weathers very light gray (*N*8); very fine grained; composed of quartz grains with sparse red accessory minerals; highly gypsiferous; strong calcareous cement; consists of festoon cross-laminations (1/8–3/8 in. thick); weathers to form distinct white ledge that wedges out along strike — 4.5
13. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained and silty; contains scattered fine quartz grains and sparse black accessory minerals; gypsiferous; silica masses seen at top of unit; firm calcareous cement; unit is tabular with bedding concealed; weathers to form shaly slope — 8.8
12. Sandstone, pale-reddish-brown (10*R* 5/4); weathers moderate reddish orange (10*R* 6/6); fine to very fine grained; composed of quartz grains and common to sparse fine-grained white mica; calcareous cement; horizontally laminated; weathers to form shaly slope — 10.2
11. Limestone, medium-gray (*N*7); weathers same color; dense; contains sparse to common very fine quartz grains; bed-

U36. PONCHO HOUSE—Continued

Cutler Formation—Continued

Cedar Mesa Sandstone Member—Continued *Feet*

ding mostly concealed, but where seen is thinly cross-laminated; unit forms two ledges separated by poorly exposed claystone parting; upper limestone bed is lenticular ---------- 5.0

10. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained; composed of quartz grains and common black accessory minerals, abundant white mica along lamination planes; highly gypsiferous; unit is tabular, horizontally laminated (1/8–3/8 in. thick) and locally ripple laminated; weathers to form poorly exposed shaly slope ---------- 17.0

9. Sandstone, pale-red (5*R* 6/2); very fine grained and silty; contains scattered fine to coarse quartz grains and thin elongate red silica concretions approximately 1/32–1/16 in. in diameter and as long as 1½ in.; strong calcareous cement; laminated (as thick as 3/8 in.) and fissile; splits into platy angular blocks: weathers to form ledge ---------- 2.6

8. Siltstone, pale-red (5*R* 6/2); weathers same color; poorly sorted; contains abundant fine to very fine quartz grains; highly gypsiferous; weak calcareous cement; unit is tabular, horizontally laminated; weathers to form poorly exposed slope ---------- 4.3

7. Limestone, light-gray (*N*7); weathers medium gray (*N*5); dense; very sandy; contains well-rounded fine to very fine quartz grains; horizontal bedding; splits into platy angular blocks as large as 18 in. across ---------- 0.8

6. Sandstone, pale-reddish-brown (10*R* 5/4); weathers pale red (5*R* 6/2); very fine grained with abundant silt; highly gypsiferous; gypsiferous cement, weakly calcareous; contains irregular light-gray highly calcareous zones as thick as 5 ft; horizontally laminated; platy splitting; weathers to form poorly exposed slope ---------- 15.3

5. Sandstone, pale-red (10*R* 6/2); weathers pale reddish brown (10*R* 5/4); some pale-green (6*G* 7/2) mottling in streaks and spots with the round green spots having a black center; very fine grained with abundant silt; contains common well-rounded clear quartz grains and sparse very fine grained white mica; firm calcareous cement; horizontally bedded (1–2 ft thick) with some laminations; splits into irregular platy angular blocks; weather to form ledge ---------- 12.2

4. Limestone, medium-light-gray (*N*6); dense and finely crystalline; contains sparse fine quartz grains; unit is tabular and horizontally stratified. Unit seems to be gradational into overlying unit ---------- 1.2

3. Siltstone, dark-reddish-brown (10*R* 3/4); weathers same color and pale reddish brown (10*R* 5/4); some pale-green (5*G* 7/2) mottling in bands and scattered blebs; contains abundant clay, sparse to common quartz grains, and sparse white mica; gypsiferous seams; firm calcareous cement; horizontally crudely bedded; unit forms lower part of first prominent ledge above base of Cedar Mesa Sandstone Member ---------- 7.0

2. Siltstone and sandstone, pale-reddish-brown (10*R* 5/4); weathers same color. Siltstone, generally contains abundant clay and sparse very fine quartz grains; calcareous cement; laminated (as thick as 1/8 in.); slightly fissile to platy splitting. Sandstone, very fine to fine grained with abundant silt, poorly sorted; composed of subangular to subrounded quartz grains and common white mica flakes; calcareous cement. Sandstone is interbedded with siltstone in irregularly spaced zones. Unit is highly gypsiferous and is poorly exposed; weathers to form rounded slope beneath more resistant strata. Nodular concretionary weathering at top of unit ---------- 22.6

Total Cedar Mesa Sandstone Member ---------- 826.3

Halgaito Tongue (incomplete) (unmeasured):

1. Sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained with abundant silt, poorly sorted; composed of well-rounded quartz grains and sparse white mica; firm calcareous cement; contains calcareous nodules in irregular seams; unit is tabular, consists of lenticular layers as long as 5 ft and as thick as 6 in.; unit is highly fractured; weathers to form hogback at contact between Halgaito Tongue and Cedar Mesa Sandstone Member.

Total incomplete Cutler Formation ---------- 1,694.9

Base of section; not base of exposure.

U37. THE RINCON

[Measured, by J. H. Stewart, G. A. Williams, and H. F. Albee, March 1953, at The Rincon on the south side of the Colorado River near crest of Waterpocket fold. Long 110°47′ W., lat 37°19.5′ N. San Juan County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Monitor Butte Member (incomplete):

6. Silty claystone (95 percent) and sandstone (5 percent). Silty claystone, greenish gray

U37. THE RINCON—Continued

Chinle Formation—Continued

Monitor Butte Member—Continued *Feet*

(5*GY* 6/1) and light olive gray (5*Y* 6/1); contains common flakes of carbonaceous material and cylindrical bodies that are probably fossilized tree trunks; noncalcareous; stratification and splitting concealed. Sandstone, grayish orange (10*YR* 7/4) and pale yellowish orange (10*YR* 8/6); weathers brownish black (5*YR* 2/1); fine grained, well sorted; composed of subangular clear quartz and sparse black accessory minerals; well cemented, slightly calcareous; horizontally and ripple laminated; platy splitting. Sandstone constitutes 20 percent of lower 54 ft of unit where it occurs as thin to thick sets interbedded with siltstone; sandstone seems contorted and blocks of sandstone lie with strikes and dips at all angles to the regional attitude. A limestone bed 54 ft above base of unit is light olive gray (5*Y* 6/1); weathers same color and brownish gray (5*YR* 4/1); dense; well cemented; consists of horizontal laminae and possible ripple laminae; massive splitting; weathers to form bench. Lower half of unit is poorly exposed and the limestone bed may have slumped to its present position; however, the Monitor Butte Member contains a prominent limestone bed in about the same stratigraphic position east of section line — 210.6

Total incomplete Monitor Butte Member — 210.6

Shinarump Member:

5. Sandstone, very pale orange (10*YR* 8/2), grayish-orange (10*YR* 7/4), yellowish-gray (5*Y* 8/1), and very light gray (*N*8); weathers dominantly grayish orange (10 *YR* 7/4); abundant grayish-yellow (5*Y* 8/4) stain; medium to coarse grained, fair sorted; common granules and pebbles as large as 1.5 in. in diameter occur locally in unit; composed of subangular to subrounded clear quartz and common black and red accessory minerals; poorly, to firmly cemented, slightly calcareous; common carbonaceous and petroliferous material (a log about 1.5 ft in diameter composed of coal occurs 69 ft above base of unit); consists of thin to thick trough sets of medium-scale low-angle cross-laminae, some very low angle cross-laminae or horizontal laminae; platy and massive splitting; weathers to form steep ledgy slope and cliff, top 40 ft forms a prominent cliff — 194.9

Total Shinarump Member — 194.9

Total incomplete Chinle Formation — 405.5

U37. THE RINCON—Continued

Moenkopi Formation:

Upper slope-forming(?) member: *Feet*

4. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; top 2½ ft of unit is dark yellowish orange (10*YR* 6/6); firmly to well cemented, calcareous; horizontally and ripple laminated, sparse very thin beds; platy splitting; weathers to form steep ledgy slope. The Moenkopi on north side of river is light brown and grayish orange along crest of Waterpocket fold — 53.0

Total upper slope-forming(?) member — 53.0

Conglomerate unit:

3. Cobble and pebble conglomerate, grayish-orange (10*YR* 7/4); weathers same color and olive gray (5*Y* 4/1); granules to cobbles are as much as 6 in. long, are composed of white and light-brown chert and are set in a matrix of well-rounded fine to medium grains of clear quartz; well cemented, calcareous; very thinly bedded to thin bedded; platy to massive splitting; weathers to form prominent dark-colored ledge — 11.1

Total conglomerate unit — 11.1

Total Moenkopi Formation — 64.1

Unconformity (erosional) marked by scours as much as 1½ ft deep cut into underlying unit.

