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STRATIGRAPHIC SECTIONS IN SOUTHWESTERN UTAH AND NORTHWESTERN ARIZONA.

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INTRODUCTION.

The stratigraphic data contained in this paper were gathered in the autumn of 1919 during the course of a reconnaissance of part of Washington County, Utah, and Mohave County, Ariz., made chiefly to procure information as to the possibility of the occurrence of petroleum in that region. As very few detailed data on the stratigraphy of the region are available in published literature and also as the stratigraphy of the region has features of general interest it has seemed worth while to record our observations, though they are somewhat scattered.

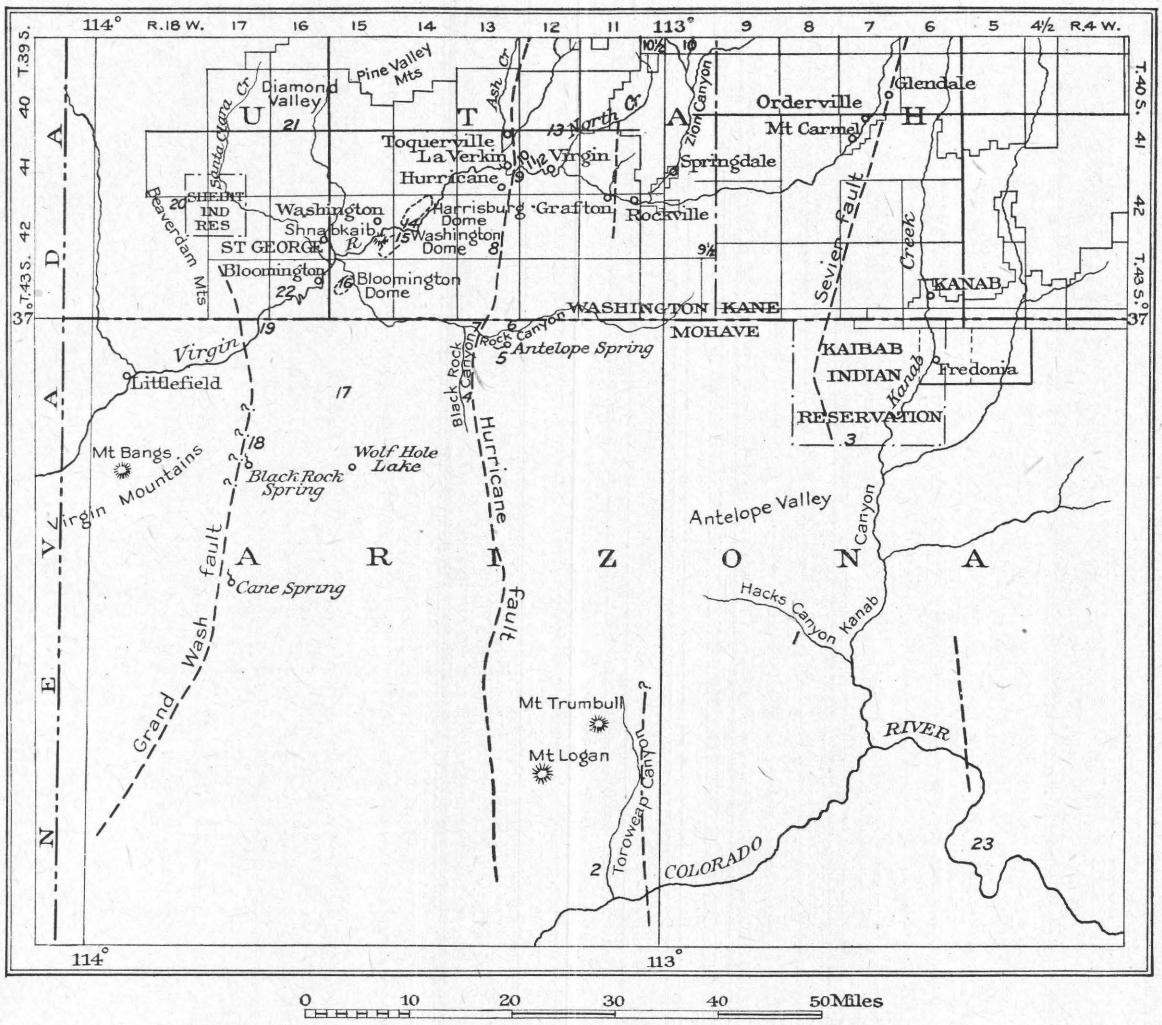


FIGURE 10.—Map showing localities where sections were measured in Washington County, Utah, and Mohave County, Ariz.

Washington County lies in the extreme southwest corner of Utah, and Mohave County in the extreme northwest corner of Arizona. The region is part of the Colorado River drainage basin—in fact, it might be considered to be within the northern confines of the Grand

Canyon district. It contains deeply dissected areas in which the rocks are well exposed. The climate is arid, but farming by irrigation is very successful. Along Virgin River and its few perennial tributaries settlements are fairly numerous, but away from the streams there are none. St. George, the largest town in the region and the seat of Washington County, has about 2,000 inhabitants. Other smaller settlements are shown on the map (fig. 10).

STRUCTURE.

The dominating structural features of the region are the north-south faults of the Great Basin system. The famous Hurricane fault crosses it (see fig. 10) and, it is believed, the Grand Wash fault also. Other unnamed minor faults are present. One prominent fold, known as the Virgin anticline, extends northeastward from the district a few miles south of St. George almost to the Hurricane fault—a distance of approximately 15 miles. On this anticline cross folds have formed three domes known as the Harrisburg dome, Washington dome, and Bloomington dome. Other minor folds occur here and there but are relatively unimportant elements in the general structure of the region.

STRATIGRAPHY.

GENERAL SECTION.

The rocks of the region are classified in this paper as follows:

Geologic formations of southwestern Utah and northwestern Arizona.

System.	Series.	Formation.	Member.	Character of rocks.	Thickness (feet).
Quaternary.				Alluvium, dune sand, etc.	
Tertiary(?).				Basalt flows with associated boulder beds and cinder cones.	
				Massive yellow sandstone with some pink staining, separated by soft sandstone, much of it red, and red shale. The series as a whole is pink.	1,500+
Cretaceous(?).				Buff sandstones with some intercalated shale.	1,000±
				Variegated shale, with a little thin limestone in upper part and some platy limestone in lower part.	140
Jurassic.				Greenish-gray, cream-colored, and brown fossiliferous marine limestone, underlain by brick-red sandstone, shale, and gypsum.	460±
				Massive cross-bedded sandstone, red in lower part and white above, the boundary between the colored parts varying in position from a level near the middle to the top.	2,100

Geologic formations of southwestern Utah and northwestern Arizona—Continued.

System.	Series.	Formation.	Member.	Character of rocks.	Thickness (feet).
Triassic.	Upper Triassic.	Chinle formation.		Brick-red to deep-red shale and sandstone.	200
				Massive medium-grained mauve sandstone, cross-bedded and ripple-marked.	90
				Brick-red sandstone and shale.	420
				Variable coarse arkosic cross-bedded sandstone, banded with gray, white, and mauve and containing fossil wood. Locally known as the "Silver Reef sandstone."	25
				Variegated "gumbo" clay shale, bluish gray, greenish gray, mauve, red, and rarely brown; contains fossil wood.	260
	Upper Triassic(?).	Shinarump conglomerate.		At top 20 feet of gray platy sandstone, underlain by 20 feet of gray and green shale with some fossil wood; at base 75 feet of brown sandstone, with lines and lenses of pebbles of chert, quartz, silicified wood, and rarely igneous rock; fossil logs abundant.	115
	Lower Triassic.	Moenkopi formation.		Brick-red to deep-red and brown shale and sandstone; upper part very dark; locally contains massive beds of yellow medium-grained sandstone.	475±
			Shnabkaib shale member.	Gray to white sandy shale and soft sandstone, with some pink layers and much gypsum.	360–630
				Red beds similar to those underlying the Virgin limestone member.	435±
			Virgin limestone member.	Three layers of earthy yellow limestone separated by yellow and red calcareous shale.	11–160
				Red to brown shale and sandstone, with soft tan sandstone near base and layers, streaks, and veinlets of gypsum throughout.	360±
			Rock Canyon conglomeratic member.	Variable assemblage of shale, limestone, gypsum, conglomerate, and a minor amount of sandstone.	0–288

Geologic formations of southwestern Utah and northwestern Arizona—Continued.

System.	Series.	Formation.	Member.	Character of rocks.	Thickness (feet).
Carboniferous.	Permian.	Kaibab limestone.	Harrisburg gypsiferous member.	Gypsum, shale, and limestone, with platy chert. Locally the "*Bellerophon* limestone" at top.	0–280±
				Massive cliff-forming cherty gray limestone, with locally a thick limestone breccia in lower part.	185–455
				Soft beds resembling basal member.	80–285
				Massive gray limestone with much chert.	150–230
				Gypsum, gray and yellow shale, soft gray sandstone, and some thin-bedded dark-drab limestone.	0–100
	Permian (?).	Coconino sandstone.		Deep-yellow to buff sandstone at top locally; massive white friable sandstone in middle; pale-yellow sandstone below.	90±
	Pennsylvanian (?).	Supai formation.		Brick-red sandstone and shale in the southeastern part of the region, changing northwestward into a yellow massive sandstone with only patches of pink color.	1,300–1,500
	Pennsylvanian.	Redwall limestone.		Dense siliceous gray limestone, with some sandstone layers; mostly heavy bedded; light gray on fresh surface, dark gray and brown on weathered surface.	1,500±
	Mississippian.				

As the field work dealt chiefly with the formations between the Redwall limestone and the Shinarump conglomerate the larger part of this paper pertains to them. The fossils collected all came from the Kaibab limestone and from the Rock Canyon conglomeratic member and Virgin limestone member of the Moenkopi formation. They were submitted to G. H. Girty for examination, and the identifications supplied by him, as well as a statement of their bearing on the stratigraphy, are included in the appropriate places.

REDWALL LIMESTONE.

The Redwall limestone was seen in the Virgin River narrows (section 19, p. 75) below St. George, where more than 500 feet of it is exposed east of a fault on the east side of Heber Valley. It is a dense siliceous gray limestone with some sandstone layers, mostly heavy-bedded, light gray on the fresh surface and red-brown and dark gray on the weathered surface. About 200 feet beneath the top there is a thin-bedded, very dark gray, highly silicified limestone layer 20 feet thick. This rock has been thought by the residents of the region to contain petroleum, but it does not respond favorably to any tests. A few fragmentary fossils were seen but none collected. The correlation with the Redwall limestone of the Grand Canyon district is made on stratigraphic position and lithology.

The limestone was examined again at a locality 2 miles north of the Apex copper mine and about 20 miles west of St. George (section 20, p. 76), near the pass where the Arrowhead Trail to Los Angeles cuts through the Beaverdam Mountains. In this locality the upper

part of the formation has been altered locally by mineralizing solutions and bears deposits of copper of commercial value.[1] Below this soft, porous altered zone the beds consist of hard limestone apparently somewhat less massive and less silicified than the beds in the Virgin River narrows, with a few rather heavy beds of calcareous sandstone near the top that are very similar to the beds of calcareous sandstone and arenaceous limestone seen at the top of the Redwall limestone on the rim of the Grand Canyon at the mouth of Toroweap Valley. The thickness was not determined but is more than 1,500 feet.

Longwell[2] divided the limestones beneath the Supai sandstone in the Muddy Mountains of Nevada into three formations. The uppermost, the Callville limestone, contains Pennsylvanian fossils and may in part represent what is here called Redwall limestone.

SUPAI FORMATION AND COCONINO SANDSTONE.

The names Supai formation and Coconino sandstone were applied by Darton[3] to parts of the "Aubrey sandstone" of the earlier students of the region. In the Shinumo quadrangle, Ariz.[4] (see fig. 10, locality 23), the Supai formation consists of hard fine-grained cross-bedded red sandstone with interbedded red shale and, in the lower 100 feet, interbedded limestone, the whole series 850 feet thick, overlain by soft red shaly sandstone and red shale 400 feet thick, a total thickness of 1,250 feet for the formation. It is locally as much as 1,400 feet thick. The Supai formation is overlain by the Coconino sandstone, a massive buff to creamy-white sandstone, very fine and even grained and apparently in a single bed 250 to 350 feet thick.

In Kanab and Hacks canyons (section 1, p. 69) the Supai formation is composed entirely of brick-red sandstone and shale more than 1,100 feet thick. In the upper part of Hacks Canyon the Coconino sandstone consists of a massive white friable saccharoidal sandstone with a deep-yellow to buff sandstone above it and a pale-yellow sandstone beneath, the whole formation 90 feet thick. The upper deep-yellow member is present only in the upper part of the canyon, wedging out at a point about 6 miles from the mouth of the canyon on Kanab Creek. In Toroweap Canyon (section 2, p. 69) the Supai formation is all red and 1,300 feet thick, and the Coconino shows an upper deep-yellow layer, a middle whitish layer, and a lower paler-yellow layer, the whole 96 feet thick. In Black Rock Canyon (section 4, p. 70) the Coconino and Supai were not differentiated, but an exposure of 1,200 feet contains mainly yellow beds separated in the interval from 200 to 500 feet beneath the top by soft brick-red sandstones. At the mouth of Rock Canyon (section 7, p. 71) an exposure of 500 feet of sandstone shows mingled red and yellow beds except for the upper 17 feet, which contains the apparent equivalent of the Coconino—an upper deep-yellow bed, a middle white bed, and a lower yellow bed. At the locality 6 miles south of Hurricane (section 8, p. 71; Pl. IX, *A*, *B*) an exposure of 250 feet of sandstone is mostly yellow, but the upper 65 feet contains an upper yellow layer 20 feet thick underlain by a white sandstone 45 feet thick, which may represent the Coconino sandstone. In Virgin Narrows (section 19, p. 75) the Supai is a massive sandstone 1,450 feet thick with considerable irregular red staining in the middle part. The color of the staining is not a deep red and at many points is really a pink. The 45 feet of beds above this unit consist of an upper deep-yellow sandstone, a middle white sandstone, and a lower cream-colored sandstone and probably represent the Coconino sandstone. In the section on the Arrowhead Trail through the Beaverdam Mountains (section 20, p. 76) the Coconino and Supai are represented by a very massive sandstone 1,400 feet thick that is predominantly of a pale-yellow color with local pinkish patches. In brief, the red shale and sandstone of the typical Supai formation and the typical white Coconino sandstone gradually change toward the northwest into a massive yellow sandstone with no real red and only a little pink coloring. The total thickness of sandstone seems to vary but little in the sections examined, though the apparent equivalent of the Coconino sandstone thins steadily.

