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Measured Stratigraphic sections of Jurassic San Rafael Group and Adjacent Rocks in Kane County, Utah

By J. C. Wright, D. D. Dickey, and R. P. Snyder

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Illustration

Figure 1.--Map showing locations of stratigraphic sections---------- 3

Measured Stratigraphic Sections of Jurassic San Rafael Group and Adjacent Rocks in Kane County, Utah

By J. C. Wright, D. D. Dickey, and R. P. Snyder

Introduction

These sections were measured prior to 1960, before adoption of the metric system. Publication was delayed by other assignments of the authors and later by the untimely death of J. C. Wright. They are being released at this time because of the increased interest in the uranium potential of Jurassic rocks. The San Rafael Group is represented by the Carmel, Entrada, Summerville, and Bluff Formations in these sections.

Figure 1 is a map showing the locations of the stratigraphic sections included in this report. The following terms used in this report were found convenient in helping to describe stratigraphic sections on the Colorado Plateau.

Entrada berries.--Very well rounded, nearly spherical, frosted sand grains larger than grains of the matrix and composing a very small part of the total volume. They are common in the Entrada Sandstone, but are not exclusive to it.

Slickrim.--A slightly rounded or curved cliff of sandstone as opposed to a vertical cliff.

Stonepecker holes.--Small holes, a few millimeters to a few centimeters in diameter in the face of a sandstone cliff. They usually form in horizontal rows along a thin bed of material of a slightly different texture from the main sandstone body.

Hoodoos.--Weathering style characteristic of sandstone and siltstone beds with disrupted internal bedding. The hoodoo forms stand in columns and have an appearance of rounded boulders stacked on top of each other. "Boulder" tops and bottoms of adjacent columns are at the same stratigraphic level because they are controlled by softer thin beds or bedding planes.

Informal member names of some formations were used to aid in local correlations. The informal Notom unit of the Carmel Formation used in these sections is equivalent to the gypsiferous member used elsewhere by us. The informal Fruita unit is equivalent to the limestone member used elsewhere. The informal Co-op, Escalante, and Kanarraville units were used in the western area, and are approximately, if not exactly, equivalent to the gypsiferous, banded, and limestone members mapped later by Cashion (1967b). These three units along with the Winsor Member occupy the stratigraphic interval assigned to the Notom unit to the east.

The Thousand Pockets Tongue, assigned to the Navajo Sandstone and the upper part of the Navajo Sandstone in these sections is now considered to be Page Sandstone (see Peterson and Pipiringos, 1979).