Kaibab(?) Limestone:

2. Sandstone, very pale orange (10*YR* 8/2); weathers grayish orange (10*YR* 7/4); fine to medium grained with abundant coarse grains, fair sorted; composed of subrounded to rounded clear quartz with possibly 25 percent interstitial and intergranular calcite locally; firmly cemented, calcareous; abundant limonite spots; consists of horizontal laminae and very thin beds and possibly some ripple laminae; platy to flaggy splitting; weathers to form ledgy slope above cliff of unit 1 — 10.8

Total Kaibab(?) Limestone — 10.8

Cutler Formation (incomplete):

De Chelly Sandstone Member (incomplete):

1. Sandstone, light-olive-gray (5*Y* 4/1); weathers pale yellowish brown (5*YR* 6/2) and grayish orange (10*YR* 7/4); fine to medium grained, well sorted; composed of rounded clear quartz, no accessory minerals seen; firmly cemented, slightly calcareous; highly petroliferous; common limonite spots; very thick sets of large-scale cross-laminae and thin beds; platy and massive splitting; weathers to form cliff. Entire

U37. THE RINCON—Continued

Cutler Formation—Continued

De Chelly Sandstone Member—Continued — Feet

unit not examined in detail; 50–75 ft more of unit is exposed on north side of river — 58.0

Total incomplete De Chelly Sandstone Member — 58.0

Total incomplete Cutler Formation — 58.0

Base of section; base of exposure at Colorado River.

U38. STEER MESA

[Measured, by J. H. Stewart and D. A. McManus, June 1954, up west side of exposure capped by outlier of Wingate Sandstone; about ½ mile northwest of Steer Mesa. Section starts about ½ mile south of place where White Rim Sandstone Member is last exposed up Green River. Long 110°00′ W., lat 38°25′ N. San Juan County]

Top of section; not top of exposure. — Feet

Chinle Formation (incomplete); Moss Back Member (incomplete) (unmeasured):

10. Limy sandstone, greenish-gray (5*GY* 6/1); weathers pale brown (5*YR* 5/2); fine to medium grained with sparse coarse and very coarse grains, fair sorted; composed of subrounded clear quartz set in a lime matrix; well cemented; stratification concealed; weathers to form cliff. Only basal 2 ft of unit examined in detail.

Moenkopi Formation:

Upper slope-forming and ledge-forming members undifferentiated:

9. Siltstone; pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2) in basal 23.6 ft of unit, light-olive-gray (5*Y* 6/1), greenish-gray (5*GY* 6/1), pale-olive (10Y 6/2), and dusky-yellow (5*Y* 6/4) 23.6 to 184.8 ft, grayish-red (10*R* 4/2) 184.8 to 247.5 ft, and pale-olive (10*Y* 6/2) 247.5 ft to top of unit; weathers dominantly pale olive (10*Y* 6/2); contains common fine-grained white mica; firmly to well cemented, slightly calcareous; consists of horizontal and ripple laminae and minor structureless siltstone; weathers to form steep ledgy slope — 249.5

Total upper slope-forming and ledge-forming members undifferentiated — 249.5

Sinbad Limestone Member:

8. Limestone, medium-gray (*N*5) and common grayish-orange (10*YR* 7/4); weathers grayish orange (10*YR* 7/4), dense; well cemented; contains abundant petroliferous material that seems to fill small cavities; a stringer of pyrite about 0.5 in. long was seen; consists of horizontal very thin beds and laminae; weathers along with basal 1 ft of overlying unit to form conspicuous ledge and bench. This unit is probably the limestone unit noted by McKnight (1940) — 2.1

Total Sinbad Limestone Member — 2.1

U38. STEER MESA—Continued

Moenkopi Formation—Continued

Lower slope-forming member: — Feet

7. Siltstone to sandy siltstone, grayish-red (10*R* 4/2) with about 30 percent pale-red (10*R* 6/2), very pale orange (10*YR* 8/2), yellowish-gray (5*Y* 8/1), and greenish-gray (5*GY* 6/1); top 20± ft of unit is dominantly grayish orange (10*YR* 7/4) and pale yellowish orange (10*YR* 8/6); weathers pale reddish brown (10*R* 5/4) and grayish orange (10*YR* 7/4) in top 20 ft; sandy (very fine grained); firmly cemented, calcareous; consists of very thin to thick horizontal sets composed of ripple and horizontal laminae, minor structureless siltstone; weathers to form steep slope. Unit contains sandstone 3.9 to 8.3 ft above base that is similar to that in underlying unit — 66.1

6. Sandstone, grayish-orange-pink (10*R* 8/2) and very pale orange (10*YR* 8/2); weathers light brown (5*YR* 6/4); very fine to fine grained with sparse siltstone pebbles; composed of subrounded milky grains, accessory minerals concealed; poorly to well cemented, slightly calcareous; consists of thin to thick trough sets of small- and medium-scale cross-laminae, (basal 2 ft of unit is horizontally laminated); one thin horizontal bed of greenish-gray siltstone seen; contains a very few sets of contorted stratification; unit is massive splitting and weathers to form a cliff. Unit is the most prominent sandstone in the Moenkopi Formation — 16.5

5. Siltstone to sandstone, pale-reddish-brown (10*R* 5/4), pale-red (10*R* 6/2), and grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); very fine grained; basal 0.2 ft is medium- to coarse-grained silty sandstone composed of subangular grains (composition concealed); well cemented, slightly calcareous; ripple laminated and minor thin horizontal beds and sets of contorted stratification; weathers to form cliff. Basal contact of unit is sharp and has many mud-crack fillings — 6.1

4. Siltstone, grayish-red (10*R* 4/2) with common thin bands of grayish-yellow (5*Y* 8/4) and grayish-orange-pink (5*YR* 7/2); weathers grayish red (10*R* 4/2); contains sparse very fine grained white mica; consists of interstratified very thin to thick sets of ripple-laminated, horizontally laminated, and structureless siltstone; weathers to form steep slope at base and cliff at top. Sets in top 25 ft of unit dip eastward and are truncated by horizontal beds of the overlying unit with an angular discordance of 10°; downward in unit the dip of these

U38. STEER MESA—Continued

Moenkopi Formation—Continued

Lower slope-forming member—Continued — *Feet*

sets gradually decreases and becomes horizontal — 108.0

Total lower slope-forming member — 196.7

NOTE.—Section offset along top of Hoskinnini Member, so that unit 4 measured 1,500 ft east of underlying units.

Hoskinnini Member:

3. Sandy siltstone to silty sandstone, grayish-red (10*R* 4/2); weathers same color and pale reddish brown (10*R* 5/4); yellowish-gray (5*Y* 8/1) mottled layer at 33.6 ft and yellowish-gray thin bands at 48.8 ft and at top of unit; grades from silty fine- and medium-grained sandstone to sandy siltstone, parts of unit are poorly sorted; sandy siltstone characterized by presence of sparse to abundant medium to very coarse sand grains; well cemented, calcareous; unit consists of thick horizontal tabular and lenticular beds containing wavy laminae; weathers to form steep slope and cliff — 58.7

Total Hoskinnini Member — 58.7

Sandstone unit: Note: This unit is provisionally separated from the White Rim and Hoskinnini. It may be equivalent to the conglomerate and sandstone unit at the base of the Moenkopi in the Range Canyon section.

2. Sandstone, yellowish-gray (5*Y* 8/1); weathers same color; fine to medium grained with sparse coarse and very coarse grains, poorly sorted; composed of subrounded clear quartz, no accessory minerals seen; stratification poorly exposed and indistinct, but seems to be mostly wavy laminae; weathers to form light-colored slope. Top surface of unit seems to undulate as much as 3 ft along exposure — 20.3

Total sandstone unit — 20.3

Total Moenkopi Formation — 527.3

Cutler Formation (incomplete):

White Rim Sandstone Member (incomplete) (unmeasured):

1. Sandstone, very pale orange (10*YR* 8/2); weathers same color; very fine to fine grained, well sorted; composed of rounded to well-rounded clear and frosted quartz and sparse black accessory minerals; poorly cemented, calcareous; consists of very thick sets of large-scale cross-stratification; weathers to form cliff. About 30 ft of unit exposed above level of Green River.

Base of section; base of exposure.

U40. CLIFF CREEK

[Measured, by F. G. Poole and Carl Koteff, August 1956. Section begins in Burdett Wash and ends in first major reentrant northeast of Cliff Creek water gap. Line of section trends N. 42° W. through SW¼ sec. 15, SE¼ sec. 16, and sec. 22, T. 5 S., R. 24 E., SLM. Uintah County]

Top of section; not top of exposure.