Longwell's work [5] in the Muddy Mountains of Nevada and the Virgin Mountains of Arizona

[1] Butler, B. S., and others, Ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, pp. 595–597, 1920.

[2] Longwell, C. R., Geology of the Muddy Mountains, Nev., with a section to the Grand Wash Cliffs in western Arizona: Am. Jour. Sci., 5th ser., vol. 1, p. 46, 1921.

[3] Darton, N. H., A reconnaissance of parts of northwestern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, pp. 25–27, 1910.

[4] Noble, L. F., The Shinumo quadrangle, Grand Canyon district, Ariz.: U. S. Geol. Survey Bull. 549, p. 68, 1914.

[5] Longwell, C. R., op. cit., p. 47.

shows that a change similar to that described above occurs westward from the typical area toward the Muddy Mountains. The Coconino sandstone thins and loses its identity, and the Supai formation changes largely from red to gray.

Nothing was observed to indicate an unconformity beneath or within the Supai formation, though continuous tracing might disclose it.

Schuchert[6] in 1918 called attention to the thinning of the Coconino sandstone northward and northwestward from the typical area, suggesting, however, that the component sands came from that direction.

KAIBAB LIMESTONE.

The "Upper Aubrey" or "Aubrey limestone" of the older literature of southern Utah and northern Arizona was named the Kaibab limestone by Darton,[7] the name Aubrey being retained in its broad sense, as a group term, to include the Supai formation, the Coconino sandstone, and the Kaibab limestone. In the Shinumo quadrangle, Ariz.[8] (see map, fig. 10, No. 23), the Kaibab limestone is 520 feet thick and consists, in descending order, of a cherty gray limestone 75 feet thick, a white crystalline limestone 200 feet thick, a soft calcareous sandstone, locally a conglomerate of soft sandstone pebbles, 20 feet thick, a red and white calcareous sandstone 135 feet thick, a buff crystalline siliceous limestone 40 feet thick, and a calcareous white sandstone 50 feet thick. The 200-foot limestone and the 40-foot limestone form cliffs.

In most of the exposures seen in our work the Kaibab limestone shows a fivefold topographic and lithologic division—(1) a lower soft member consisting of gypsum, gray and yellow shale, soft gray sandstone, and subordinate amounts of thin-bedded dark-drab limestone; (2) a lower cliff-forming member of gray massive limestone with much brown to black concretionary chert; (3) an upper soft member with much the same character as the lower one; (4) an upper massive cliff-forming limestone which is similar to the lower one but contains more chert and which from Bright Angel Creek to southwestern Utah shows tower-like erosion forms along its upper cliff face; (5) a topmost member (Pl. IX, *C*), less resistant than the underlying beds and highly variable in composition and thickness, consisting of shale, gypsum, and limestone. The limestone of the top member is at some places arenaceous, at others partly silicified, at still others filled with masses of light-colored chert that breaks into flat platy fragments; at many places the upper layers contain many small angular fragments of chert. In color it is light gray, yellowish brown, pink, and rarely a sugary white. The sandstone is gray to yellow, calcareous, and locally gypseous—that is, it has a gypsum cement. The shale may be gray, yellow, or rarely red. It is usually gypseous and in some places sandy.

These divisions of the Kaibab limestone vary much in thickness from point to point, and it seems unlikely that exactly the same beds enter into the same divisions at all localities. However, over as long a stretch as that along the Hurricane fault scarp from a point some distance south of Black Rock Canyon to Virgin Canyon—a distance of 25 miles—the lower four divisions are continuously exposed, though varying in thickness from place to place. The uppermost division is present locally but at a distance can not be distinguished from the overlying basal Moenkopi beds.

The lowest division is thin or lacking at several localities but is usually from 75 to 100 feet thick. The lower cliff-forming division ranges from 150 to 230 feet in thickness in the sections examined. The upper slope-forming division ranges from 80 to 285 feet in thickness. The upper cliff-forming division is variable, ranging from 185 to 455 feet. A thick limestone breccia occurs in the lower part of this unit in Virgin Narrows, below St. George (section 19, p. 75).

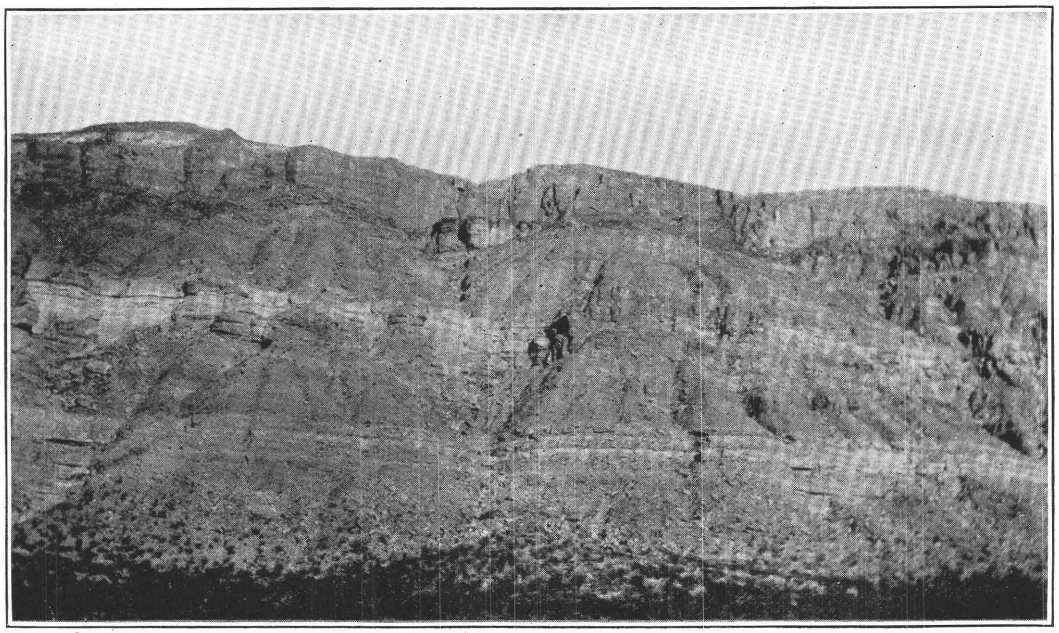
The uppermost member is composed of peculiar and characteristic rocks. It may be recognized, in spite of its variability, wherever it occurs, and as it is a definite unit between the upper cliff-forming limestone of the Kaibab and the basal beds of the Moenkopi formation it is here named the Harrisburg gypsiferous member, from its occurrence in the Harrisburg dome, 8 miles east of St. George. A section measured here (section 14, p. 73) shows a thickness of 280 feet. This member may be absent from some of the sections examined, but in others it reaches a thickness of nearly 300 feet. It is apparently the same unit as that designated "Super-Aubrey beds" by Huntington and Goldthwait.[9] The uppermost limestone

[6] Schuchert, Charles, On the Carboniferous of the Grand Canyon of Arizona: Am. Jour. Sci., 4th ser., vol. 45, pp. 347–369, 1918.

[7] Darton, N. H., A reconnaissance of parts of northwestern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, p. 28, 1910.

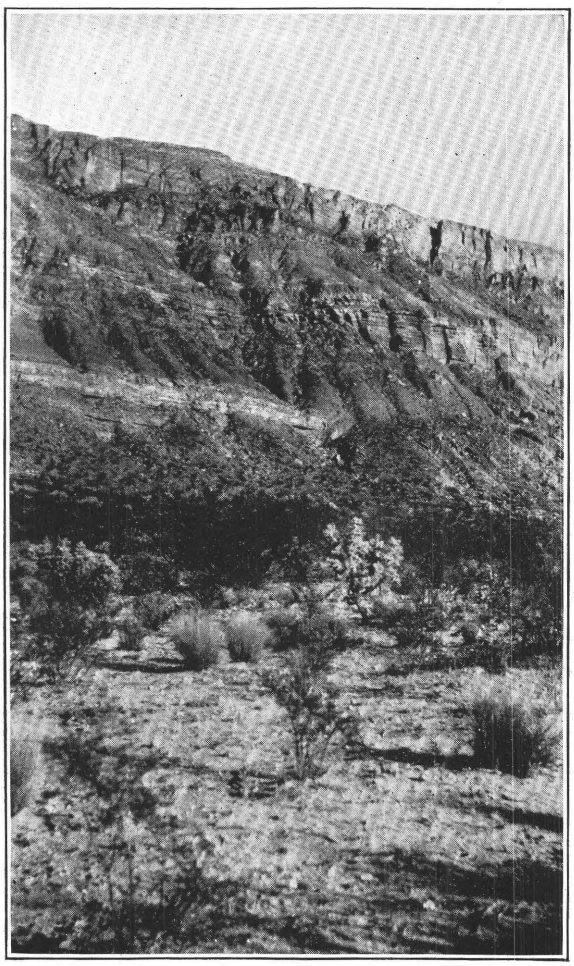
[8] Noble, L. F., The Shinumo quadrangle, Grand Canyon district, Ariz.: U. S. Geol. Survey Bull. 549, p. 70, 1914.

[9] Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Harvard Coll. Mus. Comp. Zool. Bull., vol. 42, p. 203, 1904.

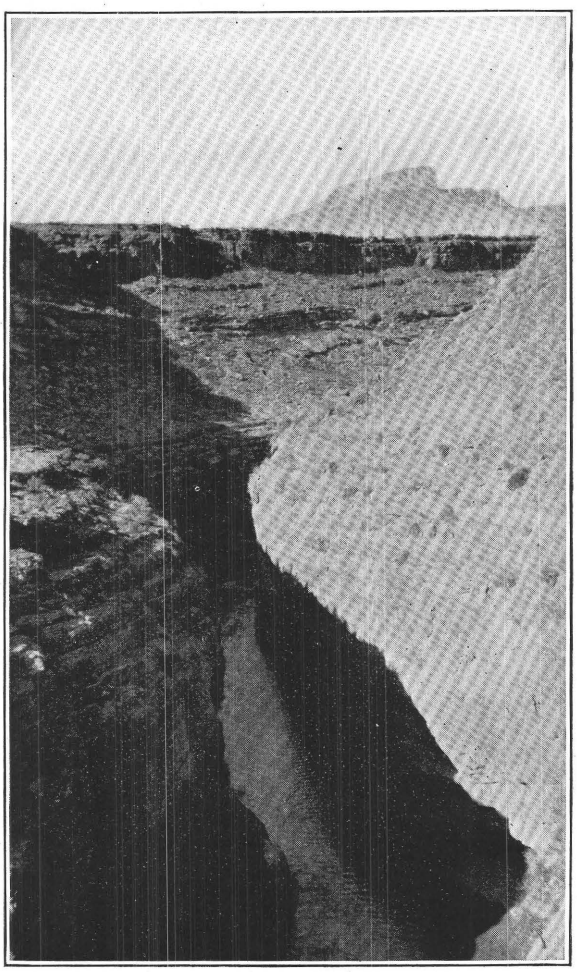


A. COCONINO SANDSTONE AND KAIBAB LIMESTONE IN HURRICANE FAULT SCARP, 6 MILES SOUTH OF HURRICANE, UTAH.

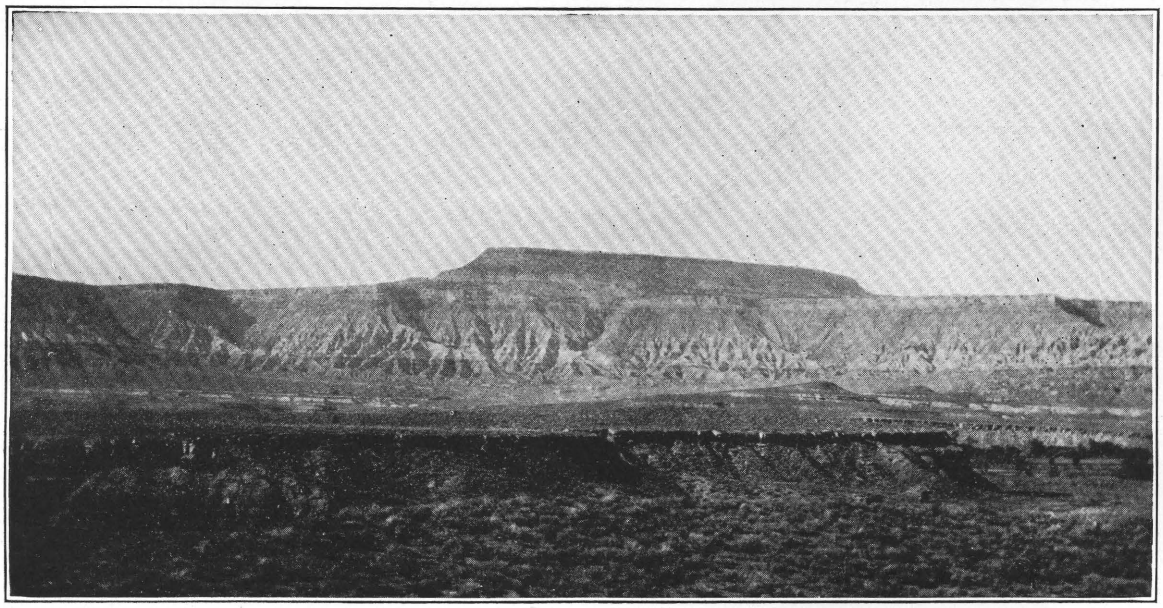
The Supai formation may be represented at the base.