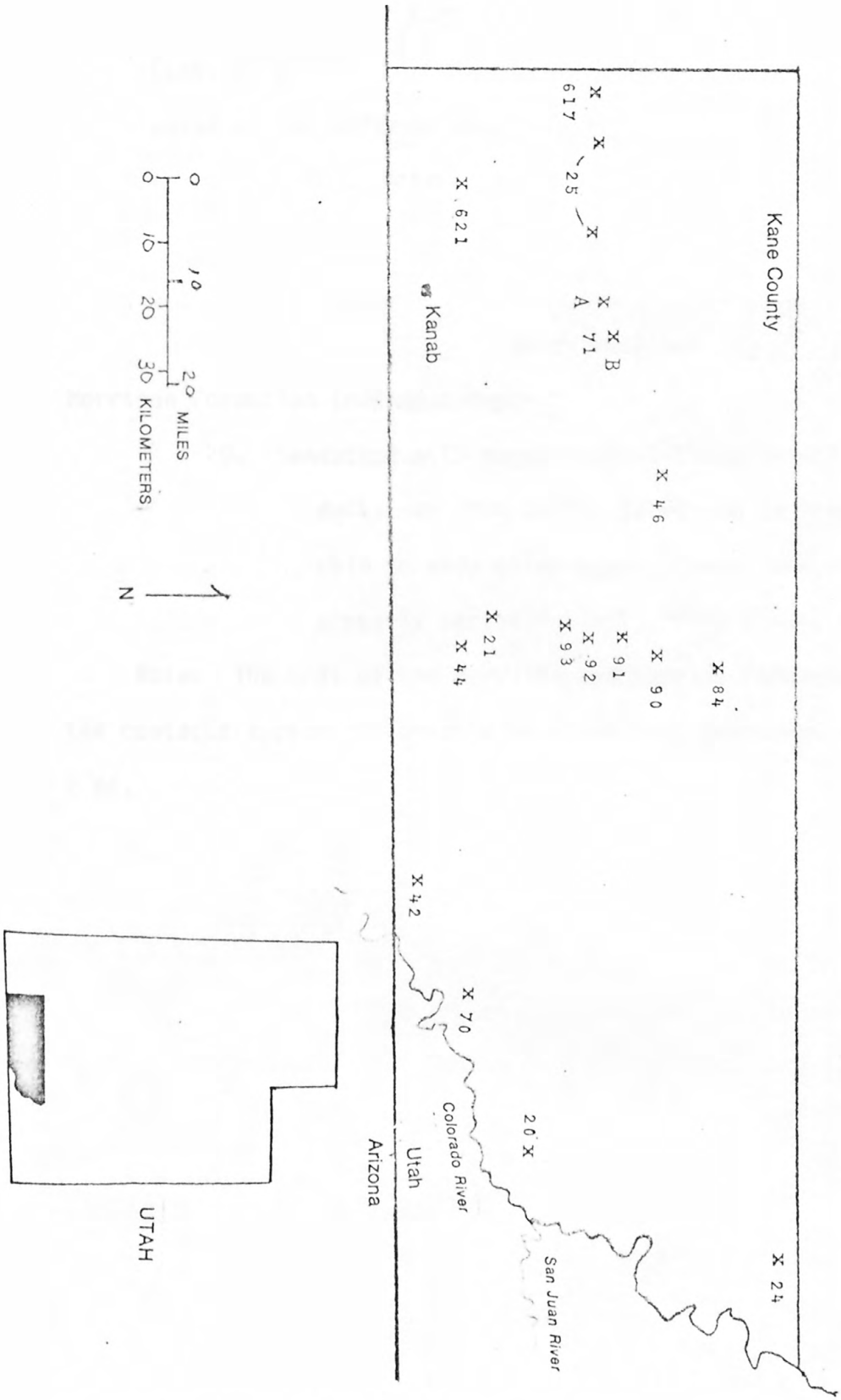

Figure 1. Map showing locations of stratigraphic sections in this report. (Section numbers are in system used by Wright and Dickey, 1963.)

KANE COUNTY - UTAH

FORTY MILE CREEK section (20)

[Lat. 37°15'30" N., long. 111°00'30" W., measured near a spur 7 mi north of the extreme southeast tip of Straight Cliffs; measured by J. C. Wright and D. D. Dickey, July 12, 1956]

Thickness

Feet

Upper Jurassic

Morrison Formation (not measured):

20. Sandstone with subordinate interbedded claystone, dusky red (10R 3/2). Sandstone in irregular thin to very thick beds. Forms irregular ledges on a nearly vertical cliff. Very thick; exceeds 50 ft.

Note: The beds of the Morrison and Entrada Formations are parallel and the contacts appear conformable on cliff-face exposures visible for about 2 mi.

	Thickness Feet
Middle Jurassic	
Entrada Sandstone:	
19. Sandstone, greenish white (5GY 9/1), stains orange pink (10R 6/4) on many faces; very fine to fine grained, rounded grains; well cemented; the lower two-thirds has sets as much as 30 ft thick with large-scale cross-laminae; grades upward into thinner sets of small-scale cross-strata, and even-bedded cosets 0.5-5 ft thick. Forms vertical cliff that in many places is an unbroken continuation with unit 18, and in other places is prominent as a white band----------	95.0
18. Sandstone, to siltstone, sandy, pale reddish brown (10R 5/4), weathers same, very fine grained, well cemented. Bedding ranges from sets 1-2 ft thick of medium-scale cross-laminae to minor even-laminated sets. Forms persistent vertical-jointed cliffs----------	120.0

	Thickness Feet
Entrada Sandstone--Continued	
17. Siltstone, sandy, reddish brown (10R 4/4) to moderate reddish orange (10R 6/6); irregular even bedded; contains about 5 percent streaks of grayish-white fine-grained sandstone in thin beds, and a few minor interbeds of reddish-brown shaly-weathering siltstone. A sandstone, moderate reddish orange (10R 6/6), very fine grained, with medium-scale cross-strata occupies the interval 105-125 ft above the base. In the upper half of the unit are several purple clay partings. Near the top of unit are several sandstones, very fine grained; partly light greenish gray (5GY 8/1) and partly moderate reddish orange, with medium-scale crossbeds. Whole unit forms an extremely steep slope----------	198.0

Thickness

Feet

Entrada Sandstone--Continued

16. Sandstone, pale reddish orange (10R 7/6), weathers same, fine grained; composed of well-rounded grains; has stonepecker holes weathered out along some bedding planes. The following subdivision may be made on the basis of bedding style.

Feet above base:

380-428	Large-scale cross-strata. This subdivision is lenticular, and locally absent where unit 17 fills hollows in unit 16.
366-380	Planar beds; mostly very fine grained.
367	Purple clay parting.
296-366	Medium-scale cross-strata in tabular cosets with subordinate cosets of flat strata.
283-296	Sets of cross-strata with many intervening cosets of flat strata; this subdivision is redder, finer grained, and less resistant than the bulk of the unit; it forms a broadly sloping bench within the cliff.

		Thickness Feet
Entrada Sandstone--Continued		
16.--Continued		
77-283	Cross-strata, in a few thick tabular cosets, separated by horizontal truncation planes, grade from medium to large scale upwards; a few cross-strata are comprised of medium-grained sandstone; the subordinate flat beds are generally comprised of very fine grained reddish sandstone.	
65-77	Planar beds; dark reddish.	
0-65	About half medium-scale cross-strata and half even-strata; bedding indistinct above deformed part of unit; bleached whitish for a few feet at base.	
	Total thickness of unit 16----------	428.0

Note: Offset several hundred yards westward, along base of main slickrim cliff (unit 16), to measure the upper part of the section. Unit slumped about 50 ft downwards into the underlying softer units, which apparently failed. This disruption is believed to be approximately consistent over the whole area of the offset. Same is probably true of the slickrim in the area so that the total thickness is probably correct. The failure appears to have taken place after about 77 ft of unit 18 was deposited, and then the resulting uneven surface appears to have been filled in by crossbeds as general deposition continued.

	Thickness Feet
Entrada Sandstone--Continued	
15. Siltstone and claystone like unit 13----------	6.0
14. Sandstone, pale reddish orange (10R 7/6), weathers same, very fine grained; bedding indistinct; some large-scale low-angle crossbeds, some even bedding; some disturbance of bedding. Forms rounded slickrim slope. Lower contact of this sandstone is uneven, as though soft underlying formations had failed locally beneath it. The sandstone appears lenticular, as well; in some places it is only a few feet thick, in others it extends nearly to unit 16 at the expense of unit 15----------	20.0
Total thickness of Entrada Sandstone----------	867.0
Carmel Formation:	
13. Siltstone and claystone like unit 11. Some thin lenses of light greenish gray, very fine-grained sandstone. Mostly covered----------	44.0

Note: Offset from northeast side of the road to the base of the spur on the southwest side of the road to measure the upper beds.