Chinle Formation (incomplete):

Mottled strata (incomplete): — *Feet*

10. Siltstone, mottled very dusky red (10*R* 2/2), grayish-red-purple (5*RP* 4/2), yellowish-gray (5*Y* 8/1), moderate-yellowish-brown (10*YR* 5/4), dark-yellowish-orange (10*YR* 6/6), pale-yellowish-orange (10*YR* 8/6), pale-red-purple (5*RP* 2/6), dusky-blue (5*PB* 3/2), and light-greenish-gray (5*GY* 8/1); weathers same colors and lighter shades; firmly to well cemented, noncalcareous to slightly calcareous; irregularly bedded; weathers to form smooth slope. This unit may be a weathered zone (regolith) at top of Moenkopi Formation — 10.1

NOTE.—Section offset on top of Moenkopi Formation so that overlying unit measured about 200 ft N. 45° E.

Unconformity.

Moenkopi Formation:

9. Siltstone (50 percent) and claystone (50 percent), grayish-red (10*R* 4/2), dark-reddish-brown (10*R* 3/4), and minor greenish-gray (5*GY* 6/1); firmly cemented, calcareous; thinly laminated to very thin bedded; papery and shaly splitting. Unit as a whole weathers to form steep smooth slope that is darker red than underlying unit — 38.4

8. Siltstone to sandy siltstone (60 percent), claystone (35 percent), and gypsum (5 percent). Siltstone to sandy siltstone, grayish-red (10*R* 4/2), light-brown (5*YR* 6/4), and minor light-greenish-gray (5*GY* 8/1 and 5*G* 8/1); weathers same colors and lighter shades; sandy siltstone contains well-rounded very fine clear and amber-stained quartz grains and abundant to sparse white and black mica and chlorite flakes; firmly to poorly cemented, calcareous; persistent horizontal laminae to thin beds, ripple laminae, and minor small-scale cross-strata; weathers to form gentle smooth slope with minor shaly to slabby ribs. Claystone, grayish-red (10*R* 4/2) and subordinate greenish gray (5*GY* 6/1 and 5*G* 6/1); firmly cemented, noncalcareous; horizontally thinly laminated and laminated; papery and shaly splitting; weathers to form smooth slope. Gypsum, white (*N*9), pinkish gray (5*YR* 8/1), and grayish-pink (5*R* 8/2); weathers same colors and pale red (10*R* 6/2); firmly to poorly cemented, calcareous; occurs as lenticular laminae and beds and as vertical and horizontal veinlets. Unit as a whole weathers light brown and orange red. Top of unit is placed at top of orange-red interval — 203.4

U40. CLIFF CREEK—Continued

Moenkopi Formation—Continued *Feet*

7. Gypsum and minor evaporitic limestone, white (*N*9), pinkish-gray (5*YR* 8/1), pale-pink (5*RP* 8/2), moderate-orange-pink (10*R* 7/4), and pale-reddish-brown (10*R* 5/4); weathers same colors and light shades of gray; firmly to poorly cemented, calcareous; weathers to form gentle rough slope. Evaporitic limestone occurs as sparse wavy laminae in the gypsum ---- 6.4

6. Sandy siltstone (80 percent) and claystone (20 percent). Sandy siltstone, grayish-red (10*R* 4/2), light-brown 5*YR* 6/4), minor light-greenish-gray (5*GY* 8/1) and pinkish-gray (5*YR* 8/1); contains very fine quartz grains and abundant to sparse white and black mica and chlorite flakes; firmly to poorly cemented, calcareous, gypsiferous; thinly laminated to thin bedded, much of siltstone is ripple laminated; shaly to slabby splitting; weathers to form steep smooth slope and cliffs. Claystone, grayish-red (10*R* 4/2) and minor greenish-gray (5*GY* 6/1); weathers same colors; contains common very fine grained mica; firmly cemented, noncalcareous; thinly laminated; papery splitting; weathers to form steep smooth slope. Unit as a whole weathers chocolate brown and contains many horizontal and vertical veinlets of white gypsum. Top of unit is placed at base of overlying lenticular gypsum unit that, in general, forms the base of the overlying orange-red interval ---- 292.2

NOTE.—Section offset on top of unit 5 so that overlying units measured 100±ft N. 60° E.

5. Siltstone (90 percent), claystone (7 percent), and sandstone (3 percent). Siltstone, grayish-red (10*R* 4/2) and grayish-orange (10*YR* 7/4); weathers same colors and lighter shades; contains abundant chlorite flakes; firmly to poorly cemented, calcareous, gypsiferous; thinly laminated to thin bedded with strata being parallel and persistent, about one-fourth is ripple laminated; papery to slabby splitting; weathers to form steep slope. Claystone, grayish-red (10*R* 4/2); weathers same color and lighter shades; contains abundant very fine grained chlorite flakes; firmly to poorly cemented, noncalcareous; weathers to form smooth slope. Sandstone, grayish-orange (10*YR* 7/4) and grayish-red (10*R* 4/2); weathers same colors and lighter shades; very fine grained, silty, well sorted; composed of rounded to well-rounded clear and limonite-stained quartz grains and common black mica and chlorite; firmly cemented, calcareous, gypsiferous; laminated to thin bedded; platy to slabby splitting; weathers to form resistant ribs on smooth slope. Unit as a whole weathers to form dull-red steep smooth slope with minor yellowish-gray bands. Top of unit is placed at top of highest yellowish-gray band ---- 96.8

4. Siltstone (90 percent), sandstone (5 percent), and claystone (5 percent). Siltstone is grayish orange (10*YR* 7/4), light olive gray (5*Y* 6/1), and minor grayish red (10*R* 4/2); weathers same colors; contains common very fine grained white mica and iron oxide; firmly to well cemented, calcareous; resistant ledges are well cemented and ripple laminated whereas nonresistant siltstone seems structureless; thinly laminated to thin bedded; papery to slabby splitting; weathers to form conspicuous ledges. Sandstone is dark yellowish brown (10*YR* 4/2), pale yellowish brown (10*YR* 6/2), and grayish orange (10*YR* 7/4); weathers same colors and light brown (5*YR* 6/4); very fine grained, silty, well sorted; composed of rounded to well-rounded clear and limonite-stained quartz grains and common fine to very coarse grained white and black mica and limonite; firmly cemented, calcareous; thinly laminated to thin bedded; platy to slabby splitting; weathers to form conspicuous ledges. Claystone is greenish gray (5*GY* 6/1); weathers light olive gray (5*Y* 6/1); firmly cemented, slightly calcareous; thinly laminated; papery splitting; weathers to form smooth slope. Unit as a whole forms yellowish-gray band containing minor pale-red and lies above Park City tawny beds and below Moenkopi red beds. Lower contact of unit is provisionally placed at base of lowest red coloration. This unit may be partly equivalent to the Dinwoody Formation of southwest Wyoming ---- 47.9

Total Moenkopi Formation ---- 685.1

Park City Formation:

Franson Member:

3. Siltstone, yellowish-gray, description similar to siltstone in unit 4 of Moenkopi Formation ---- 30.0

2. Interbedded limy and cherty sandstone, sandy and cherty limestone, and chert. Limy and cherty sandstone is very light gray (*N*8) and light gray (*N*7); weathers yellowish gray (5*Y* 8/1) and pinkish gray (5*YR* 8/1); very fine grained with common medium and coarse grains, fair to well sorted; composed of rounded to well-rounded clear and milky quartz grains (the medium and coarse grains are well-rounded clear and milky quartz), common interstitial black substance (solid hydrocarbon or iron oxide), and uncommon pink quartz and dark-gray accessory mineral; common stringers and angular fragments of light-

U40. CLIFF CREEK—Continued

Park City Formation—Continued

Franson Member—Continued *Feet*

gray (*N*7) chert; firmly to well cemented; irregularly bedded with common contorted bedding; weathers to form jagged ledges. Most of the sand is probably reworked from underlying Weber Sandstone. Sandy and cherty limestone is light olive gray (5*Y* 6/1); weathers same color and yellowish gray (5*Y* 8/1), common iron oxide stain scattered throughout unit; dense; many limestone layers are oolitic; contains common stringers of light-gray (*N*7) chert that are commonly fossiliferous; laminated to thin bedded; weathers to form small ledges. Chert is light gray (*N*7), very light gray (*N*8), and white (*N*9); weathers same colors; laminated to thin bedded with some layers as much as 3 ft thick in upper part of unit; weathers to form resistant cliff. Upper contact of unit is placed at top of highest cherty and limy sandstone; contact seems conformable with overlying unit. 37.6

Total Franson Member of Park City Formation 67.6

Unconformity?