B. CLOSER VIEW OF MIDDLE PART OF SCARP SHOWN IN *A*.

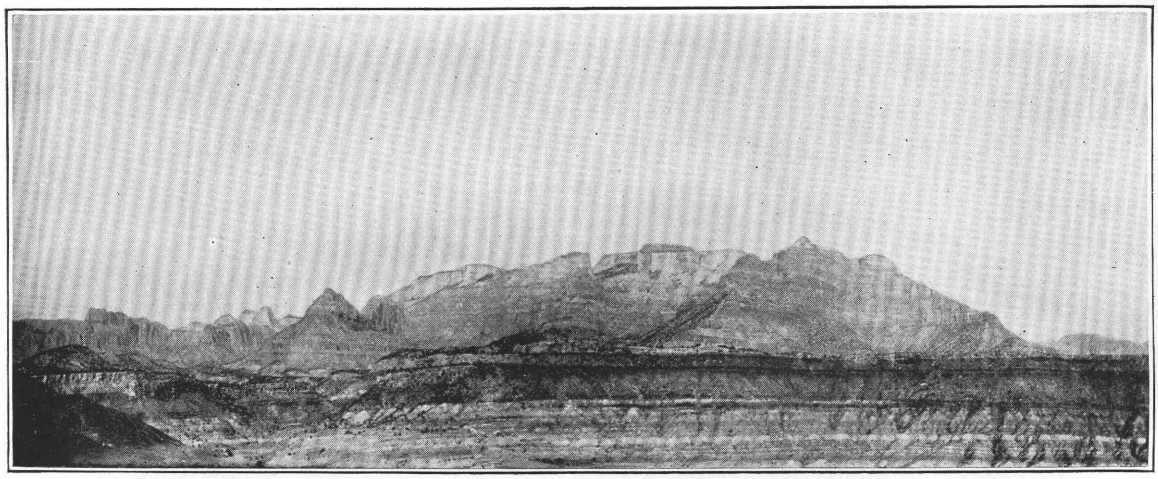


C. UPPER PART OF KAIBAB LIMESTONE AND BASAL MEMBER (ROCK CANYON) OF MOENKOPI FORMATION IN VIRGIN CANYON, 1½ MILES WEST OF VIRGIN CITY, UTAH.



A. VIEW NORTHWARD TOWARD SMITH'S MESA FROM A POINT JUST SOUTH OF VIRGIN CITY, UTAH.

Benches in foreground are the Virgin limestone member of the Moenkopi formation. Cliffs in background are the Moenkopi formation capped by the Shinarump conglomerate and supporting an outlier of the Chinle formation. The white Shnabkaib shale member of the Moenkopi forms a conspicuous band.



B. PANORAMA ALONG EAST SIDE OF COALPITS WASH, NEAR GRAFTON, UTAH.

The Shnabkaib member of the Moenkopi formation forms the foreground, with the upper dark-red member of the Moenkopi and the Shinarump conglomerate above it. This is followed by the Chinle formation and the massive red and white burassic sandstone, which forms the West Temple of the Virgin (Steamboat Mountain) in the background.

beds locally contain an abundance of a species of *Bellerophon* and are the "*Bellerophon* limestone" of some of the earlier geologists.

The Kaibab limestone of our area, as is shown in the data here presented, differs from that of the typical area in the absence of definite large sandstone units. This difference is apparent even in Hacks Canyon and Toroweap Valley. The upper cherty limestone of the Shinumo section (see p. 58) is comparable to our Harrisburg gypsiferous member, the 200-foot limestone to our upper cliff-forming member, the next lower 155 feet to our upper slope-forming member, the next lower 400 feet to our lower cliff-forming member, and the thin lower sandstone to our lower slope-forming member.

Longwell[10] found in the Muddy Mountains of Nevada that the Kaibab limestone contained four divisions much like our four lowest members described above. The Harrisburg gypsiferous member, if present, is placed in his Moenkopi formation. The thickness ranges from 400 to 700 feet.

In tabular form the thickness of the several units in our sections may be stated thus:

Thickness of members of the Kaibab limestone, in feet.

Section.[a]	Harrisburg gypsiferous member.	Upper limestone member.	Upper slope-forming member.	Lower limestone member.	Lower slope-forming member.	Total Kaibab limestone.
1	190	315	125	180	20	830
2	190	185	175	225	(?)	775
4	.....	.....	225	195	147	.....
5	160	40+	.....	.....	.....	.....
6	0?	400	.....	.....	.....	.....
7	0?	400	225	215	108	948
8	160?	260	200	230	80	930
9	150	280	100	200+	.....	.....
10	0?	.....	.....	.....	.....	.....
11	0?	.....	.....	.....	.....	.....
14	280±	(?)	(?)	(?)	(?)	1,059
15	0?	.....	.....	.....	.....	.....
16	272	115+	.....	.....	.....	.....
17	259?	315	285	150+	.....	.....
18	110	250+	.....	.....	.....	.....
19	137	455	80	220	65	957
20	184?	195	260	170	115	924
23	75	200	155	40	20	490

[a] Numbers refer to detailed sections given on pp. 69–77, except No. 23, which is the section in the typical area in the Shinumo quadrangle, and to localities shown on the map (fig. 10).

[10] Longwell, C. R., Geology of the Muddy Mountains, Nev., with a section to the Grand Wash Cliffs in western Arizona: Am. Jour. Sci. 5th ser., vol. 1, p. 48, 1921.

MOENKOPI FORMATION.

The name Moenkopi formation was applied by Ward[11] to the beds known in the older literature as the lower division of the "Shinarump group," bounded below by Carboniferous limestone and above by the Shinarump conglomerate. A generalized section compiled by Gregory[12] from Ward's descriptions gives a thickness of about 700 feet, composed of saliferous and gypsiferous chocolate-brown shale and sandstone in the upper 500 feet, underlain by 100 feet of white calcareous shales, underlain in turn by 100 feet of brown shale. Ward mentions a discontinuous bed of white impure limestone in the calcareous unit. Gregory gives also an accurate section to serve as a type section, measured on Little Colorado River 5 miles below Tanner's Crossing and showing a thickness of 389 feet, mainly red and brown gypsiferous shale and sandstone, with unconformities at the top and bottom. Some conglomerate also is present. In eastern Arizona Gregory found a massive sandstone formation, the De Chelly sandstone, appearing between the ordinary Moenkopi red beds and the Shinarump conglomerate.

Shimer[13] traced the Moenkopi formation from the type locality to Hurricane, Utah, and found it, though variable in composition, to extend over the entire area as a series of "thin-bedded red shales and sandstones, separated at usually rare intervals by limestone lenses."

In the area reconnoitered by us the beds that lie between the Carboniferous limestone and the Shinarump conglomerate and are referred to the Moenkopi formation are much thicker than at the typical locality. They may be grouped into five persistent lithologic units, with another discontinuous one at the base of the formation. The persistent units are (1) lower red beds, consisting of red to brown shale and sandstone with soft tan sandstone near the base and gypsum throughout in layers, streaks, and veinlets; (2) a limestone member consisting normally of three layers of yellow earthy limestone separated by yellow and red calcareous shale and carrying abundant

[11] Ward, L. F., Status of the Mesozoic floras of the United States: U. S. Geol. Survey Mon. 48, pt. 1, pp. 18–19, 1905.

[12] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, p. 23, 1917.

[13] Shimer, H. W., Permo-Triassic of northwestern Arizona: Geol. Soc. America Bull., vol. 30, pp. 493–494, 1919.

marine fossils, chiefly pelecypods; (3) middle red beds, much like the lowest unit but purer red in color; (4) gray to white sandy shale and soft sandstone, with some pink layers and much gypsum, presenting a marked banded unit in cliff faces; (5) upper red beds, consisting of brick-red to deep-red and brown shale and sandstone, color in upper part very dark, locally containing massive beds of yellow medium-grained sandstone. The writers propose the name Virgin limestone member for the second unit above the basal conglomerate member of the formation, from Virgin City, where the unit is splendidly exposed. For the white banded sandy shale unit the name Shnabkaib shale member is proposed, from the striking isolated mesa which lies 2 miles southwest of the town of Washington, on the northwest flank of the Washington dome, and which is still known by its old Indian name.[14] (See Pl. X.) Section 13 (p. 73), measured near Virgin City, and section 14 (p. 73), measured 2 miles east of Shnabkaib, show the thickness and relation of these units to the whole formation.

The basal discontinuous unit is an exceedingly variable assemblage of shale, limestone, gypsum, conglomerate, and a minor amount of sandstone. To this unit we have given the name Rock Canyon conglomeratic member, from Rock Canyon, 5 miles north of Antelope Spring, Ariz. A detailed section at this locality is given on page 70 (section 6). The limestone is gray to pink, is usually coarse, and contains chert fragments. The shale may be gray, yellow, or red. The conglomerate is made up of limestone and chert boulders, locally as much as 3 feet in diameter but usally less than a foot, in a limestone cement and occurs in very irregular beds, which may lie at any stratigraphic level in the basal unit. Locally the included limestone fragments are angular and the material is really a breccia, though at most points observed they are rounded or only subangular. Locally this basal member is absent, as the sections show, and the lower red beds rest directly on limestones containing Kaibab fossils. At the head of Rock Canyon a great gash 700 feet wide and 250 feet deep has been cut into the Kaibab and filled with a confused mass of limestone, shale, gypsum, and conglomerate. This mass contains thin veins of asphaltite and zones impregnated with asphaltic material.

Lee [15] found near Cedar City conglomeratic beds 175 feet thick resting unconformably on hard cherty Kaibab limestone and overlain by red shales. About 50 miles farther north, in Beaver Canyon, limestones and shales containing the Virgin limestone fauna rest on a thin conglomerate, and this in turn rests on cherty fossiliferous Kaibab limestone. Longwell [16] found in the Muddy Mountains of Nevada depressions in the top of the Kaibab limestone filled with chert and limestone fragments. These fragmental deposits are the base of the Moenkopi formation.

Two complete sections were measured through the Moenkopi formation. Section 13 (p. 73), measured near Virgin City, shows a total thickness of 1,775 feet, of which 170 feet is the Rock Canyon conglomeratic member, 360 feet the lower red beds, 80 feet the Virgin limestone member, 400 feet the middle red beds, 360 feet the Shnabkaib shale member, and 405 feet the upper red beds. The other complete section (No. 14, p. 73) was measured on the south side of the Harrisburg dome, 8 miles west of Virgin City. Here the total thickness is 2,035 feet, of which 335 feet is assigned to the lower red beds, 160 feet to the Virgin limestone member, 435 feet to the middle red beds, 630 feet to the Shnabkaib shale member, and 475 feet to the upper red beds. The Rock Canyon conglomeratic member seems to be lacking at the Harrisburg dome.

Sections of parts of the formation were measured at several localities. In the Washington dome, just west of the Harrisburg dome (section 15, p. 74), the Rock Canyon conglomeratic unit is 288 feet thick, and the lower red beds are 320 feet thick. In the Bloomington dome (section 16, p. 74), south of St. George, the lower red beds are about 320 feet thick. Near Black Rock Spring (section 18, p. 75) the lower red beds are 180 feet thick. Near Bullrush, 12½ miles southwest of Freedonia, Ariz. (section 3, p. 70), the Virgin limestone member seems to be represented by a calcareous unit 11 feet thick. Farther west, in the neighborhood of Antelope Spring, it

[14] Shnabkaib is said by Dr. J. P. Harrington, of the Bureau of American Ethnology, to be most probably a corruption of shöna'agaiv, from shöna'a, coyote, and gaiv or kaib, rocky hill, or mountain.

[15] Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, p. 362, 1907.

[16] Longwell, C. R., op. cit., p. 49.

forms a conspicuous member of the Moenkopi formation, perhaps 75 feet thick, and may be traced as a series of three marked benches near the base of the red cliffs of softer rock which stand high above the Hurricane fault scarp. West of this fault the Virgin limestone is conspicuous in every exposure of the lower part of the Moenkopi formation. In the Washington dome it is 160 feet thick and locally shows four limestone beds instead of the usual three beds. In the Bloomington dome it is 130 feet thick. Near Black Rock Spring it is 100 feet thick. The Shnabkaib shale member is a marked unit in the upper part of the Moenkopi formation at least as far east as a locality 8 or 10 miles east of Fredonia, Ariz. The Virgin limestone member was not observed here and may be entirely absent. The calcareous unit of Ward's typical section farther east may represent the extension of the Virgin limestone.

The sandstones in the upper red beds are not very conspicuous near Virgin City, but they are present along the Virgin anticline and northwest of St. George; along the Arrowhead Trail to Los Angeles they make up a considerable part of the upper red-bed unit. Though they nowhere stand up in massive cliffs they suggest in their position the De Chelly sandstone of Gregory, which occurs in eastern Arizona between the usual red beds of the Moenkopi formation and the Shinarump conglomerate.

The red sandstones of the Moenkopi are spotted locally with green copper stains that have caused much fruitless prospecting. The upper limestone of the Virgin limestone member at many places contains disseminated lead, zinc, and copper sulphides in small amount.

Huntington and Goldthwait [17] give a section of the Moenkopi formation near Toquerville, about halfway between our two complete sections, in which our units are recognizable but the thicknesses are very different. This section shows, at the base, soft red shales, 170 feet; gray and red shales with three limestone benches, 115 feet; soft red shales, with some harder gray layers, 250 feet; white and red shales, 390 feet; chocolate-colored, gray, and lavender shale and sandstone, 380 feet; total, 1,205 feet. There is no apparent thinning westward from Virgin City to Toquerville, but rather the reverse, and we question the accuracy of this section.

Near Cedar City, Utah, Lee [18] measured sections which show a total thickness of 2,650 feet for the beds here called the Moenkopi formation. They contain a fossiliferous limestone member equivalent to the Virgin limestone member. About 50 miles farther north Lee found the Virgin limestone fauna to persist through a thickness of 350 feet of shale and limestone, overlain by unfossiliferous limestones making a total of at least 600 feet of strata with limestone beds above the fossiliferous Kaibab limestone.

Longwell [19] found that in the Muddy Mountains of Nevada the Moenkopi formation consists of thin-bedded limestones, shale, and sandstone. The thickness ranges from 1,200 to 1,600 feet, of which the lower half is predominantly marine limestone and the upper half continental deposits.

Apparently the red beds of the typical Moenkopi formation pass westward and northwestward into marine limestones. The thin limestone of the typical area is the edge of a wedge which increases to the Virgin limestone member and then to the thicker limestone members found by Lee and Longwell.

Walcott [20] found in Kanab Valley a limestone and shale unit like our lower Moenkopi beds, 198 feet thick, overlain by a shale and sandstone unit 666 feet thick. These beds lie between the "*Bellerophon* limestone" of the Kaibab formation and the Shinarump conglomerate. The limestone in the lower division carries Walcott's "Permian" fauna, now known to be Lower Triassic.