12. Sandstone, grayish orange pink (10R 8/2) weathers moderate reddish orange (10R 6/6) to pinkish white (10YR 9/2), very fine grained, indistinct even bedding. Forms ledge----------	8.0

	Thickness Feet
Carmel Formation--Continued	
11. Siltstone and claystone, partly concealed. Siltstone moderate reddish orange (10R 6/6); claystone reddish brown (10R 4/4), laminated. Forms slope. Contains purple clay parting near middle, with a 6 in. light-greenish-gray, very fine grained sandstone beneath it----------	21.0
10. Sandstone, greenish white (5GY 9/1) weathers same, very fine grained. Forms ledge. Upper 0.5 ft has very abundant 1 mm nodules cemented with gypsum and calcite. Weathers in indistinct even beds. Has a mostly covered reddish silty shale parting 3 ft from top, weathering pale reddish brown----------	9.0
9. Siltstone and claystone; grades from siltstone, moderate reddish orange (10R 6/6), at bottom to claystone, reddish brown (10R 4/4), at top. Forms slope----------	26.0
8. Sandstone, like unit 5----------	2.5
7. Mostly covered; siltstone, weathers reddish orange (10R 5/6); 3 ft above base is a bed of better-cemented sandstone like unit 5----------	11.0

	Thickness Feet
Carmel Formation--Continued	
6. Sandstone, moderate orange pink (10R 7/4), weathers grayish brown (5YR 4/2); top 0.5 ft is grayish orange pink (10R 8/2), weathers same (10R 8/2); very fine grained, well cemented, limy; ripple-marked on top, both current and oscillation types. Forms ledge----------	3.5
5. Sandstone, pale reddish orange (10R 7/6) with round bleached white spots 1 mm to 2 cm in diameter; very fine to fine grained; rounded grains. Massive----------	2.0
4. Claystone, reddish brown (10R 4/4), nearly pure clay; laminated, weathers shaly. Mostly concealed on slope----------	16.5
3. Sandstone, lithology same as unit 2, except grains are extraordinarily spherical; cross-strata are low angle, medium scale; some even beds. Forms cap on cliff----------	2.5
Total of Carmel Formation----------	146.0

Note: The Carmel-Navajo contact appears even and conformable on outcrops a few hundred feet long.

	Thickness Feet
Jurassic and Triassic(?)	
Navajo Sandstone (incomplete):	
2. Sandstone, moderate reddish orange (10R 6/6), weathers same; very fine to medium-grained sandstone, moderately well sorted, well cemented, limy; some spots 1 mm in diameter stained with purple hematite, on less worn surfaces these form carbonate-cemented nodules composed of rounded frosted grains. Large-scale cross-strata. Forms cliff----------	20.0
1. Sandstone, weathers grayish orange pink (10R 8/2) to pale reddish orange (10R 7/6). Large-scale sweeping crossbeds in sets as much as 30 ft thick. Forms cliff in wash----------	>150.0
Total of incomplete Navajo Sandstone----------	>170.0

CATSTAIRS section (21)

[NW 1/4 sec. 30 and SW 1/4 sec. 19, T. 42 S., R. 1 W. Section is in West Cove about 0.5 mi north of the highway to the Glen Canyon Dam, with its base near the top of the Cockscomb; measured by J. C. Wright and D. D. Dickey, July 14 and October 25, 1956]

	Thickness Feet
Upper Cretaceous	
Dakota Sandstone (incomplete):	
30. Sandstone, pale orange (10YR 7/2) weathers same to very pale orange (10YR 8/2); fine-grained, silty, poorly sorted; moderately well cemented; composed of rounded quartz and feldspar grains; scattered limonite nodules as much as 3 in. in diameter; planar beds, with minor small- and medium-scale cross-stratification; fills channels at base. Forms ledge. This unit is overlain by greenish gray shale with interbedded lenticular sandstone----	6.0
29. Shale, grayish black (N 2); carbonaceous; thinly laminated; contains gypsum and sulfur on fractures; grades into sandstone at base; upper contact cut by scour channels. Weathers to soil-covered slope----------	15.0

	Thickness Feet
Dakota Sandstone (incomplete)--Continued	
28. Sandstone, like unit 27, except that it is stained light greenish yellow (10Y 7/2) and light olive brown (5Y 5/6) with streaks of dark yellowish orange (10YR 6/6). Contains gypsum seams. Lateral to section, coaly shale occupies this interval. Appears to be a reworking of Entrada Sandstone associated with pre-Dakota erosion----------	10.0
Total of incomplete Dakota Sandstone----------	>31.0

Note: The Dakota-Entrada contact, although regionally unconformable, appears conformable here; some material from the Entrada is reworked; coaly shale is common in the lower few feet of the Dakota and where this coaly seam is not present the contact might erroneously be placed above the reworked Entrada just beneath the more characteristic Dakota Sandstone ledge.

Middle Jurassic

Entrada Sandstone:	
27. Sandstone, like unit 26 in color and lithology, except possibly slightly less well sorted, and more poorly cemented; flat bedded with some small-scale cross-strata; forms steep earthy slope protected by Dakota ledge. Contains several thin beds of greenish gray (5GY 7/1), better-cemented sandstone; locally these beds are reddish----------	61.0

	Thickness Feet
Entrada Sandstone--Continued	
26. Sandstone, greenish yellow, white (10Y 9/2) weathers same, very fine grained, moderately well sorted, rounded; poorly cemented; contains pink, amber, and black accessory grains. Very thick (at bottom) to thick (at top), large-scale wedging planar sets of cross-strata. Lower part forms steep cliff; upper part, rounded slickrim knobs weathering back on bench-----	165.0

Note: Offset to the southeast about 0.5 mi (following units 23 to 25) in order to measure the uppermost part of the section.