Weber Sandstone (incomplete) (unmeasured):

1. Sandstone, yellowish-gray (5*Y* 7/2 and 5*Y* 8/1) and very pale orange (10*YR* 8/2); weathers same colors and pale yellowish brown (10*YR* 6/2); very fine grained with common coarse grains, well sorted (bimodal); composed of rounded to well-rounded clear quartz grains (coarse grains are well-rounded clear quartz), uncommon pink quartz, and uncommon to sparse feldspar and white and dark-gray accessory minerals; most coarse grains occur along cross-stratum surfaces; firmly cemented, calcareous; composed of trough and planar sets of medium- and small-scale cross-strata; weathers to form rounded ledge. Upper contact is smooth and slightly undulatory. Only upper 10 ft of Weber examined in detail.

Base of section; not base of exposure.

U41. VERNAL

[Measured, by J. H. Stewart and R. F. Wilson, October 1955, about 1 mile west of old Vernal-Manila highway (State Route 44), starting at most southeasterly exposure of Weber Sandstone along Brush Creek at Brush Creek Gorge and continuing up cliffs S. 19° E. from base of section; W½ sec. 32, T. 2 S., R. 22 E., and NW¼ sec. 5, T. 3 S., R. 22, E., SLM (location from pl. 1 of Kinney, 1955). Uintah County]

Top of section; not top of exposure.

Chinle Formation (incomplete)

Gartra Member:

12. Sandstone (95 percent) and conglomerate (5 percent), very pale orange (10*YR* 8/2); weathers same color. Sandstone, medium to very coarse grained, fair to poorly sorted; composed of subangular to angular

U41. VERNAL—Continued

Chinle Formation—Continued

Gartra Member—Continued *Feet*

milky quartz and feldspar and sparse accessory pink feldspar and black grains; sandstone grades to conglomerate. Conglomerate, granules and pebbles are composed of white and pink quartz with minor chert and possibly quartzite; poorly cemented, slightly calcareous in parts. Unit consists of thin to thick lenticular trough and wedge-shaped planar sets of small- and medium-scale cross-laminae; weathers to form ledge. Base of unit is sharp and rests on pre-Chinle erosional surface; about 2,000 ft east of section line Gartra fills a channel cut 15 ft into the Moenkopi Formation 64.8

Total Gartra Member 64.8

Total incomplete Chinle Formation 64.8

Unconformity.

Moenkopi Formation:

11. Siltstone, moderate-brown (5*YR* 4/4 and 5*YR* 3/4) and minor light-brown (5*YR* 6/4); weathers same colors; contains sparse very fine grained accessory white mica; firmly to well cemented, noncalcareous. Unit is bipartite: the lower part is horizontally laminated to very thick bedded, contains sparse cuspate ripple marks and a few trough sets of small-scale low-angle cross-laminate, and weathers to form ledgy slope; whereas the upper part consists of structureless finer grained siltstone and weathers to form steep slope. Unit as a whole weathers to form ledgy interval at top of Moenkopi and is darker brown than rest of Moenkopi 59.2

10. Siltstone (90 percent) to sandstone (5 percent) and gypsum (5 percent). Siltstone to sandstone is moderate brown (5*YR* 4/4) and minor light brown (5*YR* 6/4) and grayish red (10*R* 4/2), common light-greenish-gray (5*GY* 8/1) color bands from 131.3 to 179.2 ft; weathers light brown (5*YR* 6/4); grades from silt to very fine grained sand, sandy parts are well sorted; contains common fine and very fine grained accessory white and dark mica; poorly to well cemented, noncalcareous, gypsum cement in some parts; stratification mostly concealed, but where exposed, it is horizontally thinly laminated to very thin bedded with sparse ripple laminations and a few trough sets of small-scale low-angle cross-laminae; contorted stratification seen in siltstone at several horizons, contortion possibly due to penecontemporaneous slumping along bedding planes. Gypsum is white (*N*9) and pale red (10*R* 6/2); weathers same colors; dense or very finely crys-

U41. VERNAL—Continued

Moenkopi Formation—Continued *Feet*

talline; well cemented; occurs as very thin seams and as thin to very thick horizontal sets interstratified with siltstone, gypsum sets consist of thin horizontal laminae and contorted stratification; gypsum forms about 50 percent of interval from 263.2 to 285.6 ft above base of unit, but is sparse in rest of unit; desiccation cracks are common in this gypsum interval. Unit as a whole weathers to form rolling hills in lower part and steep slope in upper part; the interval that contains abundant gypsum forms a prominent cliff. Top of gypsum interval is provisionally correlated with top of Thaynes Formation........ 582.4

9. Siltstone (95 percent) and gypsum to gypsiferous siltstone (5 percent), conspicuous moderate-brown (5*YR* 4/4) color bands occur from 106.4 to 115.0 ft and from 168.0 to 181.2 ft above base of unit. Siltstone is greenish gray (5*GY* 6/1) and pale olive (10*Y* 6/2); weathers pale greenish yellow (10*Y* 8/2); contains common very fine grained accessory white mica; firmly cemented, noncalcareous; horizontally laminated to very thin bedded, about 5 percent has parallel ripple lamination. Gypsum to gypsiferous siltstone is white (*N*9) and light greenish gray (5*GY* 8/1); weathers same colors; gypsum occurs as fibrous seams that locally crosscut stratification and as detrital very fine grains that comprise horizontal thin beds. Top 50 ft of unit contains more gypsum than rest of unit. Unit as a whole weathers to form rolling hills.............................. 196.0

8. Siltstone, light-olive-gray (5*Y* 6/1) and greenish-gray (5*GY* 6/1); weathers same colors; contains sparse fine-grained accessory white mica; well cemented, calcareous, contains petroliferous material; horizontal laminae and minor parallel and cuspate ripple laminae, parallel ripples commonly have amplitude of 3.5 in. Weathers to form ledge that is locally prominent............ 7.6

7. Siltstone, dusky-yellow (5*Y* 6/4) and pale-olive (10*Y* 6/2); weathers grayish yellow (5*Y* 8/4); contains minor very fine sand grains; firmly cemented, slightly calcareous in parts; some seams of gypsum seen at top of unit; stratification mostly concealed, but where seen, consists of some ripple laminae. Weathers to form badland topography.... 125.4

Total Moenkopi Formation............. 970.6

Park City Formation:

Franson Member:

6. Siltstone (60 percent) and limestone (40 percent). Siltstone is greenish gray (5*GY* 6/1); weathers light greenish gray (5*GY*

U41. VERNAL—Continued

Park City Formation—Continued

Franson Member—Continued *Feet*

8/1); firmly cemented, noncalcareous; stratification concealed. Limestone is yellowish gray (5*Y* 8/1), light olive gray (5*Y* 6/1), and very light gray (*N*8); weathers yellowish gray (5*Y* 8/1); dense, locally grades into dolomite; well cemented; horizontal very thin beds. Limestone occurs as thin sets interstratified with siltstone. Unit as a whole weathers to form slope with small ledge of limestone in top 3 ft....... 14.6

5. Limestone, light-olive-gray (5*Y* 6/1) to olive-gray (5*Y* 4/1) and minor very light gray (*N*8); weathers yellowish gray (5*Y* 8/1); dense to very finely crystalline; contains about 5 percent gray chert nodules; well cemented; horizontally laminated to very thin bedded; weathers to form ledge...... 14.2

4. Siltstone, greenish-gray (5*GY* 6/1), pale-olive (5*Y* 6/2), and sparse pale-yellowish-orange (10*YR* 8/6); weathers light greenish gray (5*GY* 8/1); firmly cemented, calcareous; stratification concealed. Weathers to form steep slope................. 42.8

3. Dolomite and limestone, yellowish-gray (5*Y* 8/1) and light-greenish-gray (5*GY* 8/1); weathers same colors; dense; contains about 10 percent gray chert nodules; well cemented; horizontally thin to very thin bedded in lower 10 ft and gnarly bedded in upper 18 ft. Top 5 ft of unit is dominantly limy sandstone to sandstone composed of subrounded fine quartz grains and of about 20 percent medium to coarse dark-gray grains that may be phosphate pellets or oolites. Weathers to form ledge........... 28.0

Total Franson Member................ 99.6

Meade Peak Phosphatic Shale Member:

2. Phosphate rock (50 percent) and siltstone (50 percent). Phosphate rock is light olive gray (5*Y* 6/1) to olive gray (5*Y* 4/1); weathers same colors; composed of fine to medium size phosphate oolites (some as much as 4 mm in diameter), well sorted; well cemented, slightly calcareous in parts; occurs as thin to thick sets of horizontal laminae interstratified with siltstone. Siltstone is greenish gray (5*GY* 6/1) to light greenish gray (5*GY* 8/1); weathers same colors; contains abundant silt-sized white mica; well cemented, noncalcareous; horizontally laminated with some laminae poorly defined. Unit seems to grade from pure siltstone to oolitic phosphate rock; middle of unit contains several very thin beds containing greenish-gray chert nodules. Unit as a whole weathers to form steep slope. Examined in prospect pit about

U41. VERNAL—Continued

Park City Formation—Continued

Meade Peak Phosphatic Shale Member—Continued *Feet*

200 ft north of trail bridge across Brush Creek ---------- 20.4

Total Meade Peake Phosphatic Shale Member ---------- 20.4

Total Park City Formation ---------- 120.0

Unconformity?