The Moenkopi formation is unconformable on the Kaibab limestone. The basal conglomeratic member of the Moenkopi, the variation in the thickness of the Harrisburg member of the Kaibab limestone, and the presence of a gash cut deep into the massive Kaibab and filled with Moenkopi materials near the head of Rock Canyon show an erosion interval. Evidence of an erosional interval at this horizon

[17] Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Harvard Coll. Mus. Comp. Zool. Bull., vol. 42, p. 203, 1904.

[18] Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, p. 362, 1907.

[19] Longwell, C. R., op. cit., p. 49.

[20] Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Ariz.: Am. Jour. Sci., 3d ser., vol. 20, pp. 221–225, 1880.

has been noted by a number of observers. Powell,[21] Walcott,[22] Dake,[23] Lee,[24] Gregory,[25] Shimer,[26] and Longwell [27] have all cited evidence of its presence over a wide area and of its considerable magnitude.

SHINARUMP CONGLOMERATE.

The Shinarump conglomerate forms a marked stratum throughout northern Arizona and southern Utah. It is thin but resistant and in many places caps mesas or forms prominent benches. (See Pl. X.)

The name was originally given by Powell [28] to the middle member of his "Shinarump group."

In our area only one detailed section was made, that north of Virgin City (section 13, p. 73), where the Shinarump conglomerate was found to consist of three members—(1) at the base a brown sandstone 75 feet thick, with lines and lenses of pebbles of chert, quartz, silicified wood, and rarely of igneous rock and with fossil logs; (2) gray and green shale with some fossil wood, 20 feet thick; and (3) at the top gray platy sandstone with a few pebbles, 20 feet thick. The base of the lower sandstone is irregular and is marked by a discontinuous layer of dark shale. This plane is an evident disconformity, but of what significance it is difficult to say. At the Harrisburg dome (section 14, p. 73) the Shinarump conglomerate is about 100 feet thick and consists of sandstone. It seems to be fairly uniform over most of the area examined, but 15 miles northwest of St. George it is less than 50 feet thick and not as resistant as usual. To the east, on the Kanab-Fredonia road, the conglomerate is 40 feet thick.

The Shinarump locally contains crusts of iron and manganese oxides which are high in manganese but do not occur in sufficient amount to have a commercial value. The fossil logs are locally replaced in part by copper sulphides instead of silica.

CHINLE FORMATION.

The name Chinle formation was given by Gregory [29] to the beds above the Shinarump conglomerate and below the Wingate sandstone. Gregory was able to distinguish four persistent divisions, which are, in ascending order, (1) dark-red, light-red, chocolate-colored, or rarely gray shales (70 per cent) and shaly sandstone (30 per cent), with brown conglomerate of limestone and clay pebbles; (2) shales and "marls" with rare calcareous sandstone, all lenticular, exceedingly friable, red, ash-colored, and purple, with characteristic limestone conglomerate; (3) gray, pink, and purple cherty limestone and light to dark red shale in alternating bands; (4) red, brown, pink, or rarely gray calcareous shales and shaly sandstones, with a few thin bands of limestone and limestone conglomerate. In a composite section given by Gregory division 1 is 203 feet thick; 2, 450 feet; 3, 214 feet; and 4, 315 feet.

In our area only one section of the Chinle formation was measured, though the formation is a prominent member of the stratigraphic series. (See Pl. XI, *A*.) This section (No. 13, p. 73) is near Virgin City and aggregates 995 feet in thickness. No limestones were observed. The basal member consists of 260 feet of variegated, bluish-gray, greenish-gray, mauve, red, and rarely brown "gumbo" clay shale and contains fossil wood. Upon this rests 25 feet of variable coarse arkosic cross-bedded sandstone banded with gray, white, and mauve and containing fossil wood. This sandstone is overlain by 420 feet of brick-red shale and sandstone, forming a slope. Next comes a massive medium-grained cross-bedded ripple-marked cliff-forming mauve sandstone 90 feet thick. Above this sandstone lies about 200 feet of brick-red to deep-red shale and sandstone.

The banded gray, white, and mauve sandstone is locally known as the "Silver Reef sandstone," as it is said to be the zone which in the Silver Reef, near Leeds, Utah, contains the fossil logs impregnated with silver minerals

[21] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains, U. S. Geog. and Geol. Survey Terr., 2d div., 1876.

[22] Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Ariz.: Am. Jour. Sci., 3d ser., vol. 20, pp. 221–225, 1880.

[23] Dake, C. L., The pre-Moenkopi (pre-Permian?) unconformity of the Colorado Plateau: Jour. Geology, vol. 28, pp. 61–74, 1920.

[24] Lee, W. T., General stratigraphic break between Pennsylvanian and Permian in western America [abstract]: Geol. Soc. America Bull., vol. 28, pp. 169–170, 1917.

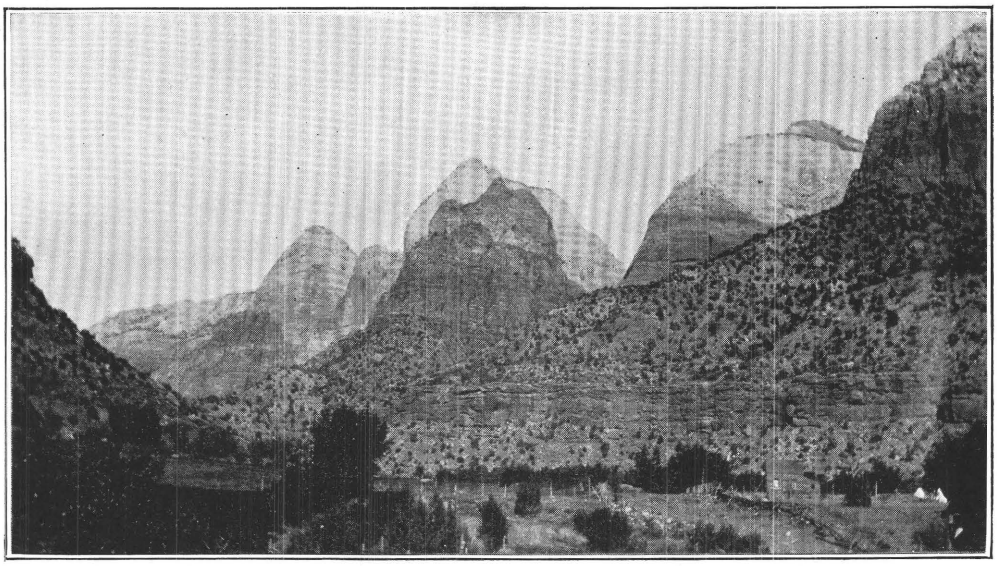
[25] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, p. 30, 1917.

[26] Shimer, H. W., Permo-Triassic of northwestern Arizona: Geol. Soc. America Bull., vol. 30, p. 494, 1919.

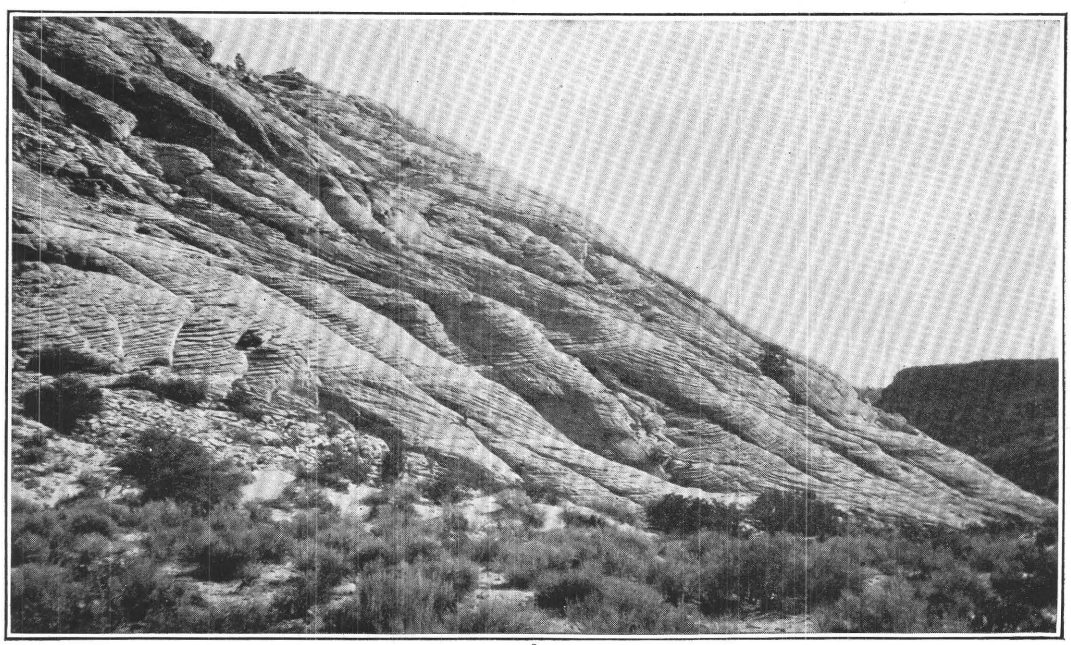
[27] Longwell, C. R., Geology of the Muddy Mountains, Nev., with a section to the Grand Wash Cliffs in western Arizona: Am. Jour. Sci., 5th ser., vol. 1, p. 49, 1921.

[28] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains, pp. 53, 68–69, U. S. Geog. and Geol. Survey Terr., 2d div., 1876.

[29] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, pp. 42–43, 1917.



A. CHINLE FORMATION AND OVERLYING MASSIVE JURASSIC SANDSTONE IN ZION CANYON ABOVE SPRINGDALE, UTAH.



B. CROSS-BEDDING IN WHITE UPPER PART OF MASSIVE JURASSIC SANDSTONE 12 MILES NORTH OF ST. GEORGE, UTAH, ON ST. GEORGE-MODENA ROAD.

that in the eighties supported several flourishing mining enterprises.[30]

The mauve cliff-forming sandstone is the "mauve sandstone" of Huntington and Goldthwait.[31] These authors give the thickness of the Chinle (their "Painted Desert formation") near Toquerville as only 350 feet, though they seem not to have included the beds above the mauve sandstone. Lee[32] observed at a locality near Cedar City, Utah, 520 feet of red shale and sandstone resting upon the Shinarump conglomerate, overlain by 250 feet of massive cross-bedded sandstone, and that in turn by 180 feet of sandstone and red, purple, and gray shale, a total of 950 feet. In a later report[33] Lee placed only the lower 520 feet of this series in the Chinle formation, but the entire 950 feet evidently corresponds to our Chinle formation, which is included between the massive sandstone described below, whose basal part, at least, is probably equivalent to the Wingate sandstone, and the Shinarump conglomerate. Longwell[34] refers to the Chinle formation in Nevada as a variable assemblage of conglomeratic sandstone, finer sandstone, and gypsiferous shale. Its thickness ranges from 800 to 3,000 feet.

Walcott found in Kanab Valley a fossiliferous zone[35] about 900 feet above the Shinarump conglomerate, which seems from the description to be near the top of the Chinle formation, though possibly it is in the base of the overlying sandstone, which is not as massive as it is farther west. The fossils were fish and reptilian teeth, *Estheria*, and a fragment of an ammonite and are said to suggest Jurassic rather than Triassic relationship.

JURASSIC SANDSTONE.

Gregory[36] assigned three formations in eastern Arizona and western New Mexico to the La Plata group—the Wingate sandstone below, the Todilto formation in the middle, and the Navajo sandstone above. The Wingate sandstone is a massive cross-bedded fine-grained cliff-forming dark-red to light-red or orange-red sandstone, in which the cross-bedding is largely tangential and gives rise on weathering to characteristic arches and caves; its thickness ranges from 200 to 500 feet. The Todilto is a very thin formation of calcareous sandstone and limestone, barren of fossils. The Navajo sandstone is tangentially cross-bedded massive yellow to red sandstone with a few thin layers of blue limestone. It is resistant and cliff-forming and usually weathers into domes and rounded forms at the top; its thickness ranges from 100 to more than 1,000 feet. The whole group ranges from perhaps 400 feet to well over 1,000 feet in thickness.

In Washington County, Utah, there lies above the Chinle formation a massive cross-bedded sandstone that is locally all red but in most places red in the lower part and white above, the red portion making up one-half or more of the unit. The lower part characteristically forms arches, and the upper part weathers to rounded pinnacles and domes. (See Pl. XI, *A*, *B*.) Upon this white sandstone rests a series of brick-red sandstone and shale perhaps 200 feet thick. This unit is soft and is conspicuous only where it is left as erosional remnants on the white sandstone. It seems to belong rather to the succeeding unit than to the sandstone. Only one measurement of the thickness of the sandstone was attempted, and that with rather unsatisfactory results. This measurement was made by triangulation from Coalpits Wash, just west of Zion Canyon, on the west side of the West Temple of the Virgin, or, as it is locally known, Steamboat Mountain, and gave a total thickness of 2,100 feet, mostly in sheer wall. There appears here to be no break of any kind in the sandstone wall; not even a single soft layer is observable. Farther east, toward Kanab, Utah, the sandstone is less massive and contains softer layers. To the west, near St. George, Utah, the same is true; in fact there appear to be many softer layers, and the sandstone forms a number of benches. Northwest of St. George, in the valley of Santa Clara Creek, the unit again takes on a massive cliff-forming character and stands in high, sheer walls with the top weathered into rounded

[30] Butler, B. S., and others, Ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, pp. 582-594, 1920.

[31] Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Harvard Coll. Mus. Comp. Zool. Bull., vol. 42, p. 203, 1904.

[32] Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, p. 362, 1907.

[33] Lee, W. T., Early Mesozoic physiography of the southern Rocky Mountains: Smithsonian Misc. Coll., vol. 60, No. 4, p. 22, 1918.

[34] Longwell, C. R., op. cit., p. 51.

[35] Discussed in Cross, Whitman, and Howe, Ernest, Red Beds of southwestern Colorado and their correlation: Geol. Soc. America Bull., vol. 16, pp. 486-487, 1905.

[36] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93 p. 52, 1917.

forms. Here the tangential cross-bedding of the upper white part is a striking feature and resembles that of the Navajo sandstone farther east. The thickness is comparable with that at Zion Canyon.