25. Sandstone, similar to unit 23. Thickness estimated----	6.0
24. Sandstone, probably like unit 22, except that bedding is indistinct, mostly even. Thickness estimated----	35.0
23. Sandstone, very fine grained, moderate reddish brown (10R 4/6); bedding indistinct, possibly disturbed. Forms slope between two vertical cliffs; thickness estimated----------	6.0
22. Sandstone, white (N 9), fine grained, rounded, well sorted; composed of quartz grains with some black and many orange grains; medium-scale sets of cross-strata 2-5 ft thick. Forms inaccessible vertical cliff; thickness estimated----------	30.0

CATSTAIRS section--Continued

	Thickness Feet
Entrada Sandstone--Continued	
21. Claystone and clayey friable siltstone, light greenish gray (5GY 8/1). Exposed at base of vertical cliff, and makes slope wash for about 5 or 10 ft below outcrop----------	4.5
20. Interbedded siltstone, and sandstone very fine grained, with a shale bed at bottom, moderate reddish brown (10R 4/6) with some of the sandstone making light greenish gray bands a few inches to 3 ft thick; bedding indistinct or massive. Forms steep weathered slope----------	81.0
19. Interbedded sandstone, siltstone, and minor shale, in beds 1-3 ft thick, similar to units 17 and 18. Contains some sandstone beds in lower part that are light grayish red (10R 5/2); very fine grained, well cemented, with some gray and some orange, medium-grained Entrada berries. These grayish red sandstone beds form ribs----------	77.5
18. Same as unit 17, but better exposed. Some sandstone weathers bluish white (5B 9/1) in contrast to predominant greenish white of other sandstones. Very fine to medium grained, composed of rounded quartz grains with orange accessory grains----------	56.0

	Thickness Feet
Entrada Sandstone--Continued	
17. Covered. Interbedded sandstone, siltstone, and minor shale are visible about 0.5 mi north; similar to unit 15, but sandstone probably comprises 60 or 70 percent of total thickness and occurs in beds 5-15 ft thick----------	68.5
16. Sandstone, light greenish gray (5GY 8/1), mostly fine grained, but contains very fine and medium grains; composed of rounded quartz grains with orange accessory grains; firmly cemented; bedding is indistinct to massive, medium- to large-scale, low-angle cross-strata. A few purple horizontal clay beds as much as a foot thick occur in lower 30 ft----------	112.5
Total of Entrada Sandstone----------	703.0

	Thickness Feet
Entrada Sandstone--Continued	
Gypsiferous member:	
15. Sandstone (45 percent), siltstone (45 percent), and claystone (10 percent), interbedded. Sandstone, light greenish gray (5GY 8/1), very fine grained, poorly cemented; flat even beds about 1-8 ft thick. Siltstone, moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4); massive beds 1-5 ft thick; some siltstones show obvious contortions involving thin sandstone layers. Shale, dusky red (10R 3/2), in recesses a few inches to 3 ft thick. The whole unit is generally in planar beds but close inspection shows small-scale irregularities, particularly in the shale. Forms a soft, red and white banded cliff----------	144.0
Total of gypsiferous member----------	144.0

	Thickness Feet
Carmel Formation--Continued	
Judd Hollow Tongue--Continued	
9. Limestone, pale yellowish brown (10YR 6/2); contains oolites about 0.1-0.2 mm in diameter; ripple laminations; forms a ledge. Unit 8 grades into unit 9----------	7.5
8. Siltstone, light greenish gray (5GY 8/1), very calcareous, irregular laminations; poorly exposed in recess----------	2.5
7. Limestone, with gypsum in blebs and fine seams; light gray (N 7), weathers greenish gray (5GY 7/1); thin planar beds. Forms receding ledge above unit 6-----	0.5
6. Siltstone, grayish yellow (5Y 8/4) weathers same, sandy, well sorted, firmly cemented with abundant calcite, thin laminations with ripple marks. Forms a jointed ledge----------	4.5
5. Sandstone, light greenish yellow (10Y 7/2), very fine grained, silty, well sorted, moderately well cemented with calcite. Forms a recess----------	1.0
4. Siltstone, dolomitic, very light gray (N 8) to yellowish gray (5Y 7/2), compact, dense; weathers and fractures like a limestone but gives only light effervescence with dilute hydrochloric acid. Forms a blocky-jointed ledge----------	4.5

	Thickness Feet
Carmel Formation--Continued	
Judd Hollow Tongue--Continued	
3. Sandstone, yellowish gray (5Y 7/4), with a band 6 in. above base stained grayish blue green (5BG 5/2), and a band in the middle colored pale red purple (5RP 6/2); very fine grained, well sorted, firmly cemented with calcite; irregular thin flat beds. Forms a recess----------	3.0
2. Sandstone, irregularly banded dark red (5R 3/6), to pinkish white (5R 9/2), weathers same; very fine grained, well sorted, but some strata have a conspicuous secondary mode of well-rounded, frosted medium grains; composed of reworked Navajo sand, partly impregnated with hematite; irregular thin planar beds. Forms a very weak receding ledge at the top of the Navajo cliff-------	7.0
Total of Judd Hollow Tongue----------	56.5
Total of Carmel Formation----------	86.5

Note: The Carmel-Navajo contact is a flat, beveled surface truncating the cross-strata with minor wavy undulations of 1 to 2 in. amplitude.