Weber Sandstone (incomplete) (unmeasured):

1. Sandstone, very pale orange (10*YR* 8/2) and yellowish-gray (5*Y* 8/1); weathers same colors and light olive gray (5*Y* 6/1); fine to medium grained, fair sorted; composed of subrounded clear quartz, uncommon feldspar, and sparse black accessory mineral; grains are frosted or etched; poorly cemented, slightly calcareous; some limonite staining; consists of tabular and wedge-shaped planar sets 2–15 ft thick of medium- and large-scale cross-laminae; sparse contorted stratification. Forms gorge at bottom of stream valley. Only top 20 ft of Weber examined in detail.

Base of section; base of local exposure.

U42. CAPITOL WASH

[Measured, by J. H. Stewart, September 1952. Line of section runs from outcrop of "Kaibab Limestone" in prominent canyon S. 30° W. about ⅝ mile from Dinosaur Rock (1 mile northwest of place where Capitol Wash crosses outcrop of Shinarump Member) through point on road about 100 yds northwest of Dinosaur Rock, Capitol Reef National Monument; SW¼ sec. 12, T. 30 S., R. 6 E. Wayne County]

Feet

Top of section; not top of exposure.

Chinle Formation (incomplete):

Shinarump Member (incomplete):

11. Sandstone, yellowish-gray (5*Y* 8/1); weathers pale reddish brown (10*R* 5/4); fine to very fine grained, well sorted; composed of clear quartz and sparse black accessory minerals; firmly cemented, calcareous; locally contains some green siltstone along bedding planes; unit is lenticular, consists of trough sets of medium- to large-scale cross-laminae and crossbeds, minor ripple beds; massive splitting; weathers to form prominent cliff ---------- 30.0±

Total Shinarump Member ---------- 30.0

Total incomplete Chinle Formation ---------- 30.0

Unconformity.

Moenkopi Formation:

Cliff-forming member:

10. Siltstone, similar to unit 9 except 50 percent consists of thin to very thick ripple-laminated sets (75 percent parallel type and 25 percent cuspate type) that are interstratified with structureless to horizontally laminated siltstone; unit weathers to form ledgy steep slope and local cliff ---------- 137.5

Total cliff-forming member ---------- 137.5

U42. CAPITOL WASH—Continued

Moenkopi Formation—Continued

Upper slope-forming member: *Feet*

9. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; argillaceous, common gypsum laminae, and common moderate-reddish-orange (10*R* 6/6) gypsum nodules that generally occur along stratification planes; firmly cemented; horizontally laminated to structureless, about 10 percent is ripple-laminated (parallel type); shaly splitting; basal 54.3 ft contains common sets of ripple-laminated siltstone that are less than 1 ft thick form to form frothy steep slope ---------- 307.1
small ledges; unit as a whole weathers

Total upper slope-forming member ---------- 307.1

Ledge-forming member:

8. Silty sandstone, pale-reddish-brown (10*R* 5/4); weathers same color; very fine grained with abundant silt; firmly cemented, calcareous; predominantly horizontally laminated, minor current-ripple laminations, minor trough sets of low-angle cross-laminae, and minor horizontal very thin to thin beds; platy to massive splitting; weathers to form cliff with a prominent broad bench formed on upper contact. Basal contact is a channeled surface. Thickness of unit varies locally from about 10 to 25 ft ---------- 17.0

7. Siltstone, pale-reddish-brown (10*R* 5/4) to grayish-red (10*R* 4/2); weathers pale reddish brown; common light-colored laminae; argillaceous and micaceous in parts; firmly cemented; horizontally laminated and current-ripple laminated, shaly to flaggy splitting; weathers to form rubble-covered steep slope ---------- 37.3

6. Sandstone to siltstone and siltstone, interbedded. Sandstone to siltstone is light olive gray (5*Y* 6/1); weathers light brown (5*YR* 5/6); silt to very fine sand grains; firmly cemented, calcareous, abundant limonite(?) spots, light-olive-gray coloration probably due to petroliferous material; unit is lenticular, consists predominantly or horizontal laminae and current-ripple laminae with uncommon pseudocross-laminations, minor trough sets of large-scale cross-laminae with common shallow channels about 40 ft wide; platy to massive splitting. The light-olive-gray sandstone to siltstone sets vary in thickness and are locally absent along outcrop; where absent entire unit cannot be distinguished from overlying or underlying units. Siltstone is pale reddish brown (10*R* 5/4) and grayish red (10*R* 4/2); weathers same colors; argillaceous; firmly cemented, calcareous; consists of horizontal laminae and cur-

U42. CAPITOL WASH—Continued

Moenkopi Formation—Continued

Ledge-forming member—Continued *Feet*

rent-ripple laminae; shaly to flaggy splitting. Unit as a whole weathers to form cliffs and steep slopes 40.8

NOTE.—Section offset about 700 ft on top of unit 5.

5. Siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); argillaceous in parts (interval from 52.2 to 87.0 ft above base of unit contains many grayish-orange (10*YR* 7/4) ledges that contain abundant very fine sand grains); firmly cemented, calcareous; current-ripple laminated, common contorted stratification related to intraformational slumping, sparse trough cross-stratification, a few channels seen; unit weathers to form steep slope with small ledges and cliffs 114.0

Total ledge-forming member 209.1

NOTE.—Section offset on top of Sinbad Limestone Member so that overlying units measured about 2,000 ft east.

Sinbad Limestone Member:

4. Limestone and siltstone. Limestone is pale yellowish brown (10*YR* 6/2) with minor very pale orange (10*YR* 8/2); weathers light brown (5*YR* 5/6); composed of dense calcite and minor medium- to coarse-grained oolitic calcite; well cemented; sparse fossils fragments and common worm trails seen on bedding planes; consists predominantly of horizontal laminae with minor very thin to thin beds, sparse ripple-laminated beds confined to oolitic parts, sparse very small scale contorted bedding; platy to blocky splitting. Siltstone is grayish red (10*R* 4/2) and pale olive (10*Y* 6/2); weathers same colors; altered to pale olive (10*Y* 6/2) directly below limestone beds; firmly cemented; horizontally and ripple laminated; shaly splitting. Unit as a whole weathers to form cliff in lower two-thirds and blocky steep slope in upper one-third. Unit contains the following lithologic types, in ascending order: limestone, 5.8 ft; siltstone, 3.8 ft; limestone, 12 ft; siltstone, 4.6 ft; limestone, 33.7 ft; siltstone, 3.4 ft (poorly exposed); limestone, 2 ft; siltstone(?), 9.5 ft (covered by blocks); and limestone, 5.6 ft. Locally, siltstone occurs elsewhere in unit as thin laminae to very thin beds within limestone layers 80.4

Total Sinbad Limestone Member 80.4

U42. CAPITOL WASH—Continued

Moenkopi Formation—Continued

Lower slope-forming member: *Feet*

3. Siltstone and claystone, predominantly grayish-red (10*R* 4/2) and pale-reddish-brown (10*R* 5/4), minor pale-yellowish-orange (10*YR* 8/6); weathers dark reddish brown (10*R* 3/4) and minor pale yellowish orange (10*YR* 7/6), basal 30 ft of unit is mostly pale yellowish orange; firmly to well cemented, calcareous; unit is tabular, consists of horizontal and minor current-rippled thin laminae to very thin beds; papery splitting; unit weathers to form frothy steep slope. Unit contains common laminae and very thin beds of limestone and limy siltstone and common laminae and beds of gypsum as thick as 4 in. Some very small scale contorted structures occur. Lithology along basal contact of unit is variable; very coarse grained sandstone, silty limestone, and abundant limonite occur locally in basal few feet of unit. Basal contact of unit is probably an erosional surface as the uppermost beds of unit 2 are cut out locally 67.3

Total lower slope-forming member 67.3

Basal unit:

2. Limy sandstone to sandy limestone, medium-light-gray (*N*6); weathers light gray (*N*7) and dark yellowish orange (10*YR* 6/6); sand fraction is very fine grained; composed of clear quartz, no accessory minerals seen; common very thin beds or lenses of white chert and sparse hematite nodules; firmly cemented, highly calcareous, highly petroliferous; consists of horizontal thin laminae to thin beds (upper one-third of unit contains horizontal beds with irregular or wavy bounding surfaces and a few thin shallow trough sets of very low angle cross-laminae); shaly to blocky splitting, weathers to form cliff 31.5

Total basal unit 31.5

Total Moenkopi Formation 832.9

"Kaibab Limestone" (unmeasured):

1. Dolomitic limestone or dolomite, olive-gray (5*Y* 4/1); weathers light olive gray (5*Y* 6/1); contains fine green grains of apatite(?) and abundant irregular and nodular chert masses; molds of sponge spicules(?) seen; firmly cemented, highly calcareous, highly petroliferous; unit is tabular, consists of horizontal very thin to thick beds; flaggy to massive splitting; weathers to form steep slope containing small rounded ledges.