The white upper part of the sandstone seems to be the White Cliff sandstone, and the red lower part the Vermilion Cliff sandstone of Dutton and other earlier students of the geology of the region. Huntington and Goldthwait [37] called the red part the "Kanab sandstone" and the white part the "Colob sandstone." As the color boundary within a short distance may vary from the middle to the top of the Jurassic sandstone, units based on color alone are hardly tenable in this area.

Lee [38] found on Coal Creek, near Cedar City, two massive sandstones separated by a softer unit that aggregate 1,700 feet in thickness and seem to represent our sandstone unit. Lee [39] later included about 400 feet more of lower beds with these, but the character of the lower beds fits the Chinle formation better, and they should perhaps be assigned to that formation. Lee considered the whole thickness of 2,100 feet to be the equivalent of the Wingate sandstone.

Longwell [40] found in the Muddy Mountains of Nevada a cross-bedded sandstone ranging from 800 to 2,000 feet in thickness, resting upon the Chinle formation. He correlated this unit with the La Plata group.

Whether this Jurassic sandstone of southwestern Utah and adjacent regions represents the entire La Plata group of Gregory may be questioned. It seems to be identical with Emery's Wingate sandstone [41] of the San Rafael Swell region and with the Wingate of Lee's Coal Creek section. Dake [42] believes that it represents the entire La Plata group of Gregory, not merely the typical Wingate, and disputes the interpretation of Emery and Lee.

The Wingate is reported to be unconformable on the Chinle formation at some places. We saw no evidence of this unconformity in the area covered by our work, though close examination was not made at many points.

[37] Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Harvard Coll. Mus. Comp. Zool. Bull., vol. 42, p. 203, 1904.

[38] Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, p. 362, 1907.

[39] Lee, W. T., Early Mesozoic physiography of the southern Rocky Mountains: Smithsonian Misc. Coll., vol. 60, No. 4, p. 22, 1918.

[40] Longwell, C. R., op. cit., p. 51.

[41] Emery, W. B., Green River Desert section: Am. Jour. Sci., 4th ser., vol. 46, pp. 551–577, 1918.

[42] Dake, C. L., The horizon of the marine Jurassic of Utah: Jour. Geology, vol. 27, pp. 634–646, 1919 (1920).

JURASSIC LIMESTONE AND SHALE.

Resting on the thick Jurassic sandstone just discussed lies a series of beds which consist of red shale and sandstone, with some gypsum, in the lower part and greenish-gray, cream-colored, and brown marine fossiliferous limestone in the upper part. The only section of these beds obtained was measured on the east side of Diamond Valley, 15 miles north of St. George, Utah (section 21, p. 77). Here the red shales and sandstone form the floor of the valley between the sandstone and the limestone and are but poorly exposed. Their total thickness is about 160 feet. The patch of red rock on the top of the West Temple of the Virgin (Steamboat Mountain) seems to include this interval but is a little thicker than the beds in Diamond Valley. Above the red shales at Diamond Valley is 300 feet of limestone with some shale and gypsum layers, much of it cream-colored, but some layers, especially in the upper part, brownish, gray, and greenish white. Fossils were observed in a number of layers but were so poorly preserved as not to be worth collecting. However, abundant *Pentacrinus* stem joints, *Trigonia* sp. like *T. americana*, and a small *Ostrea* were recognizable and fix the age as undoubtedly that of the marine Jurassic of the region.

Lee [43] measured near Cedar City 40 feet of red shale and gypsum resting on the massive Jurassic sandstone, then 250 feet of brown earthy limestone which seems to correspond to our beds. Stanton [44] measured near Glendale a section with 8 feet of red shale near the base, overlain by 292 feet of fossiliferous limestone and shale. Dake [45] found near Teasdale 449 feet of gypsiferous limestone and shale above his La Plata group.

We saw no evidence of unconformity in this series, but close examination was made at only one locality.

CRETACEOUS (?) VARIEGATED SHALE.

Above the marine Jurassic limestone occurs a bluish-gray, red, and greenish-gray "gumbo"

Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, p. 362, 1907.

[44] Stanton, T. W., unpublished notes.

[45] Dake, C. L., The horizon of the marine Jurassic of Utah: Jour. Geology, vol. 27, pp. 634–646, 1919 [1920].

shale, with a little thin limestone in the upper part and some platy sandstone in the lower part. At Diamond Valley (section 21, p. 77) it is 140 feet thick. We can not say from the data obtained in the small area examined closely whether this unit is conformable or unconformable on the underlying beds.

Lee [46] noted near Cedar City a similar unit 350 feet thick; Stanton,[47] near Glendale, Utah, the same, 550 feet or more; and Dake,[48] near Teasdale, the same, over 375 feet.

CRETACEOUS (?) SANDSTONE.

Resting upon the variegated shale just described is a series of buff sandstones with some intercalated shale. These are visible at many places along the lower flanks of the Pine Valley Mountains, north of the region covered by our work. A section of these sandstones was made at Diamond Valley. The lower 90 feet of this series is light-gray to brown sandstone, mostly soft but with some hard layers and a little gray and purple shale. This sandstone shows stem imprints and carbonaceous matter. Above it is a thin layer of very dense reddish and blue-gray quartzite, and upon this 30 feet of gray shale and carbonaceous sandstone. Above this lower part comes 750 feet, more or less, of heavy-bedded buff sandstone, of which the lower 300 feet has soft sandstone layers and shale between the harder sandstones, but the upper 450 feet is buff sandstone with one reddish layer. Above the rocks just described, at the point of measurement, wash and basaltic lava conceal the bedrock. No fossils were observed other than the impressions of plant stems mentioned.

Lee [49] found on Coal Creek, near Cedar City, above the shale which rests upon the marine Jurassic limestone an unconformity marked by a conglomerate, followed by 780 feet of variegated shale and gray or light-colored sandstone, upon which rests 125 feet of gray and yellow sandstone, with coal and minor shale layers and carrying Cretaceous fossils. Above these coal-bearing beds in Lee's section is exposed 455 feet of sandstone with a minor amount of shale and limestone and carrying marine Cretaceous fossils. Richardson [50] found in the Colob coal field, not far from the areas examined by Lee, 2,500 feet of buff sandstone and drab shale, with coal in the lower part, all of which he referred to the Colorado group. Beneath it he found 800 feet of varicolored shale and sandstone, gypsum, and marine limestone representing the Cretaceous (?) shale and Jurassic limestone of this paper. Richardson [51] also found in the valley of Virgin River near Mount Carmel a series of beds including, in ascending order, 15 feet of conglomerate, 400 feet of coal-bearing shale and sandstone, 700 feet of shale with marine fossils, and 1,000 feet of alternating sandstone and shale containing marine and brackish-water Colorado fossils near the base. On these beds rests 10 feet of conglomerate, then 700 feet of fresh-water sandstone and shale possibly of Montana age, then another conglomerate, probably Tertiary. Stanton [52] found near Glendale, 6 miles from Mount Carmel, 91 feet of coal-bearing gray sandstone and shale resting on the Cretaceous (?) variegated shale above the marine Jurassic. Upon this coal-bearing unit rests 1,000 feet, more or less, of drab sandy marine shale of Colorado age, and upon this, in the section examined, 280 feet of brown sandstone and shale with Colorado fossils.

TERTIARY (?) SANDSTONE.

Above the buff Cretaceous sandstone series is exposed in the flanks of the Pine Valley Mountains a pink sandstone series. At a point near Diamond Valley, 3 miles south of the locality where the buff sandstone was measured, an exposure of 1,500 feet of these pink sandstones was examined. It consists of massive sandstone beds, yellow with some red staining and separated by soft sandstone, much of it red in color, and red shale. As a mass this series is pink and contrasts sharply with the lower buff sandstone series. So far as could be determined by inspection from a high point several miles away, the base of this exposure is very close to the to pof the Cretaceous (?) sandstone. Intervening outcrops piercing the wash and lava cover aid in judging this, though continuous tracing is impossible.

[46] Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, p. 362, 1907.
[47] Stanton, T. W., unpublished notes.
[48] Dake, C. L., op. cit.
[49] Lee, W. T., The Iron County coal field, Utah: U. S. Geol. Survey Bull. 316, p. 362, 1907.
[50] Richardson, G. B., The Harmony, Colob, and Kanab coal fields, southern Utah: U. S. Geol. Survey Bull. 341, p. 381, 1908.
[51] Richardson, G. B., unpublished notes.
[52] Stanton, T. W., unpublished notes.

TERTIARY (?) AND QUATERNARY ROCKS.

Basaltic flows, apparently of late date, in places little weathered and with only a thin soil cover, occupy considerable areas of the region. Associated with them are local thick boulder beds and here and there cinder cones. (See Pls. XII; XIII, *B*.) At some places large areas of dune sand occur, notably that 8 miles southeast of St. George. Along Virgin River alluvial flats supply land for irrigation farming.

AGE OF THE FORMATIONS.

The Redwall limestone at the locality of its typical occurrence is believed to be in part Mississippian and in part Pennsylvanian. In the Beaverdam Mountains we collected *Marginifera* aff. *M. splendens* (catalog No. 3059) at a horizon 650 to 700 feet beneath the top of the formation, and *Chaetetes milleporaceus* (catalog No. 3061) at a horizon about 1,000 feet beneath the top. G. H. Girty reports both these species to indicate either Pennsylvanian or Permian age. It is therefore probable that at least 1,000 feet of the Redwall limestone, as here conceived, is Pennsylvanian.

The Supai formation, Coconino sandstone, and Kaibab limestone for years were considered to represent the Pennsylvanian. The evidence accumulated from many sources, however, is increasingly in favor of a correlation of all three formations with the Manzano group of New Mexico, now classified as Permian. In this paper the Supai formation and the Coconino sandstone are assigned doubtfully to the Pennsylvanian and the Permian, respectively, as the available evidence of their age is still insufficient to warrant a definite assignment. The Kaibab limestone is placed in the Permian, because it afforded a number of lots of fossils, and although no attempt was made to gather complete collections, those obtained permit correlation with part of the Manzano group. The following combined lists show the determinations made by Mr. Girty:

1. Five collections (catalog Nos. 3054 to 3058) from the "*Bellerophon* limestone" of the Harrisburg gypsiferous member:

Phyllopora? sp.
Dielasma sp.
Nucula levatiformis.
Leda obesa.
Pteria (Bakewellia?) sp.
Pseudomonotis? sp.
Myalina sp.
Schizodus wheeleri.
Aviculipecten? sp.
Pleurophorus mexicanus.
Plagioglypta canna.
Bellerophon majusculus.
Bucanopsis aff. B. bella.
Euphemus sp.
Pleurotomaria sp.
Goniospira sp.
Naticopsis? sp.
Platyceras sp.
Eumophalus sp.
Metacoceras sp.
Nautilus sp.

2. Five collections (catalog Nos. 3047 to 3051) from lower strata of the Harrisburg gypsiferous member:

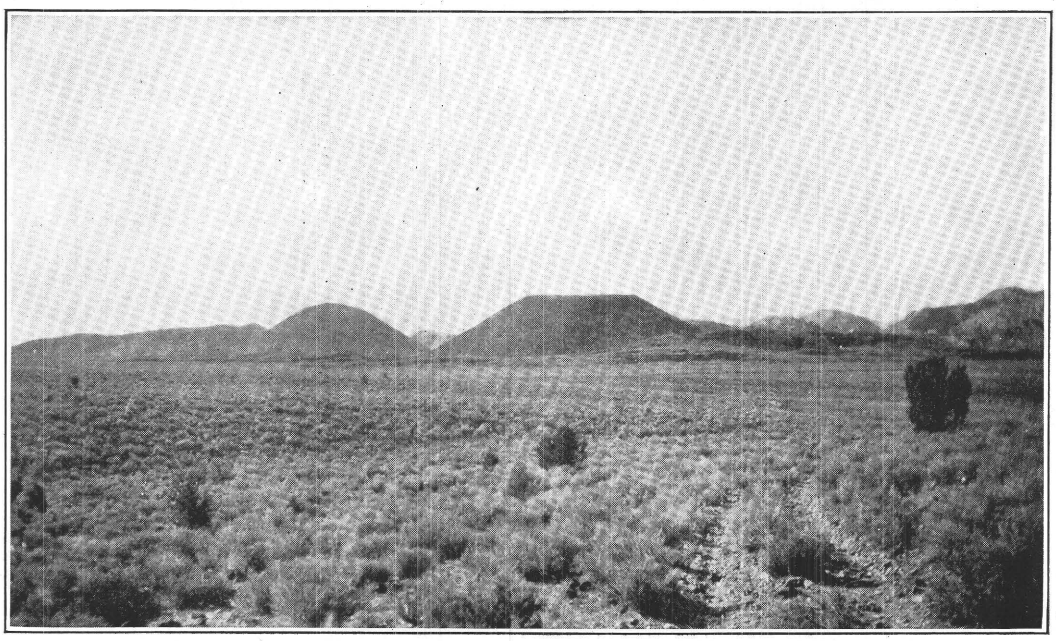
Batostomella n. sp.
Polypora sp.
Phyllopora? sp.
Derbya? sp.
Chonetes hillanus.
Pugnax osagensis var.
Spirifer sp.
Spiriferina sp.
Squamularia guadalupensis.
Composita subtilita.
Composita n. sp.
Myalina aff. M. deltoidea.