SWEETWATER SPRING section--Continued

	Thickness Feet
Jurassic and Triassic(?)	
Navajo Sandstone, main body (incomplete):	
1. Sandstone, very pale orange (10YR 8/2) weathers grayish orange pink (5YR 7/2) fine grained, well sorted, firmly cemented with calcite; rounded transparent quartz with sparse black opaque accessory grains;; thick wedging sets of large-scale cross-strata----------	>60.0
Total of incomplete Navajo Sandstone (including Thousand Pockets Tongue)---------- >155.0	

COTTONWOOD CREEK section (91)

[S 1/2 sec. 27, T. 40 S., R. 1 W. unsurveyed; measured at a small dry gap in the hogback formed by the East Kaibab monocline, 3 mi north of the mouth of Hackberry Creek; measured by J. C. Wright and R. P. Snyder, May 27, 1959]

Note: The Thousand Pockets Tongue is present, but cannot be measured because of faulting and sharp buckling of monocline. It appears to be approximately 125-150 ft thick, and has a soft, red recess-forming unit (about 10 ft thick) about 50 ft above its base. Locally the main mass of the Carmel Formation is present in small flatirons above the Thousand Pockets Tongue of the Navajo. It is dragged, sheared, and crumpled, so that no distinct stratigraphic sequence can be recognized.

	Thickness Feet
Middle Jurassic	
Carmel Formation:	
Judd Hollow Tongue:	
9. Mostly covered; float indicates siltstone, moderate reddish brown (10R 4/6). Approximately----------	24.0
8. Limestone, yellowish gray (5Y 7/2); oolitic, slightly silty; thin to thick flat beds; forms massive, blocky-jointed ledge. Upper part is light gray (N 7), contains irregular areas of local of grayish blue stain (5PB 5/2), and has a peculiar fragmental texture, partly recrystallized----------	16.5
7. Covered, talus in recess. Approximately----------	12.0

	Thickness Feet
Carmel Formation--Continued	
Judd Hollow Tongue--Continued	
6. Siltstone, dolomitic, like unit 5, but with thick flat beds; forms ledge----------	7.0
5. Siltstone, pale purple (5P 6/2) to very light gray (N 8), dolomitic, dense, compact; thin flat beds concealed in a talus-covered recess----------	2.5
4. Poorly exposed siltstone, reddish orange (10R 5/6); concealed in talus-covered recess. Approximately---	1.5
3. Sandstone, yellowish orange (10YR 7/6), fine grained, well sorted, firmly cemented with calcite and limonite; irregular, flat massive bed. Forms ledge capping the Navajo flatiron----------	3.0
2. Sandstone, pale reddish brown (10R 5/4), fine grained, well sorted, very firmly cemented with calcite and hematite; massive flat bed capping the Navajo Sandstone. Irregular contact with unit 3----------	4.0
Total of Judd Hollow Tongue. Approximately----	70.5
Total of Carmel Formation. Approximately------	70.5

Note: The Carmel-Navajo contact is a nearly flat surface, that bevels cross-strata of the Navajo. It has undulating irregularities, of about 6 in. amplitude.

	Thickness Feet
Jurassic and Triassic(?)	
Navajo Sandstone (not measured):	
1. Sandstone, light grayish orange (10YR 8/4) weathers same, fine grained, well sorted, firmly cemented; contains many well-rounded, gray frosted, medium-sized grains; thick to very thick wedging sets of large-scale cross-strata. Forms hogback----------	>200.0
Total of Navajo Sandstone----------	>200.0

HACKBERRY CREEK section (92)

[T. 41 S., R. 1 W., sec. 9, center; measured about 200 ft up, on south side of canyon; measured by J. C. Wright and R. P. Snyder, May 27, 1959]

Note: Main mass of Carmel Formation concealed under alluvium.

	Thickness Feet
Middle Jurassic	
Navajo Sandstone:	
Thousand Pockets Tongue:	
10. Sandstone, white (N 9), weathers pale orange (10YR 7/2), very fine grained, well sorted, moderately well cemented with calcite; contains some spherical, well-rounded, gray frosted, medium quartz grains; about 75-100 ft above base is a band of orange pink (10R 6/4) sandstone that forms a slight recess. Approximate thickness----------	175.0
Total of Thousand Pockets Tongue. Approximate thickness----------	175.0

Note: Offset to creek level on north side of canyon to measure the Thousand Pockets Tongue.

Carmel Formation:	
Judd Hollow Tongue:	
9. Mostly concealed on talus slope; siltstone, moderate reddish brown (10R 4/6), with subordinate claystone greenish gray (5GY 6/1). Approximate thickness----	22.0

	Thickness Feet
Carmel Formation--Continued	
Judd Hollow Tongue--Continued	
8. Mostly concealed on talus slope; limestone, very light gray (N 8), weathers yellow gray (5Y 8/1); oolitic, silty; thin flat beds. Approximate thickness	8.0
7. Poorly exposed on talus slope; probably claystone, greenish gray (5GY 6/1), and siltstone reddish brown (10R 4/4). Approximate thickness	10.0
6. Limestone, light gray (N 7), silty; thin even beds; forms ledge	2.5
5. Siltstone, red purple (5RP 5/2) to light brownish gray (5YR 6/1), slightly dolomitic; thin even beds and laminae; forms small ledge, grades into unit 6	3.5
4. Claystone, greenish gray (5GY 7/1), mostly concealed	0.5
3. Sandstone pale yellowish orange (10YR 8/6), fine grained, well sorted, firmly cemented by calcite; bedding indistinct; forms small ledge	2.5
2. Siltstone, reddish brown (10R 4/4), bedding indistinct; poorly exposed; forms recess	3.5
Total of Judd Hollow Tongue. Approximate thickness	52.5

Note: The Carmel-Navajo contact is mostly concealed. It appears generally conformable, but perhaps slightly disturbed by bedding plane slips.