Base of section; not base of exposure.

U43. CHIMNEY ROCK

[Measured, by J. H. Stewart and G. A. Williams, October 1952, from Sulphur Creek northward to promontory, about 1,000 ft north of Chimney Rock, Capitol Reef National Monument; secs. 5 and 7, T. 29 S., R. 6 E. Wayne County]

Top of section; not top of exposure.
Chinle Formation (incomplete):
Shinarump Member:

	Feet
11. Sandstone, yellowish-gray (5*Y* 8/1) weathers grayish orange (10*YR* 7/4) fine to coarse grained, fair sorting; composed of subangular clear quartz and sparse black and orange accessory minerals, common limonite spots; poorly to firmly cemented, calcareous; thin to thick trough sets of medium-scale high-angle cross-laminae; blocky to massive splitting; weathers to form cliff	49.0
Total Shinarump Member	49.0
Total incomplete Chinle Formation	49.0

Unconformity.
Moenkopi Formation:
Cliff-forming member:

10. Siltstone, similar to unit 9 except for about 50 percent thin to thick ripple-laminated sets (cuspate type 30 percent and parallel type 70 percent) interstratified with structureless and horizontally laminated siltstone; unit weathers to form ledgy slope or, in places, a cliff	124.2
Total cliff-forming member	124.2

Upper slope-forming member:

9. Siltstone, grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); uncommon very thin bands of very pale orange (10*YR* 8/2) to grayish orange (10*YR* 7/4); very argillaceous in parts; micaceous; firmly cemented; horizontally laminated to structureless with 10 percent of unit containing parallel ripple laminae; lower 54 ft of unit contains sparse well-cemented thin sets of ripple-laminated siltstone that form small ledges; unit weathers to form gentle slope. Common laminae of white gypsum discordant to bedding	269.6
Total upper slope-forming member	269.6

Ledge-forming member:

	Feet
8. Sandstone, pale-red (10*R* 6/2); weathers same color and pale reddish brown (10*R* 5/4); very fine grained with abundant silt and common mudstone granules and pebbles, fair sorted; firmly cemented, calcareous; unit is tabular, but varies in thickness; consists predominantly of horizontal laminae with well-defined current lineation, minor ripple laminae near base and thick to very thick trough sets of medium-scale high-angle cross-laminae in upper part; predominantly massive splitting; weathers to form prominent ledge	24.2
7. Siltstone and claystone interstratified, grayish-red (10*R* 4/2); weathers pale reddish brown (10*R* 5/4); argillaceous and micaceous; firmly cemented, calcareous; unit is tabular, consists of horizontal laminae and ripple laminae, several very thick massive splitting beds in upper half; predominantly shaly and platy splitting; weathers to form long gently sloping bench	51.3
6. Siltstone, pale-red (5*R* 6/2) and pale-reddish-brown (10*R* 5/4); weathers pale reddish brown (10*R* 5/4); silt with minor very fine sand grains, micaceous; firmly to well cemented, calcareous; unit is tabular, but varies in thickness; consists of ripple laminae and thick to very thick trough sets of medium- to large-scale high-angle cross-laminae; platy to massive splitting; weathers to form prominent cliff. A few small scours occur along lower contact	27.5
5. Siltstone, pale-reddish-brown (10*R* 5/4); weathers same color; silt with minor very fine quartz sand grains, micaceous; well cemented, calcareous; unit is tabular, consists of horizontally laminated and ripple-laminated strata; platy to massive splitting; weathers to form rubble-covered steep slope with prominent cliff in middle of unit	115.4
4. Siltstone, grayish-red (10*R* 4/2) and sparse grayish-orange (10*YR* 7/4); weathers same colors; argillaceous, contains common mica; firmly cemented, calcareous; consists of horizontal thin beds and thin laminae, and of ripple laminae; shaly to slabby splitting; weathers to form cliff or steep rubble-covered slope. Unit contains a few thin sets of firmly cemented siltstone interstratified with the argillaceous siltstone. It also contains abundant thin sets of ripple-laminated dark-yellowish-orange (10*YR* 6/6) limestone; one conspicuous limestone set occurs 16.9 to 20 ft above base of unit	60.4
Total ledge-forming member	278.8

NOTE.—Section offset on top of Sinbad Limestone Member, so that overlying measured about 700 ft to north.

Sinbad Limestone Member:

3. Limestone, predominantly grayish-orange (10*YR* 7/4), minor pale-yellowish-orange (10*YR* 8/6), and pale-yellowish-brown (10*YR* 6/2); weathers pale yellowish orange (10*YR* 8/6); lithographic with common poorly defined medium-grained oolites; contains minor crumpled and intraformational conglomerate beds; con-

U43. CHIMNEY ROCK—Continued

Moenkopi Formation—Continued
Sinbad Limestone Member—Continued — *Feet*

tains common small irregular blebs of chert; well cemented; unit is tabular, consists of horizontal laminae to thin beds and horizontal very thin to thin cosets of trough sets of small-scale low-angle cross-laminae; blocky splitting; weathers to form ledgy steep slope. Unit contains sparse interbedded very thin to thin sets of horizontally laminated and ripple laminated siltstone — 156.2

Total Sinbad Limestone Member — 156.2

NOTE.—Section offset on top of lower slope-forming member, so that overlying units measured about 1,500 ft to east.

Lower slope-forming member:

2. Claystone and siltstone, grayish-red (10*R* 4/2) (bottom 21 ft and top 7.5 ft of unit are grayish orange (10*YR* 7/4); this color is discordant to bedding); weathers pale reddish brown (10*R* 5/4); contains abundant mica; firmly cemented, calcareous and argillaceous; consists of horizontal thin laminae to laminae and thin beds, abundant current ripple-laminated siltstone; platy and shaly splitting; weathers to form rubble-covered steep slope containing small ledges. Unit contains abundant horizontal laminae and cross-laminae of gypsum. Top 7.5 ft of unit contains abundant very thick to thin limestone beds — 92.4

Total lower slope-forming member — 92.4

Total Moenkopi Formation — 921.2

"Kaibab Limestone" (incomplete) (unmeasured):

1. Limestone, grayish-yellow (5*Y* 8/4); weathers light greenish gray (5*GY* 8/1); composed of lithographic calcite and dolomite with possibly some silt; contains abundant nodules, thin beds and laminae of chert; contains poorly preserved fossils; occurs in beds 2 in. to 4 ft thick; blocky to massive splitting; weathers to form cliff at creek level. Only top 100 ft of "Kaibab" examined in detail.

Base of section and exposure.

U47a. ST. GEORGE

[Measured, by J. H. Stewart and R. F. Wilson, October 1955. Measured from points 4–6 miles southwest of St. George. Units 1–5 measured 0.7 mile northwest of Virgin River along belt of outcrop in lower part of Moenkopi Formation, long 113°40'00" W. and lat 37°01'45" N.; units 6–12 measured 2.7 miles northwest of Virgin River along belt of outcrop in Virgin Limestone Member and 1,000 ft north of unimproved road, long 113°41'30" W. and lat 37°03'15" N.; units 13–26 measured along a northwest line for 1.5 miles to a prominent point along outcrop in Shinarump Member lying 3.3 miles northwest of Virgin River, long 113°40'20" to 113°38'55" W. and lat 37°03'25" to 37°04'15" N. Washington County]

U47a. ST. GEORGE—Continued

Top of section; top of exposure.

Chinle Formation (incomplete):
Shinarump Member: — *Feet*

26. Sandstone (95 percent) and conglomerate (5 percent), light-gray (*N*7) and yellowish-gray (5*Y* 8/1); weathers pale yellowish brown (10*YR* 6/2). Sandstone is fine to medium grained, sparse coarse-grained parts, fair sorted; composed of subangular clear quartz and sparse black accessory mineral; abundant limonite spots; firmly to well cemented, calcareous in parts; contains plant impressions; consists of thin to thick trough sets of medium-scale low-angle cross-laminae. Conglomerate consists of pebbles, which average ½–1 in. in diameter, of quartz, chert, quartzite, and siltstone in a sand matrix. Unit weathers to form cliff capping an escarpment. Base of unit is an erosional surface with channels cutting as much as 50 ft into underlying Moenkopi Formation. Only basal 10 ft of Shinarump examined in detail; total thickness estimated — 125.0±

Total Shinarump Member estimated — 125.0±

Total incomplete Chinle Formation — 125.0±

Unconformity.