3. A single lot (catalog No. 3060) from a coral-bearing limestone near the top of the Harrisburg gypsiferous member in the Harrisburg dome:

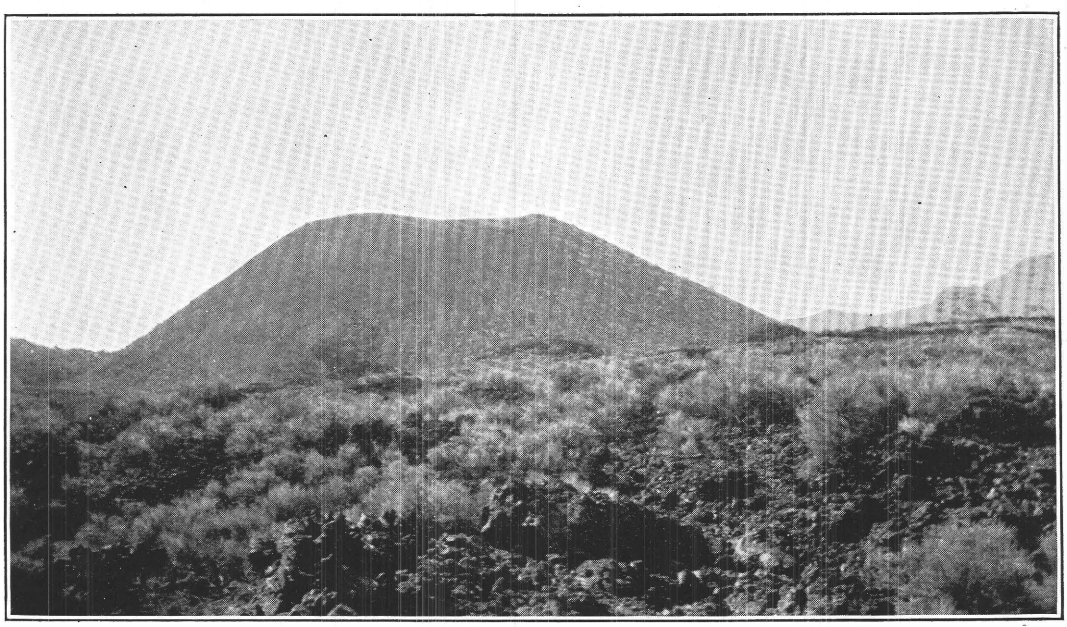
Favosites? n. sp.
Lithostrotion? n. sp.
Campophyllum? n. sp.

4. Eight collections (catalog Nos. 3039 to 3046) from the massive limestone members of the Kaibab limestone:

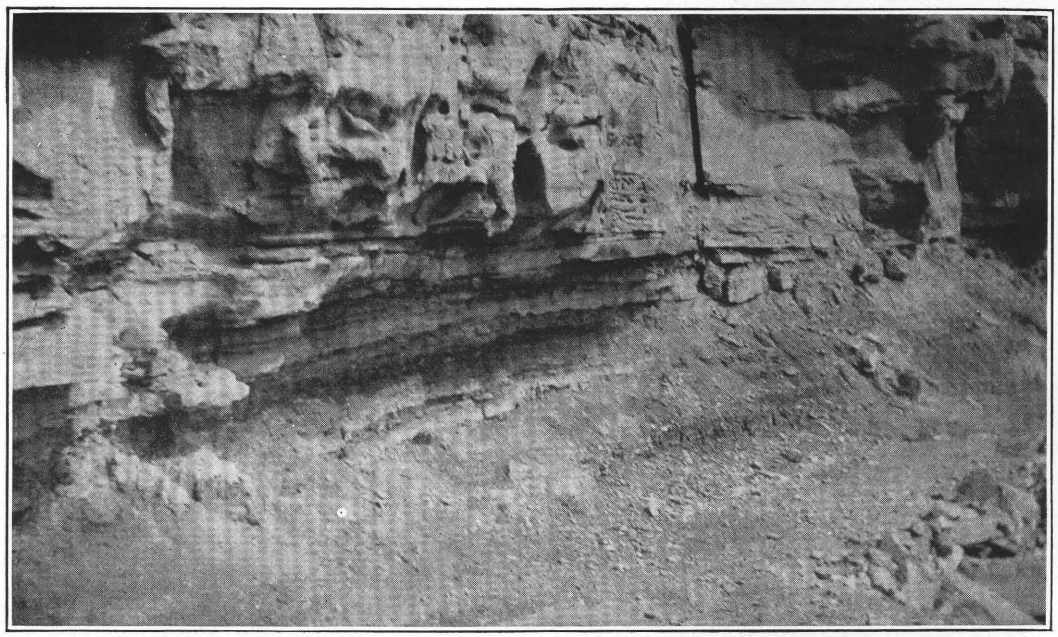
Sponge, undetermined.
Echinocrinus sp.
Spirorbis sp.
Batosomella n. sp.
Lioclema sp.
Fenestella sp.
Polypora sp.
Septopora n. sp.
Derbya aff. D. nasuta.
Orthotetes sp.
Meekella pyramidalis.
Chonetes hillanus.
Productus ivesi.
Productus occidentalis.
Productus popei.
Pustula subhorrida.
Pustula subhorrida var.
Pustula aff. P. irginae.
Marginifera splendens?
Marginifera? aff. M. splendens.
Dielasma sp.
Squamularia guadalupensis.
Spiriferina sp.
Composita mexicana?
Composita subtilita.
Pseudomonotis? sp.



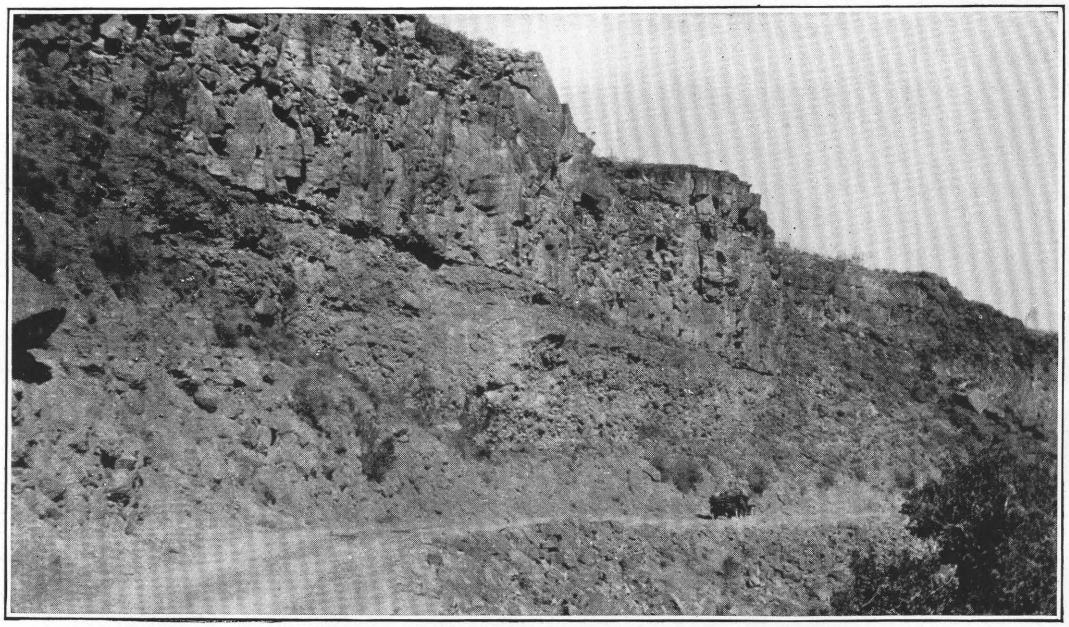
A. GROUP OF CINDER CONES OF LATE DATE AND ASSOCIATED LAVA; DIAMOND VALLEY, 12 MILES NORTH OF ST. GEORGE, UTAH.



B. NEARER VIEW OF LARGER CONE OF GROUP SHOWN IN *A*.



A. SHINARUMP CONGLOMERATE RESTING ON UPPER MOENKOPI SHALE AND SANDSTONE, SMITH'S MESA, 3 MILES NORTH OF VIRGIN CITY, UTAH.



B. LATE BASALT FLOW RESTING ON A CONGLOMERATE OF BASALT AND OTHER BOULDERS, ON ROAD FROM TOQUERVILLE TO LA VERKIN, UTAH.

Aviculipecten, 3 sp.
Acanthopecten coloradoensis.
Acanthopecten? sp.
Orthoceras sp.

Regarding these Kaibab fossils Mr. Girty says:

The fauna of the Kaibab limestone, which I regard as of Permian age, presents two fairly distinct facies corresponding to different stratigraphic horizons. The upper fauna consists largely of gastropods (especially *Bellerophon*) and pelecypods (especially *Leda*). This is clearly the horizon that was called the "*Bellerophon* limestone" by the geologists working along the Grand and Green rivers and was regarded by them as the top of the Carboniferous. (See list 1, above.)

What may be regarded as the normal Kaibab fauna, characterized by such species as *Productus ivesi*, *P. occidentalis*, *Pustula subhorrida*, and *Meekella pyramidalis*, is represented (in list 4 above). Those lots containing *Squamularia guadalupensis* in abundance accompanied by *Chonetes hillanus* form an appreciable subgroup in this fauna and perhaps represent a separate horizon. Essentially the same fauna occurs in the San Andres limestone of the Manzano group of New Mexico. (See list 2, above.)

The coral fauna (list 3, above) is unique. It is totally unlike any other fauna in the collection, and I do not recall ever having seen it before.

The Moenkopi formation was attributed by some earlier geologists to the Permian and by some to the Triassic. Later, largely on the basis of Walcott's work near Kanab, Utah, it was universally accepted as Permian, and this assignment received some confirmation from a few very poorly preserved plants that bear considerable resemblance to certain species of the well-known Permian genus *Walchia*.[53] The Moenkopi formation has been regarded generally as equivalent to the "Permo-Carboniferous" of the Wasatch Mountains. The latter beds have lately been proved equivalent to beds in Idaho [54] whose age is accepted universally as Lower Triassic. The Moenkopi formation must therefore be considered of Lower Triassic age. Mr. Girty's restudy of Walcott's original "Permian" fossils from the Moenkopi near Kanab, Utah, and the collections made during the present work lend strong support to this correlation. The fossils collected by us came from the Rock Canyon conglomeratic member, at the base of the entire Moenkopi red-bed series, and from the Virgin limestone member. The following combined lists show the species identified by Mr. Girty:

[53] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, p. 31, 1917.

[54] Girty, G. H., in Butler, B. S., and others, The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, p. 642, 1920.

5. Single lot (catalog No. 7791) associated with oil-bearing layer at the oil seep 1½ miles west of Virgin City, near top of Rock Canyon conglomeratic member:

Bakewellia sp. (small form).
Myalina sp. (small form).
Myophoria? sp.
Pleurophorus sp.
Pseudomelania? sp.
Ostracoda.

6. Single lot (catalog No. 7781) from a horizon 8 feet above that just listed but at same locality:

Bakewellia n. sp.
Pseudomonotis n. sp.
Pleurophorus sp.
Naticopsis sp.
Pseudomelania? sp.

7. Seven lots (catalog Nos. 7770 to 7775, 7780) from dark fetid limestones in thin sheets in gypsum beds; all from Rock Canyon conglomeratic member:

Bakewellia n. sp. (small form).
Myophoria sp.
Goniatite or ammonite undetermined.
Sponge spicules (amphioxes with a few triaenes).

8. Single lot (catalog No. 7788) from basal conglomerate bed in Rock Canyon conglomeratic member:

Monotis? sp.
Myalina n. sp.
Macrocheilina? sp.

9. Single lot (catalog No. 7794) from horizon 50 feet above base of Rock Canyon conglomeratic member:

Spirorbis sp.
Discina sp.
Terebratula sp.
Pseudomonotis n. sp.
Pleurophorus? (Modiola?) n. sp.
Pseudomelania n. sp.

10. Single lot (catalog No. 7796) from a horizon near top of Rock Canyon conglomeratic member:

Pseudomonotis sp.
Myalina sp.
Entolium? sp.
Naticopsis n. sp.
Bulimorpha n. sp.
Pseudomelania?, several n. sp.
Turritella, several n. sp.
Meekoceras aff. M. mushbachanum.
Numerous undetermined gastropods.

11. Nine lots (catalog Nos. 7782 to 7787, 7790 to 7792) from the Virgin limestone member:

Isocrinus sp.
Spirorbis sp.
Pugnax n. sp.
Terebratula? n. sp.
Pinna? sp.
Bakewellia n. sp.
Pseudomonotis n. sp.
Monotis? sp.
Myalina n. sp.
Aviculipecten, 4 sp.
Myophoria? sp.

Pleurophorus n. sp.
Pleurotomaria, 2 sp.
Naticopsis sp.
Ammonite?

Concerning these Moenkopi fossils Mr. Girty says:

Lists 6, 8, and 11 show what I regard as the normal Moenkopi fauna.

Besides these I recognize another group (list 7) which presents a peculiar cherty lithology and a fauna composed chiefly of small species of *Bakewellia* and *Myophoria*. I do not feel sure that this group does not represent a condition rather than a geologic horizon.

List 5 may represent a distinct faunal facies, but I am inclined to believe that it belongs with list 7.

List 9 probably belongs with lists 6, 8, and 11, but it may represent a distinct subfauna.

List 10, with its innumerable gastropods, is unique in the collection, but the horizon is undoubtedly Moenkopi.

Regarding the Triassic age of the Moenkopi, from which I understand there has been obtained some very meager plant evidence having a Permian cast, I will say the following:

The age of these Moenkopi beds does not depend solely upon the fossils immediately contained in them but is bound up with the Lower Triassic fauna of Idaho. There is scarcely room for reasonable doubt that Walcott's "Permian" of the Kanab Canyon section, which is Moenkopi, is the same as the "Permo-Carboniferous" of the Wasatch Mountains, and that the "Permo-Carboniferous" of the Wasatch Mountains is the same as the well-known Lower Triassic of Idaho. This correlation is, I believe, in a general way beyond dispute. I am personally convinced of it from my own studies. If the Moenkopi is Permian, then, consequently, the Lower Triassic of Idaho is Permian. Now, I have not investigated the question myself, but there seems to be a general agreement as to the age of the beds in Idaho.

As regards the evidence furnished by the Moenkopi beds themselves, I have identified *Meekoceras*, one of the distinctive ammonites of the Idaho faunas, both in the present collections and in Mr. Walcott's, and there are a few other characteristic Triassic types, though less important ones. I may also point out that there is an almost complete faunal change from the Kaibab to the Moenkopi. Both faunas are fairly extensive, but I know of no species that they contain in common. Furthermore, all the characteristic Paleozoic genera of brachiopods become extinct with the Kaibab—*Productus*, *Chonetes*, *Derbya*, *Meekella*, *Spirifer*, *Composita*, and a score of others—not to mention the numerous bryozoan types—*Fenestella*, *Septopora*, *Rhombopora*, *Stenopora*, and many more. These types appear neither in the typical Moenkopi nor elsewhere in the Lower Triassic of this region. Furthermore, the Kaibab, which is correlated with part of the Manzano group of New Mexico (the San Andres limestone), is itself Permian, a reference suggested first by the paleobotanic evidence from the underlying Supai formation and then corroborated by the invertebrates from the Kaibab itself. In brief, I think that we have here an almost perfect example of a boundary between two geologic systems, the formations being separated by a profound erosional unconformity and by an almost complete change of fauna, the upper formation containing many diagnostic fossils of the later system and the lower formation containing many diagnostic fossils of the earlier system.