	Thickness Feet
Jurassic and Triassic(?)	
Navajo Sandstone, main body (not measured):	
1. Sandstone, white (N 9) weathers same to grayish orange (10YR 7/4), fine to very fine grained, moderately well to well sorted, firmly cemented; very few accessory grains; thick wedging sets of large-scale crossbeds. Forms main part of the monocline west of Cottonwood Creek in this area----------	>300.0
Total of incomplete Navajo Sandstone (including Thousand Pockets Tongue----------	>300.0

PARIA BOX section (93)

[T. 41 S., R. 1 W., sec. 20, center; where the Paria River cuts the hogback formed by the East Kaibab monocline; measured on the north side of the canyon in the west, hanging-wall block of Navajo Sandstone. This block, which appears to expose a complete section of Navajo, Judd Hollow, and Thousand Pockets, is in contact with the main mass of the Carmel Formation along a steep west-dipping fault. Beds on both sides of the fault dip approximately 50° E.; drag is evident locally in the Carmel beds on the footwall side of the fault. On the south side of the canyon where R. C. Moore measured his section (Gregory and Moore, 1931, p. 86); this fault omits the Judd Hollow Tongue, and probably the Thousand Pockets Tongue measured by J. C. Wright and R. P. Snyder, May 27, 1959]

	Thickness Feet
Middle Jurassic	
Navajo Sandstone:	
Thousand Pockets Tongue:	
11. Sandstone, white (N 9) weathers grayish orange (10YR 7/4), very fine to fine grained, moderately well sorted; contains abundant well-rounded, gray frosted, medium grains of quartz; contains sparse black opaque accessory grains; bedding almost completely obliterated by faulting, fracturing, and drag. Total thickness cannot be measured because of deformation. Approximately-----	100.0
Total of Thousand Pockets Tongue. Appoximately	100.0

	Thickness Feet
Carmel Formation:	
Judd Hollow Tongue:	
10. Siltstone, moderate reddish brown (10R 4/6); thin to very thin planar beds, slightly irregular, ripple marked; forms recess. Upper contact deformed by small-scale faulting; total thickness may be as much as 20 ft----------	12.0
9. Limestone, silty and gypsiferous, yellowish gray (5Y 7/4); some beds contain as much as 30 percent gypsum in disseminated 1-4 mm crystals; possibly some oolites; thin flat beds; forms ledge----------	5.0
8. Covered; mostly siltstone, like unit 6----------	2.5
7. Poorly exposed; claystone, greenish gray (5GY 6/1)------	2.5
6. Poorly exposed; siltstone, moderate reddish brown (10R 4/6) to grayish red purple (5RP 4/2); moderately well to poorly sorted; forms recess------	3.0
5. Limestone, silty, very light gray (N 8), weathers dark yellowish gray (5Y 6/2); thin laminations with ripple marks. Forms a massive blocky-jointed ledge-	3.5
4. Siltstone, probably dolomitic, light gray (N 7) to pale purple (5P 6/2); compact, dense, weathers like a limestone, but reacts only feebly with dilute hydrochloric acid. Grades into unit 5----------	5.5

	Thickness Feet
Carmel Formation--Continued	
Judd Hollow Tongue--Continued	
3. Sandstone, dark grayish orange (10YR 6/4), weathers same, fine to medium grained, well sorted, firmly cemented with calcite; massive beds, possibly with very indistinct internal ripple laminations; forms ledge----------	2.0
2. Poorly exposed; mostly siltstone, sandy, moderate reddish brown (10R 4/6); forms recess----------	4.0
Total of Judd Hollow Tongue----------	40.0
Total of Carmel Formation----------	40.0

Note: The Carmel-Navajo contact is a smooth, beveled surface truncating cross-strata.

Jurassic and Triassic(?)

Navajo Sandstone, main body (not measured):

1. Sandstone, white (N 9), weathers very pale orange (10YR 8/2), fine grained, well sorted, firmly cemented; bedding indistinct, because of tectonic deformation, large-scale cross-strata----------	>300.0
Total of Navajo Sandstone (including Thousand Pockets Tongue)----------	>400.0

CAVE CANYON section (617)

[T. 41 S., R. 9 W., sec. 8, east edge; Navajo Sandstone examined to south edge of section; base of Temple Cap Member is in SE 1/4 of section; Kanarraville unit measured along east fork of Cave Canyon near NE corner of section; upper units of Carmel outcrop just within SE 1/4 of sec. 5; measured by J. C. Wright and R. P. Snyder, May 20, 1960]

Note: Winsor outcrops not visited; present on hills at some distance. Thickness of Co-op unit and Winsor Member estimated (not measured).