Moenkopi Formation:
Upper red member:

25. Siltstone, light-brown (5*YR* 6/4) to moderate-brown (5*YR* 4/4) and grayish-red (10*R* 4/2); sparse thin light-greenish-gray (5*GY* 8/1) bands; weathers same colors; lithology ranges from fine siltstsone to silty very fine grained sandstone (about 2 percent); contains abundant very fine to coarse white and dark-green mica and common white (*N*9) gypsum seams; firmly to well cemented, calcareous; structureless to horizontally stratified, common ripple-laminated (parallel type) parts. A horizontally laminated siltstone occurs 207 to 223 ft above base of unit and forms uppermost of two prominent ledges in upper part of Moenkopi Formation. Unit as a whole weathers to form rubble-covered steep slope — 352.8

24. Sandstone, light-brown (5*YR* 6/4); weathers same color; very fine grained, well sorted; composed of subrounded clear and reddish-stained quartz and abundant black accessory mineral; poorly cemented, calcareous; mostly horizontally laminated with possibly some structureless parts; unit weathers to form lowermost of two prominent

U47a. ST. GEORGE—Continued

Moenkopi Formation—Continued

Upper red member—Continued — *Feet*

ledges or cliffs in upper part of Moenkopi Formation. Base of unit is sharp and may be an erosional surface — 33.6

23. Sandstone, light-brown (10*YR* 6/4) and minor pale-yellowish-brown (10*YR* 6/2); weathers light brown in lower half with a very pale orange (10*YR* 8/2) color band in upper 5 ft; very fine grained and silty, well sorted; composed of subrounded clear and reddish-stained quartz and abundant black accessory mineral; firmly to well cemented, slightly calcareous in parts and gypsiferous in parts; consists of thin to thick wedge-planar sets of small- and medium-scale low-angle cross-laminae; weathers to form cliff below ledge or cliff of overlying unit. Unit seems to grade into underlying unit — 18.0

Total upper red member — 404.0

Shnabkaib Member:

22. Siltstone (90 percent) and gypsum (10 percent), similar to unit 15 except for some very thin beds of dolomite in basal 20 ft — 72.8

21. Gypsum (50 percent), siltstone (40 percent), and dolomite (10 percent). Gypsum is greenish gray (5*GY* 6/1); weathers light greenish gray (5*GY* 8/1) and light brown (5*YR* 6/4); dense to finely crystalline; well cemented; horizontally laminated. Siltstone is similar to that in unit 15. Dolomite is similar to that in unit 20. Unit as a whole weathers to form ledgy slope — 112.0

20. Siltstone (70 percent), gypsum (20 percent), and dolomite (10 percent), interstratified. Siltstone is greenish gray (5*GY* 6/1); weathers pale greenish yellow (10*Y* 8/2); contains common very fine grained accessory white and dark-green mica; well cemented, noncalcareous; stratification mostly concealed, but where seen is horizontally laminated. Northwest of section line a few units of light-brown siltstone occur in upper part of unit. Gypsum is white (*N*9) and greenish gray (5*GY* 6/1); weathers same colors; very finely to coarsely crystalline; well cemented; occurs both as very thin to very thick horizontal beds of white gypsum and as laminae to very thick horizontally laminated sets of greenish-gray gypsum; forms ledges. Dolomite is white (*N*9) and

U47a. ST. GEORGE—Continued

Moenkopi Formation—Continued

Shnabkaib Member—Continued — *Feet*

yellowish gray (5*Y* 8/1); weathers white (*N*9); dense and oolitic; dolomite grades into limestone locally; well cemented; horizontally very thin bedded to laminated. Unit seems to contains all gradations among siltstone, gypsum, dolomite, and limestone. A few poorly preserved gastropods occur about 100 ft above base of unit. Unit as a whole weathers to form conspicuous greenish-yellow rolling hills in upper part of Moenkopi — 451.0

19. Siltstone (80 percent) and gypsum (20 percent), similar to unit 15 — 5.6

18. Siltstone (80 percent), gypsum (15 percent), and dolomite (5 percent). Siltstone is greenish gray (5*GY* 6/1); weathers light greenish gray (5 *GY* 8/1); contains common very fine grained accessory white and dark-green mica; well cemented, noncalcareous; stratification mostly concealed, some horizontal laminae seen. Gypsum is is similar to that in unit 15. Dolomite is similar to that in unit 16, occurs as very thin horizontal beds — 22.4

17. Siltstone (80 percent) and gypsum (20 percent), similar to that in unit 15. Stratification mostly concealed, some horizontal stratification planes seen; unit weathers to form rolling hills — 39.2

16. Dolomite (30 percent), gypsum (60 percent), and siltstone (10 percent). Dolomite is white (*N*9) to light gray (*N*7); weathers same colors; dense in some parts and oolitic in other parts; well cemented; horizontally very thin bedded; occurs as very thin to thick sets interstratified with gypsum and siltstone. Gypsum is white (*N*9) and light greenish gray (5*GY* 8/1); weathers same colors; dense to very finely crystalline; well cemented; stratification concealed. Siltstone is greenish gray (5*GY* 6/1) and grayish red (10*R* 4/2); weathers same colors; firmly cemented, noncalcareous, clay binding; stratification concealed. Unit as a whole weathers to form prominent white ledge — 24.5

Total Shnabkaib Member — 727.5

Middle red member:

15. Siltstone (80 percent) and gypsum (20 percent). Siltstone, moderate-brown (5*YR* 4/4) to grayish-brown (5*YR* 3/2) and grayish-red (10*R* 4/2); weathers light brown (5*YR* 6/4); contains common very fine grained acces-

U47a. ST. GEORGE—Continued

Moenkopi Formation—Continued

Middle red member—Continued — *Feet*

sory white mica; poorly to firmly cemented, noncalcareous; stratification mostly concealed, but where seen contains many horizontal stratification planes with some parts being horizontally laminated to thinly laminated. Gypsum, white (*N*9) and greenish-gray (5*GY* 6/1); weathers white (*N*9) and light greenish gray (5*GY* 8/1); dense to finely crystalline, grades into siltstone; well cemented; horizontally thinly laminated to laminated. Gypsum occurs as laminae to thick sets interstratified with siltstone. Unit as a whole weathers to form rolling hills; the highly gypsiferous parts form light-greenish-gray (5*GY* 8/1) color bands on exposure — 310.0

14. Gypsum (80 percent) and siltstone (20 percent). Gypsum is white (*N*9) and greenish gray (5*GY* 6/1); weathers same colors; very finely to finely crystalline; firmly to well cemented; horizontally laminated to thin bedded. Siltstone is pale reddish brown (10*R* 5/4); weathers same color; firmly cemented, noncalcareous, gypsiferous in parts; occurs as very thin to thin horizontal beds interstratified with gypsum. Unit as a whole weathers to form ledge and caps many low mesas — 7.0±

13. Siltstone (95 percent) and gypsum (5 percent). Siltstone is grayish brown (5*YR* 3/2); weathers pale brown (5*YR* 5/2); fine silt; firmly cemented, noncalcareous, clay binding; stratification mostly concealed, but sparse exposures contain thinly laminated siltstone. Gypsum is white (*N*9) and greenish gray (5*GY* 6/1); weathers same colors; dense and finely crystalline; occurs as horizontal laminae and as veinlets crosscutting stratification. Unit as a whole weathers to form slope — 16.0±

Total middle red member — 333.0±

NOTE.—Section offset on top of Virgin Limestone Member, so that overlying units measured about 1 mile N. 75° E.