The Shinarump conglomerate has been accepted for many years as Triassic on the basis of its flora and fauna and its stratigraphic position and relations. The Chinle formation seems to be closely related to the Shinarump by its fossils, and its assignment to the Triassic is unquestioned.

The massive sandstone overlying the Chinle offers an opportunity for a wide difference of opinion. Emery[55] believed that the unit which near the San Rafael Swell almost certainly represents this sandstone was to be correlated entirely with the Wingate sandstone and that the marine Jurassic above it was Gregory's Todilto formation and a still higher formation the equivalent of the Navajo sandstone. Lee followed this view. Dake,[56] however, believes that this sandstone is equivalent to the whole La Plata group of Gregory and that the marine Jurassic above it is to be correlated with some part of the McElmo formation. The problem is essentially one to be solved by tracing in the field, though we believe that the character of the sandstone suggests a correlation with the whole La Plata group rather than with the Wingate alone, as there is in our area nothing like the Navajo sandstone above the marine beds. The marine series, however, contains peculiar greenish-white beds which somewhat resemble the greenish-white beds of the McElmo formation farther east. As mentioned on page 63 Walcott found in Kanab Valley in the top of the Chinle formation or the base of this sandstone fossils which have a Jurassic aspect.

The variegated shale would seem to belong to the same group as the marine Jurassic limestone, in that there are thin limestones in its upper part, though there may be an unconformity between the two and a considerable difference in age.

The buff sandstones yielded no fossils but suggest in position and lithology a correlation with the Cretaceous beds farther north and east, on Coal Creek, which have a thin coal-bearing unit at the base overlain by sandstones containing marine Cretaceous fossils. Still farther east, near Mount Carmel, appa-

[55] Emery, W. B., The Green River Desert section, Utah: Am. Jour. Sci., 4th ser., vol. 46, pp. 564-572, 1918.

[56] Dake, C. L., The horizon of the marine Jurassic of Utah: Jour. Geology, vol. 27, pp. 634-646, 1919 [1920].

rently the same interval contains, besides a basal conglomerate unit 15 feet thick, the coal-bearing unit, 400 feet thick; marine shale, 700 feet; sandstones and shale, 1,000 feet, overlain by a thin conglomerate; and 700 feet of fresh-water sandstone, apparently all Cretaceous.

The pink sandstone and shale series is believed from its position and character to be equivalent to the Tertiary rocks of the Pink Cliffs.

LOCAL SECTIONS.

1. *Section in Hacks Canyon, Ariz.*

[Upper part measured at mouth of Robesons Canyon; lower part measured along Hacks Canyon from Robesons Canyon to the point where it joins Kanab Canyon.]

	Feet.
Kaibab limestone:	
Harrisburg gypsiferous member:	
Conglomerate, brown, of waterworn pebbles 1 inch in diameter; may be post-Mesozoic material	2
Limestone, yellow, arenaceous; weathers "sun-cracked." Silicified fossils on surface, including *Leda obesa*, *Aviculipecten?* sp., *Plagioglypta canna*, *Bucanopsis* aff. *B. bella*	8
Concealed interval	4
Sandstone, yellow, calcareous, and arenaceous limestone, with red chert and silicified fossils	25
Concealed interval	8
Limestone, impure, yellow. With units above is the "*Bellerophon* limestone."	4
Gypsum	18
Sandstone, light gray, calcareous	5
Limestone, with fragments of white chert that breaks into flat pieces, making up over half the bulk	13
Limestone, with white chert; fossiliferous	11
Limestone, with small chert nodules	2
Limestone, arenaceous, yellow on weathering, white on fresh surface; more calcareous toward the top, more sandy and friable toward the base; resistant and ledge-forming	10
Gypsum	80
Thickness of Harrisburg member	190
Limestone, thin-bedded above, with much white chert; massive in middle, with much dark chert, which weathers brown or black; thin bedded in lower part	315
Gypsum, impure	125
Limestone, gray, massive; upper part cherty and relatively thin bedded, the chert nodules white and fossiliferous; beds of main part 1 to 3 feet thick; lower part grades down into sandstone, which is gray on weathered surface, white on fresh surface.	180
Limestone, thin bedded, not sandy	20
Thickness of Kaibab limestone	830
Coconino sandstone:	Feet.
Sandstone, dark buff, locally salmon-colored, massive, cross-bedded, friable, medium to coarse grained	33
Sandstone, massive, medium grained, highly cross-bedded, friable, white, saccharoidal; a conspicuous unit. Along the strike this and the overlying unit may vary in relative thickness, so that the lower is four times as thick as the upper	44
Sandstone, massive bed with three distinct layers—a white massive cross-bedded sandstone with streaks of brown, 8 feet; hard brown sandstone, 2 feet; white argillaceous sandstone, 2 feet. Distinct from overlying unit in not being as white nor as friable	12
Thickness of Coconino sandstone	89
Supai formation:	
Sandstone, massive, brick-red, with interbedded lenses of red shale; forms a cliff, or at least a steep slope	200
Sandstone, argillaceous, brick-red, and red sandy shale, interbedded, in about equal amounts	350
Sandstone, massive, brick-red, argillaceous; weathers into rounded ledges; one conspicuous white band and several minor ones. Base of unit not seen	525+
Thickness of part of Supai formation observed	1,075

2. *Section in Toroweap Canyon, Ariz.*

[Upper part measured 5 miles above mouth of Toroweap Valley; lower part at the mouth.]

	Feet.
Kaibab limestone:	
Harrisburg gypsiferous member:	
Limestone, yellow, with silicified fossils at top of unit; concealed interval in middle; at base limestone filled with white chert that breaks into flat plates. "*Bellerophon* limestone"	65
Gypsum	38
Limestone, dark blue	12
Gypsum	27
Limestone, impure	8
Gypsum	40
Thickness of Harrisburg member	190
Limestone, massive, cherty, forming a series of steps	25
Limestone, gray, massive, with much dark-brown chert; forms cliffs and towers	160
Gypsum	175
Limestone, weathering white and hackly and forming steps	50
Limestone, gray, forming steps	50
Limestone, massive, fossiliferous throughout. At top blue, crystalline, cherty; grades downward into sandy limestone, locally a calcareous sandstone, fine grained; base argillaceous	100
Limestone, rather thin bedded, with nodules of dark chert, breaks with conchoidal fracture	25
Thickness of Kaibab limestone	775

Coconino sandstone:	Feet.
Sandstone, deep yellow to buff, somewhat friable but not notably cross-bedded	13
Sandstone, much cross-bedded, yellow and white, friable; white on fresh surface	70
Sandstone, pale yellow, fine grained, argillaceous; weathers to rounded exfoliated bosses	13
Thickness of Coconino sandstone	96
Supai formation:	
Shale, gray, sandy	14
Sandstone, red, somewhat argillaceous but massive and forming a steep slope or cliff	175
Sandstone, argillaceous, and sandy shale; both brick-red and interbedded in about equal amounts; forms a slope	375
Sandstone, massive, red	735
Thickness of Supai formation	1,299

Redwall limestone.

3. *Section on Fredonia–Mount Trumbull road half a mile northeast of Bullrush, 12½ miles southwest of Fredonia, Ariz.*

Moenkopi formation:	Feet.
Shale, white, calcareous, and impure limestone in thin plates	5
Shale, red	18
Shale, gray	10
Virgin limestone member:	
Limestone, earthy, yellow, with many small cavities lined with calcite. Thickness ranges from 1 to 2 feet	2
Shale, gray	1
Gypsum, red to gray	4
Shale, red	3
Limestone, thin bedded, earthy, yellow; fossil fragments	1
Thickness of Virgin limestone member	11
Shale, red, exposed	25

4. *Section in Hurricane fault scarp in Black Rock Canyon, Ariz., 18 miles south of Hurricane, Utah.*

Kaibab limestone:	Feet.
Limestone, gray, cherty, massive; inaccesible for measurement.	
Gypsum, shale, and some limestone	225
Limestone, gray and brownish on weathered surface, light gray on fresh surface; cherty. Unit massive except for uppermost 22 feet, which is thin bedded	190
Sandstone, gray, fine grained; weathers brown	5
Gypsum	15
Limestone, thin bedded, gray	60
Gypsum	20
Limestone, thin bedded, dark gray	7
Gypsum	45
Thickness of part of Kaibab limestone measured	567

Coconino and Supai formations (undifferentiated):	Feet.
Sandstone, medium grained, gray to white on fresh surface, yellow-brown on weathered surface, medium bedded, cross-bedded	200
Sandstone, like that above but in thinner beds separated by softer brick-red sandstone. A few layers dark gray and smelling of oil when broken	490
Sandstone, medium grained, cross-bedded, gray to white on fresh surface, yellow-brown on weathered surface; relatively thin bedded and weathering back from the unit beneath to form a bench	155
Sandstone, like the unit next above but practically in one bed and forming a sheer wall	380+
Thickness of part of sandstone exposed	1,225

5. *Section 2 miles south of Antelope Spring, on west side of Antelope Wash, Ariz.*

Moenkopi formation:
Shale, red.
Unconformity.
Kaibab limestone:

Harrisburg gypsiferous member:	Feet.
Limestone, sandy, yellowish, with much white chert; very fossiliferous; weathers hackly, with silicified fossils showing on surface. Lithology characteristic of this part of the formation	15
Gypsum, pink in large part; near middle of unit 5 feet of dark thin-bedded limestone with fetid odor when broken	140
Sandstone, coarse, gray, granular, calcareous; contains fossil fragments	5
Thickness of Harrisburg member	160
Limestone, gray, massive, with much light chert; whole unit weathers light colored; exposed	40

6. *Section at head of Rock Canyon, 5 miles north of Antelope Spring, Ariz.*

Top of hill south of Rock Canyon.
Moenkopi formation:

Rock Canyon conglomeratic member:	Feet.
Limestone, pale red, with some gray; weathers hackly and with "sun-cracked" surface and shows flecks of calcite	30
Limestone, like unit above but gray	15
Conglomerate of rounded and subangular fragments of quartz and chert, white to dark gray, as large as 12 inches across, though most are under 5 inches. The matrix is limestone. The bedding of this unit is very irregular, and locally the conglomerate is interbedded with ordinary limestone. Contains *Myalina* n. sp., *Monotis?* sp., *Macrocheilina?* sp.	55
Conglomerate of fragments of fossiliferous chert and limestone in a matrix of white granular limestone. This unit is more resistant than that below. The unit above cuts down locally clear through this unit.	15

Moenkopi formation—Continued.	Feet.
Rock Canyon conglomeratic member—Contd.	
Limestone, coarse, very fossiliferous, filled with large nodules of blue chert 1 inch to 1 foot in greatest dimension. The limestone weathers away, leaving the chert nodules with many fossils	15
Limestone, light gray, with crinoid fragments and some chert nodules. Surface usually dark from mosses and lichens. More resistant than units above and below	2
Limestone, white, knobby, chalky on fresh surface	2
Conglomerate of large blue limestone cobbles in a white granular matrix	2
Limestone, coarse, granular, base somewhat irregular; breaks into wedgy fragments	10
Sandstone, soft, limestone, and limestone breccia, cherty in part and copper-stained locally	25
Limestone, light yellow, filled with white platy chert; beds rather thin	8
Sandstone, yellowish gray, medium grained, in beds 1 foot thick, passing along strike into sandy limestone; resistant unit	6
Thickness of Moenkopi formation exposed	185
Unconformity.	
Kaibab limestone:	
Harrisburg gypsiferous member absent or included in massive unit described below	
Limestone, gray, nodular, cherty; upper part thin-bedded, but unit massive as a whole	400

7. *Section on north side of Rock Canyon at mouth, 15 miles south of Hurricane, Utah.*

Moenkopi formation:	
Rock Canyon conglomeratic member:	Feet.
Limestone, black, thin bedded, fossiliferous	25
Limestone, dense, gray	70
Gypsum and red shale	100
Thickness of part of Moenkopi formation present	195
Unconformity.	
Kaibab limestone:	
Harrisburg gypsiferous member absent or included in massive unit described below.	
Limestone, massive, gray, with much brown to black chert; contains *Batostomella* sp., *Phyllopora?* sp., *Fenestella* sp., *Septopora* n. sp., *Orthotetes* sp., *Derbya* sp., *Chonetes hillanus?*, *Productus ivesi*, *Productus popei*, *Pustula subhorrida*, *Pustula subhorrida* var., *Pustula* aff. *P. irginae*, *Pugnax osagensis* var., *Spirifer* sp., *Squamularia guadalupensis*, *Composita subtilita*, *Myalina* aff. *M. deltoidea*, *Aviculipecten* sp., *Acanthopecten coloradoensis*	400
Gypsum, impure	55
Limestone, white, thin-bedded, cherty	20
Gypsum, impure	150
Limestone, upper part light colored, lower part gray; contains relatively little chert; not very resistant; weathers rather smooth, not hackly	40
Kaibab limestone—Continued.	Feet.
Limestone, gray, cherty, massive; weathers hackly	175
Gypsum, earthy, gray, impure, with thin-bedded limestone and some gypsiferous sandstone	108
Thickness of Kaibab limestone	948
Coconino sandstone (?):	
Sandstone, deep yellow, friable	5
Sandstone, white, rather hard; forms ledge	2
Sandstone, soft, white, and sandy shale, light gray in great part but with some yellow staining	10
Thickness of Coconino sandstone (?)	17
Supai formation (?):	
Sandstone, yellow, friable	16
Sandstone, pale yellow, rather hard; massive bed forming sharp ledge	9
Sandstone, soft, gray, argillaceous	5
Sandstone, red and yellow interbedded, the yellow a little more resistant than the red	55
Sandstone, mottled yellow and red	10
Sandstone, red, argillaceous, and red sandy shale	30
Sandstone, massive, yellow, friable, cross-bedded, with several thin beds of red sandstone. Some of the yellow sandstone is white on a fresh surface and friable	35
Sandstone, massive, red, in beds 10 feet or more in thickness with thin beds (1 foot or less) of sandy shale between. On strike one of these beds grades into yellow sandstone; others are bleached yellow along cracks	40
Sandstone and shale, red, micaceous, interbedded in subequal amounts	100
Sandstone, massive, brick-red, somewhat argillaceous, with thin beds of red shale	35
Sandstone, white, friable	17
Sandstone, massive, brick-red, argillaceous, with thin beds of interbedded red sandy shale. On strike some of these beds are yellow locally. Exposed	148
Thickness of Supai formation (?) exposed	500

8. *Section on Hurricane fault scarp 6 miles south of Hurricane, Utah.*

[See Pl. IX, *A*, *B*.]