	Thickness Feet
Carmel Formation:	
Winsor Member:	
40. Siltstone, light greenish white. Poorly exposed on steep slopes	50.0
39. Siltstone, reddish brown, poorly exposed in friable soil debris	80.0
Estimated total of Winsor Member	130.0
Co-op unit:	
38. Siltstone, limy, greenish gray; weathers to shaly fragments	5.0
37. Siltstone, reddish brown, friable. Poorly exposed	15.0
36. Gypsum, white, pure. Forms crest of hills	10.0
35. Siltstone, greenish gray. Poorly exposed in gypsum debris	15.0

	Thickness Feet
Carmel Formation--Continued	
Co-op unit--Continued	
34. Gypsum, white, pure, massive. Forms ledge. Lenticular; not persistent, but sporadically widespread---------	15.0
Estimated total of Co-op unit----------	60.0
Escalante unit:	
33. Poorly exposed on dissected slopes. Dominantly reddish-brown siltstone with interbeds of sandy, friable greenish white siltstone, and of grayish purple claystone. Measured across 750-ft broad slope, with probably undulating dips, so measurement not precise----------	210.0
Total of Escalante unit----------	210.0
Kanarraville unit:	
32. Limestone, light to medium gray, weathers light yellowish gray, finely oolitic, silty, slightly sandy, massive flat beds, 3-10 in. thick, contains some fossil pelecypods. Forms highest ledges along the limestone benches. Uppermost 6 in. of limestone is vuggy and porous, as though it is the residue from dissolved gypsum----------	7.0

	Thickness Feet
Carmel Formation--Continued	
Kanarraville unit--Continued	
31. Limestone, light gray, weathers light yellow gray, slightly silty and finely oolitic; laminated to thin bedded; contains fossil pelecypods on several beds, but particularly abundantly fossiliferous float seems to come from near middle. Mostly poorly exposed; locally forms small ledges----------	6.0
30. Limestone, light brownish gray, weathers light brown; oolitic; has intraformational cobble conglomerate 3.5 ft above base, and a pebble conglomerate at top; thick flat beds. Very persistent ledge. Both intraformational conglomerates contain numerous fossil pelecypods----------	5.0
29. Limestones, interbedded shales and oolitic limestone, like unit 27. Fossils in oolitic bed just above base. Forms ledge----------	14.0
28. Limestone, medium yellow gray, weathers light yellowish gray, oolitic, massive flat bed. Forms persistent ledge----------	2.0
27. Limestone, like unit 26, with minor interbeds like unit 28----------	8.0

	Thickness Feet
Carmel Formation--Continued	
Kanarraville unit--Continued	
26. Limestone, light gray, weathers light bluish gray, microcrystalline, laminated, weathers to shaly chips. Covered on slopes, but locally exposed along small water-course at head of canyon----------	24.0
25. Limestone, medium light gray, weathers light yellowish gray, oolitic, flat beds about 1 ft thick. Forms ledges----------	3.5
24. Limestone, like unit 21, but laminated; weathers shaly. Poorly exposed on slope----------	19.0
23. Limestone, like unit 21----------	8.0
22. Concealed, local exposures indicate claystone, calcareous, light olive gray; with minor interbeds of limestone like unit 21----------	8.0
21. Limestone, light bluish gray, weathers very light bluish gray, microcrystalline; sparse casts of small pelecypods; thin flat beds; crops out poorly at base of slope----------	10.0
18. Covered----------	34.0
17. Limestone, silty, yellow gray, weathers same; beds 1-3 in. thick. Forms small ledges----------	5.0

	Thickness Feet
Carmel Formation--Continued	
Kanarraville unit--Continued	
16. Limestone, gray, weathers yellow gray, contains oolites (1.0-1.5 mm) and fossil fragments; flat beds 1-3 in. thick. Forms small ledges----------	7.0
15. Covered----------	12.0
14. Limestone, yellowish gray, weathers light yellowish gray; contains oolites about 1 mm in size; upper foot contains broken crinoid columns; planar beds about 6 in. thick. Forms small slightly folded ledge in bed of East Fork, Cave Creek----------	7.0
13. Covered, same as unit 12. Yellow and silty in upper foot. Exposed in cutbank below unit 14----------	5.0
12. Covered, but probably claystone, dark greenish gray, weathering light greenish gray, laminated. Completely concealed beneath thick talus on slopes--	4.0
11. Limestone, light gray, weathers light yellow gray to brown, slightly silty, contains abundant white gypsum blebs up to several millimeters in size, very thin flat beds with small (about 1 in. wave length) ripple marks throughout. Lower 5 ft forms capping ledge of falls, upper 5 ft exposed locally above and behind falls----------	10.0

	Thickness Feet
Carmel Formation--Continued	
Kanarraville unit--Continued	
10. Limestone, light gray, weathers light bluish gray; thin to thick massive beds. Forms cliff or outcrop in recess protected by unit 11----------	3.5
9. Limestone, silty, light yellowish gray, weathers same to very light bluish gray, irregular thin flat beds. Forms cliff or outcrop in recess protected by projecting ledge of unit 11----------	10.0
8. Limestone, silty, light gray, weathers same; lower 4 ft in thick massive beds with irregular, internal lamination; upper 5 ft in even thin beds to laminae; upper foot contains large blebs of white crystalline gypsum. This upper foot of beds has large irregular nest-like ripple marks and is most resistent bed of unit. Whole unit forms ledge at lip of falls----------	9.0
7. Limestone, dolomitic or siliceous, faintly pinkish gray, clayey and silty, fine fragmental texture, with sparse glassy quartz grains and fresh black biotite flakes, massive beds. Forms base of limestone ledge----------	2.0

	Thickness Feet
Carmel Formation--Continued	
Kanarraville unit--Continued	
6. Sandstone, silty, yellow gray, weathers same, very fine grained, abundant calcite cement obscures lithology, irregular disturbed thin flat beds with partings of claystone like that in unit 5------	1.5
5. Claystone, silty, dark red to greenish gray, laminated slightly irregular flat strata. Exposed in recess at waterfall, elsewhere concealed under talus----------	9.5
4. Sandstone, yellowish white, weathers yellow gray, lithologically like unit 3; thin irregular flat beds. Caps Navajo cliffs at waterfalls, but elsewhere concealed under talus----------	2.0
Total of Kanarraville unit----------	236.0
Total of Carmel Formation (estimated)----------	636.0

Note: The Carmel-Navajo contact is a regular truncation plane for about 100 ft where observed at waterfall in Cave Canyon.