Virgin Limestone Member:

12. Limestone, light-olive-gray (5*Y* 6/1) and light-gray (*N*7); weathers yellowish gray (5Y 8/1); dense; well cemented; horizontally very thinly to thinly bedded; sparse contorted bedding probably due to penecontemporaneous slumping; weathers to form ledge and extensive bench. (Unit 12 measured about 1 mile N. 40° E. from St. George U47b section; about 2 miles N. 50° W. from basal part and about 2.6 miles S. 68° W. from top of St. George U47a section) — 14.4

U47a. ST. GEORGE—Continued

Moenkopi Formation—Continued

Virgin Limestone Member—Continued — *Feet*

11. Mostly covered, but where seen is siltstone similar to that in unit 7. Unit contains some light-olive-gray (5*Y* 6/1) and grayish-red (10*R* 4/2) siltstone — 44.8

10. Silty limestone, light-olive-gray (5*Y* 6/1) and minor dusky-yellow (5*Y* 6/4); weathers moderate yellowish brown (10*YR* 5/4); dense and very finely crystalline; well cemented; horizontally laminated, sparse parallel and cuspate ripple laminations; weathers to form ledge — 2.0

9. Mostly covered, but where seen is siltstone similar to that in unit 7. Top foot of unit is pale-olive (10*Y* 6/2) siltstone — 22.4

8. Limestone, light-olive-gray (5*Y* 6/1), grayish-yellow (5*Y* 8/4), and light-gray (*N*7); weathers dusky yellow (5*Y* 6/4); dense; contains common crinoid columnals and pelecypod shells; well cemented; horizontally thin to thick bedded; weathers to form ledge — 8.6

7. Siltstone, brownish-gray (5*YR* 4/1); weathers same color and olive gray (5*Y* 4/1); fine silt; firmly to well cemented, slightly calcareous, clay binding; structureless with possibly some thin laminae; weathers to form rubble-covered slope. Unit is poorly exposed in parts and its contact with overlying unit was not seen — 38.2

6. Limestone, light-olive-gray (5*Y* 6/1); weathers pale yellowish brown (5*YR* 6/2); dense; contains abundant crinoid columnals and pelecypod shells; well cemented; even horizontal thin to thick beds; weathers to form ledge — 3.3

Total Virgin Limestone Member — 133.7

NOTE.—Section offset on base of Virgin Limestone Member, so that overlying units measured 2.1 miles to northwest. The lithologic character of the interval occupied by units 2–5 varies greatly along the outcrop. The interval is brownish-red siltstone with minor white gypsum in one place and 95 percent white gypsum and 5 percent limestone and reddish-brown siltstone in another place. Possible gypsum may grade laterally into siltstone within a distance of 100 ft in some places; however, in other places, the apparent local abundance of gypsum seems to be caused partly, but not entirely, by flowage of gypsum downhill over red beds.

U47a. ST. GEORGE—Continued

Moenkopi Formation—Continued

Lower red(?) member: *Feet*

(Note: some limestone in basal part of lower red(?) member may be equivalent to the Timpoweap Member of Moenkopi Formation or the alpha member of Kaibab Limestone.)

5. Siltstone (90 percent) and gypsum (10 percent). Siltstone, light-brown (5*YR* 5/6) to moderate-brown (5*YR* 4/4) and grayish-red (10*R* 4/2); weathers same colors; contains common very fine grained accessory white mica; firmly cemented, calcareous; structureless, some laminated parts and possibly some cuspate-type ripple-marks. Gypsum, white (*N*9) and light-olive-gray (5*Y* 6/1); weathers same colors; finely crystalline; poorly to well cemented; occurs as horizontal laminae to thin beds interstratified with siltstone and as seams crosscutting bedding. Unit as a whole weathers to form earthy slope ---------------------------- 112.0±
4. Limestone, yellowish-gray (5*Y* 8/1), white (*N*9), and minor grayish-orange (10*YR* 7/4); weathers very light gray (*N*8) to black (*N*1); dense; contains abundant chert nodules and some bedded chert; no fossils seen; well cemented; horizontally thin to very thick bedded; a few thin beds seem to be chert breccia similar to that in underlying unit. Unit weathers to form ledge and bench. Unit is partly covered; concealed siltstone could constitute as much as 30 percent of unit. Unit is discontinuous along exposure and seems to be displaced by gypsum laterally-- 34.0±
3. Siltstone and chert breccia. Siltstone, light-brown (5*YR* 5/6); weathers same color; contains abundant gypsum as horizontal laminae and seams crosscutting stratification; stratification mostly concealed. Chert breccia, grayish-orange (10*YR* 7/4); weathers same color; composed of angular chert pebbles and, to a lesser extent, of limestone pebbles set in a lime matrix; well cemented; occurs as horizontal thin sets 17 and 28 ft above base of unit. Unit as whole weathers to form gentle slope on siltstone and ledges on the sets of chert breccia------------------------ 78.0±
2. Limestone, very light gray (*N*8) to medium-gray (*N*5); weathers medium gray (*N*5); dense; contains sparse poorly preserved pelecypods(?); well cemented; horizontally thick to very thick bedded; weathers to form bench- 5.6

Total lower red(?) member------- 229.6

Total Moenkopi Formation--------- 1,828.2

U47a. ST. GEORGE—Continued

Kaibab Limestone (incomplete):

Beta member (incomplete) (unmeasured):

1. Limestone and dolomite, very light-gray (*N*8) to light-gray (*N*7) and yellowish-gray (5*Y* 8/1); weathers medium gray (*N*5) to black (*N*1); dense; no fossils seen; horizontally laminated to thick bedded; weathers to form cliffs along sides of gullies.

Base of section; not base of exposure.

U47b. ST. GEORGE

[Measured, by J. H. Stewart and R. F. Wilson, October 1955, 2.5 miles northwest of Virgin River along belt of outcrop in lower part of Moenkopi Formation and 500 ft south of unimproved road, long 113°42'10" W. and lat 37°02'40" N. Washington County]

Top of section; not top of exposure.

Moenkopi Formation (incomplete):

7. Virgin Limestone Member, not described; unmeasured.

Lower red(?) member: *Feet*

(Note.—part of lower red(?) member may be equivalent to the Timpoweap Member of Moenkopi Formation or the alpha member of Kaibab Limestone.)

6. Gypsum (90 percent) and limestone to dolomite (10 percent). Gypsum, similar to that in unit 2. Limestone to dolomite, yellowish-gray (5*Y* 8/1) and grayish-orange (10*YR* 7/4); weathers same colors; similar to limestone in unit 4 except for abundant chert. Unit as a whole weathers to form slope---- 33.0
5. Gypsum (75 percent), limestone to dolomite (10 percent), and siltstone to gypsiferous siltstone (15 percent). Gypsum, similar to that in unit 2. Limestone to dolomite, limestone similar to that in unit 4 except in places it contains as much as 80 percent chert. Siltstone to gypsiferous siltstone, pale-reddish-brown (10*R* 5/4) and grayish-red (10*R* 4/2); weathers same colors; contains common fine-grained accessory white mica; consists of poorly exposed thin to very thin sets interstratified with other rock types in unit. Unit as a whole weathers to form slope. Unit is separated from underlying unit by its reddish-brown coloration-- 39.2
4. Gypsum (60 percent) and limestone (40 percent). Gypsum, similar to that in unit 2. Limestone, yellowish-gray (5*Y* 8/1) and light-gray (*N*7) to medium-dark-gray (N4); weathers yellowish gray (5*Y* 8/1); dense, a few parts contain fine to medium grains of lime; contains some chert nodules; well cemented; horizontally laminated to thin bedded, occurs as very thin to 6-ft-thick sets interstratified with gypsum. One thin set of pale-reddish-brown (10*R* 5/4) horizontally laminated siltstone occurs about 6 ft below top of unit. Unit as a whole weathers to form ledgy slope------------------------ 37.8

U47b. ST. GEORGE—Continued

Moenkopi Formation—Continued

Low red(?) member—Continued

	Feet
3. Limestone, light-gray ($N7$) to medium-dark-gray ($N4$); weathers same colors; dense; well cemented; upper half of unit is petroliferous with fetid odor; horizontally very thin to thick bedded; weathers to form ledge. Unit contains pelecypods and cephalopods(?) about 2.3 ft above base	10.0
2. Gypsum, white ($N9$); weathers white ($N9$) and yellowish gray ($5Y$ 8/1); finely to coarsely crystalline; poorly cemented; stratification concealed; weathers to form slope. In places gypsum has flowed down surface of slope	14.9
Total lower red(?) member	134.9
Total incomplete Moenkopi Formation	134.9

U47b. ST. GEORGE—Continued

Kaibab Limestone (incomplete):

Beta member (incomplete) (unmeasured):

1. Limestone and dolomite, very light gray ($N8$) to light-gray ($N7$) and yellowish-gray ($5Y$ 8/1); weathers medium gray ($N5$) to black ($N1$); dense; contains 5–40 percent gray chert nodules; horizontally thin to thick bedded; weathers to form cliff along canyon with rubble-covered slope in top 30 ft. Unit contains abundant brachiopod, pelecypod, and crinoid fauna about 30 ft below top. About 60 ft of unit exposed.

NOTE.—Top of Kaibab Limestone placed at change from limestone containing abundant chert below to gypsum above. Lithology of unit 1 is typical of Kaibab Limestone, and unit 1 probably does not contain any rocks belonging to the Timpoweap Member of Moenkopi Formation.

Base of section; base of exposure.

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