	Thickness Feet
Navajo Sandstone:	
Temple Cap Member:	
3. Sandstone, yellow to white, weathers same to light gray; fine to medium grained, well sorted; firmly cemented with calcite; sparse iron-rich opaque accessory grains. Differentially cemented and eroded zones along joints suggest considerable movement of ground water through unit. Nearly tabular but slightly wedging sets, about 30 ft thick, of high-angle large-scale cross-strata; in upper 30 ft, sets are only 8-12 ft thick; near middle of unit is about 6 ft of persistent, thin flat beds and small-scale crossbeds. Unit underlies steep pine-covered walls of upper canyon----------	160.0
2. Sandstone, very silty, bright red, poorly sorted; obscurely flat bedded, some disrupted, slumped, and reworked beds; basal part of unit totally concealed, upper part only locally exposed in a caved stream-bank; can be seen to extend at least 750 ft. Approximately----------	20.0
Total of Temple Cap Member----------	180.0

	Thickness Feet
Jurassic and Triassic(?)	
Navajo Sandstone, main body:	
1. Sandstone, light orange white, weathers light gray, fine grained, moderately well sorted, firmly cemented; contains orange chert and iron-opaque accessory grains; wedging sets more than 50 ft thick of high-angle, very large scale crossbeds. Only uppermost 60 ft observed----------	>60.0
Total of Navajo Sandstone, main body----------	>60.0
Total of Navajo Sandstone----------	>240.0

CORAL SAND DUNES section (621)

[T. 43 S., R. 8 W., sec. 14, on east face of Block Mesa; measured by J. C. Wright and R. P. Snyder, June 1960]

Note: Top of local exposures. Soil overlying unit 13 weathers to pinnacles suggesting gypsum.

	Thickness Feet
Middle Jurassic	
Carmel Formation (incomplete):	
13. Large float blocks of limestone, light gray, weathers medium bluish gray, probably finely oolitic and finely laminated; top of unit may be eroded---------	4.0
12. Covered, probably claystone, greenish gray, very approximate----------	4.0
11. Limestone, light yellow, very silty----------	5.0
10. Claystone, greenish gray----------	12.0
9. Dolomite, light pinkish gray, fine ripple cross lamination. Breaks as massive ledge----------	6.0
8. Covered; probably mostly reddish brown siltstone-------	3.0
7. Sandstone, dark grayish red, cemented by hematite, tabular set of crossbeds----------	5.0
6. Covered, probably much reddish-brown siltstone---------	60.0
5. Sandstone, white to orange, low-angle medium-scale crossbeds; Navajo like----------	14.0

CORAL SAND DUNE section--Continued

	Thickness Feet
Carmel Formation (incomplete)--Continued	
4. Concealed; mostly siltstone, reddish brown, contains several 1-3 ft thick sandstone beds particularly one 43 ft above base, purple clayey siltstone (1 ft) about 6 ft above base----------	56.0
3. Sandstone, like Navajo, planar beds----------	3.0
Total of incomplete Carmel Formation----------	172.0
Jurassic and Triassic(?)	
Navajo Sandstone:	
2. Sandstone, sets of crossbeds 10-20 ft thick, base is horizontal truncation plane----------	20.0
1. Sandstone, sets of crossbeds greater than 50 ft thick. No horizontal truncation planes seen----------	>150.0
Total of Navajo Sandstone----------	>170.0

CORAL SAND DUNES supplementary section (621A)

[T. 43 S., R. 8 W., sec. 12, on east face of Block Mesa. Measured to describe locality from which biotitic altered tuff (unit 5) was collected for potassium-argon analysis]

	Thickness Feet
Middle Jurassic	
Carmel Formation, basal part:	
7. Dolomite, light yellowish white, weathers same, silty, massive flat beds. Caps exposures----------	2.0
6. Siltstone, light yellow, weathers yellow white, limy or dolomitic, faintly stained on some bedding planes by green copper carbonate, thin flat beds, very poorly exposed----------	2.0
5. Claystone, pure, with common biotite flakes 0.1-1 mm in size, purple, dusky red, and deep green----------	3.0
4. Gypsum, partly silicified, stained green, copper(?), on top upper surface has odd crystal forms. Bed is quite widespread, but lenticular and locally absent----------	0.5
3. Claystone, reddish brown, slightly silty, thinly laminated, poorly exposed on bench above Navajo cliffs----------	3.0

CORAL SAND DUNE supplementary section--Continued

	Thickness Feet
Carmel Formation, basal part--Continued	
2. Sandstone, white, weathers light orange to gray, fine and medium grained, well sorted, moderately well cemented with calcite, irregular flat beds. Caps Navajo cliffs----------	5.5
Total of incomplete Carmel Formation----------	16.0

Jurassic and Triassic(?)

Navajo Sandstone:	
1. Sandstone, yellowish white to light orange, weathers orange to gray, fine to medium grained, well sorted, contains some accessory white chert or feldspar, poorly cemented with calcite; wedging sets 10-20 ft thick of large-scale cross-strata. Forms low cliffs in which there are alcoves protected by overlying sandstone ledge----------	>100.0
Total of Navajo Sandstone----------	>100.0

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