Basalt.	
Moenkopi formation:	Feet.
Shale, red sandy, present	100±
Unconformity.	
Kaibab limestone:	
Harrisburg gypsiferous member:	
Limestone, gray, thin bedded, some of it containing angular fragments of chert; and shale, gray or yellow. Unit unresistant to weather. May possibly be basal Moenkopi	45
Limestone, brownish to yellow, with some dark-gray layers; some layers brecciated.	115
Thickness of Harrisburg member	160
Limestone, massive, gray, with much brown chert; fossils abundant in chert	260

Kaibab limestone—Continued.	Feet.
Shale, soft sandstone, and gypsum, the whole forming a gray slope	200
Limestone, gray, massive, with much brown chert; light colored on fresh surface; contains softer shaly layers near middle of unit	230
Limestone, sandy, cream-colored, cross-bedded, platy. Some limonitic staining shows	25
Limestone, thin bedded, dark drab, with oily odor; contains some soft sandy layers and some white chert in nodules	10
Gypsum, white, pure	20
Gypsum, gray; has some odor of oil	10
Gypsum, white, massive, with some thin gray sandstone layers	15
Thickness of Kaibab limestone	930
Coconino sandstone (?):	
Sandstone, creamy yellow	20
Sandstone, white	45
Supai formation (?):	
Sandstone, medium grained, cross-bedded, ripple marked, yellow-brown to light gray, exposed	200±

9. *Section near sulphur spring at mouth of Virgin Canyon, half a mile south of La Verkin, Utah.*

Moenkopi formation:	
Rock Canyon conglomeratic member:	Feet.
Limestone, dark colored, platy, with an abundance of *Bakewellia* n. sp. (small form)	1
Concealed interval covered with loose fragments of various sorts of limestone	35
Thickness of part of Moenkopi formation measured	36
Unconformity.	
Kaibab limestone:	
Harrisburg gypsiferous member:	
Limestone, variable; some of it with much light-colored platy chert, dark gray and hackly on weathered surfaces, yellow and light gray on fresh surfaces; some layers sandy and others much like the lower parts of the Kaibab formation with dark chert nodules. Some layers fossiliferous, containing *Chonetes hillanus, Squamularia guadalupensis, Composita* sp	75
Limestone, sandy limestone, calcareous sandstone, white, yellow, and gray friable sandstone, and some gypsum	75
Thickness of Harrisburg member	150
Limestone, gray, cherty, resistant, massive; has a cap layer filled with light-colored platy chert	280
Limestone, gray, cherty, less resistant than unit above and broken into a series of terraces. Some breccia and some gypsum present	50
Gypsum, white	50
Limestone, gray, cherty, very resistant, massive; exposed	200
Thickness of Kaibab limestone exposed	766

10. *Section in Virgin River canyon 3 miles west of Virgin City, Utah.*

Moenkopi formation:	
Red beds and gypsum.	Feet.
Sandstone, grayish brown, hard, very platy	3
Shale and sandy shale, yellow	5
Sandstone, brown, hard, platy	5
Shale, sandy, soft, yellow	20
Rock Canyon conglomeratic member:	
Limestone, dark gray, hackly; reddish locally and rough from weathering out of sandy fragments	8
Limestone, pink and gray, sun-cracked; weathered surface shows flecks of white calcite. On strike this unit becomes a breccia in lower part	28
Limestone, massive, yellow, with fossils showing on weathered surface. Beds 1 to 2 feet thick. This unit and unit below thin out on strike and breccias above and below unite	10
Concealed interval chiefly, but with some gray limestone	18
Breccia of chert and limestone in a limestone matrix; many fragments large (6 inches or more across), many angular. Variable unit	10
Interval largely concealed but with some sandy yellow limestone and shale and some gray limestone showing	18
Limestone, massive, bluish, with light-colored chert	45
Concealed interval of soft beds forming slope	35
Thickness of part of Moenkopi formation observed	172
Unconformity.	
Kaibab limestone:	
Harrisburg gypsiferous member absent?	
Limestone, bluish, with much black and dark-gray chert.	

A short distance from the point of measurement of this section 3 feet of soft sandstone rests upon the cliff-forming limestone, and above this is a massive breccia, whose matrix is locally brick-red and which makes up almost all of the Rock Canyon conglomeratic member.

11. *Section in Virgin Canyon 2½ miles west of Virgin City, Utah, below the mouth of Oil Seep Wash.*

Moenkopi formation:	
Rock Canyon conglomeratic member:	Feet.
Limestone, brown, full of large sand grains that weather out on surface	1
Concealed interval	5
Limestone, gray; weathers hackly	3
Concealed interval	8
Limestone, sandy, gray; weathers hackly	4
Concealed interval	17
Shale, yellow, sandy	4
Concealed interval	12
Limestone conglomerate, gray, fine grained; weathers hackly	15
Limestone, gray, with reddish patches	10
Limestone, red, interbedded with red shale and a reddish mottled limestone	60

Moenkopi formation—Continued.	Fe. t.
Rock Canyon conglomeratic member—Contd.	
Limestone breccia, gray	10
Sandstone, yellow and gray, with sandy shale and shale	15
Limestone conglomerate, grayish brown	5
Thickness of part of Moenkopi formation measured	169

Unconformity.

Kaibab limestone:

Harrisburg gypsiferous member absent?

Limestone, gray, cherty.

12. *Section in Virgin Canyon 2 miles west of Virgin City, Utah, at mouth of Oil Seep Wash.*

Moenkopi formation:	
Rock Canyon conglomeratic member:	Feet.
Limestone, gray, nodular; undeterminable fossils	1
Concealed interval	5
Limestone conglomerate, hackly and very rough on weathered surface	18
Limestone, gray, sun cracked and flecked with calcite	9
Limestone, red	20
Limestone conglomerate and breccia with fragments as much as 2 feet in diameter; matrix yellow limestone	15+

13. *Section in Smith's Mesa, 3 miles north of Virgin City, Utah.*

Jurassic sandstone.

Chinle formation:	Feet.
Shale and sandstone, brick-red; estimated (not present in Smith's Mesa, but seen at a point near by)	200
Sandstone, mauve, cross-bedded, ripple marked, resistant	90
Shale and sandstone, brick-red	420
Sandstone, coarse, arkosic, cross-bedded, gray-white and mauve; suggests volcanic ash; contains fossil wood. Locally known as the "Silver Reef sandstone"	25
Shale "gumbo," variegated, bluish gray, greenish, mauve, red, and some yellow-brown; contains fossil wood	260
Thickness of Chinle formation	995

Shinarump conglomerate (Pl. XIII, *A*):	
Sandstone, gray, platy, with a few pebbles	20
Shale, gray to green, with some fossil wood	20
Sandstone, coarse, gray-white on fresh surface, limonitic brown on weathered surface; locally filled with black blebs of wad or some similar substance. Contains lenses of pebbles of chert, variously colored, quartz, silicified wood, and minor igneous rock. Base is irregular and apparently unconformable. Unit contains abundance of fossil logs, mostly silicified, though in part replaced by copper minerals	75
Thickness of Shinarump conglomerate	115

Moenkopi formation:	Feet.
Sandstone, soft, and shale, brick-red to very deep red, with gypsum and a little lighter-colored shale; weathers to a fairly even slope	405
Shnabkaib shale member: Shale, sandy, and sandstone, soft, fine-grained, creamy white, with some pinkish layers and gypsum; weathers to a fairly even slope	360
Sandstone and shale, brick-red, and light bluish-gray gypsum, lighter colored than the upper red beds	400
Virgin limestone member:	
Limestone, yellow, earthy, fossiliferous; contains *Myalina* n. sp., *Pseudomonotis* n. sp., *Bakewellia* n. sp	5
Shale, yellow and red	25
Limestone, yellow, earthy, fossiliferous; contains *Myalina* n. sp., *Pseudomonotis* n. sp	5
Shale, yellow, calcareous	25
Limestone, fairly massive, yellow, earthy; contains *Isocrinus* sp., *Spirorbis* sp., *Terebratula?* n. sp., *Pinna?* sp., *Bakewellia* n. sp., *Pseudomonotis* n. sp., *Myalina* n. sp., *Aviculipecten*, 4 sp., *Myophoria?*, sp., *Pleurophorus?* sp., *Pleurotomaria?*, 2 sp., *Naticopsis* sp., ammonite? undet	20
Thickness of Virgin limestone member	80
Sandstone and shale, brick-red, with gypsum	360
Rock Canyon conglomeratic member: Irregular basal unit of limestone, conglomerate, etc	170
Thickness of Moenkopi formation	1,775

Kaibab limestone (see sections in Virgin River canyon).

14. *Section at the Harrisburg dome, 8 miles east of north of St. George, Utah.*

	Feet.
Shinarump conglomerate	100±
Moenkopi formation:	
Shale and sandstone, brick-red, upper part very dark colored	320
Sandstone, yellow, medium grained, massive in upper part	75
Shale, red, with some sandstone and gypsum	80
Shnabkaib shale member: Shale, sandy, white to light gray, with gypsum and some pink shale	630
Shale, red, sandy, with gypsum	435
Virgin limestone member: Limestone, earthy, greenish yellow, in three thin bands separated by greenish-yellow and reddish-brown shale. Lower band contains *Isocrinus* sp., *Pugnax* n. sp., *Aviculipecten* sp.	160
Shale, red, some of it sandy, with gypsun and a little bluish gypsiferous shale	275
Shale, yellow, gypsiferous, containing locally thin black limestone layers with *Bakewellia* n. sp. (small form)	60
Rock Canyon conglomeratic member apparently absent.	
Thickness of Moenkopi formation	2,035

Unconformity.

Kaibab limestone:	Feet.
Harrisburg gypsiferous member: Limestone, varying in character in different layers, some of the upper ones pinkish and sun cracked, others showing a coarse matrix with much angular chert. Still other layers have much whitish chert with platy fracture, and some in the lower part of the unit resemble the older part of the Kaibab with dark chert. Variation in character laterally is very great. Three collections at about the same horizon at different places near the top of the limestone show the following fossils: (1) *Productus ivesi, Pustula subhorrida;* (2) *Lithostrotion?* n. sp., *Favosites?* n. sp., *Campophyllum?* n. sp.; (3) *Dielasma* sp., *Nucula levatiformis, Leda obesa, Pteria (Bakewellia?)* sp., *Pseudomonotis?* sp., *Schizodus wheeleri?, Pleurophorus mexicanus, Plagioglypta canna, Bucanopsis* aff. *B. bella, Euphemus* sp., *Goniospira* sp., *Pleurotomaria* sp., *Naticopsis?, Platyceras* sp.	250
Shale, yellow, gypsiferous	30+

[Section continued by the log of the well of the Virgin Dome Oil Co.]

Kaibab limestone:	
Limestone of varying hardness and color and some gypsum, composing the Harrisburg gypsiferous member, 258 feet. As well mouth is 12 feet beneath top of Harrisburg member the thickness is close to that found on surface	[270]
Limestone, light colored, containing much chert	275
Limestone, salmon-colored, soft	38
Limestone, etc. (details not known)	466
Thickness of Kaibab limestone	1,049
Coconino sandstone and Supai formation:	
Sandstone to bottom of well	1,150

15. *Section in the Washington dome, 6 miles east of St. George, Utah.*

Moenkopi formation:	Feet.
Virgin limestone member	160±
Lower red-beds member	320±
Rock Canyon conglomeratic member:	
Limestone, dark gray, thin bedded, with some light-colored limestone; contains *Bakewellia* n. sp. (small form) and *Myophoria* sp	10
Shale, dark red, with gypsum stringers	33
Concealed interval, possibly red shale	57
Coarse conglomerate of limestone and chert in a limestone matrix, the whole pinkish	11
Shale, red and yellow, some of it sandy	5
Limestone, coarse, pinkish, with chert fragments	4
Concealed, probably shale	8
Limestone, pinkish, containing large boulders of limestone and chert	20
Limestone, gray, rough, silicified, with some chert nodules	12
Moenkopi formation—Continued.	
Rock Canyon conglomeratic member—Contd.	Feet.
Coarse conglomerate of limestone in a lime matrix grading upward into a gypsum matrix	53
Gypsum, pure, massive	10
Limestone, porous, gray, somewhat silicified	2
Gypsum with much fine-grained platy drab to dark-gray limestone; some breccia	83

Unconformity.

Kaibab limestone:	
Harrisburg gypsiferous member absent locally, but present here and there and containing *Schizodus* sp., *Plagioglypta canna?, Bellerophon majusculus?, Goniospira* sp., *Euomphalus* sp., *Nautilus* sp.	
Massive cherty gray limestone.	

16. *Section at the Bloomington dome, 5 miles south of St. George, Utah.*

Moenkopi formation:	Feet.
Virgin limestone member	130±
Lower red-beds member: Shale, red, some of it sandy, and gypsum. Near base contains gypsum with thin limestones and *Bakewellia* n. sp. (small form)	320±

Unconformity.

Kaibab limestone:	
Harrisburg gypsiferous member:	
Limestone, gray, filled with angular pieces of chert that break into plates. This unit is crumbly, and weathered edges of blocks are rounded	12
Limestone, like unit above, but in a single bed, harder and weathering into angular blocks with included chert projecting as brown excrescences on surface	2
Breccia of quartz fragments loosely cemented by limestone; friable and nonresistant	1
Limestone, gray, coarse, granular	3
Limestone, gray, very soft, nonresistant	6
Gypsum	4
Limestone, white, granular; weathers to powder. Contains partly silicified fossils, including *Polypora* sp., *Chonetes hillanus?, Squamularia guadalupensis, Composita* n. sp	5
Limestone, dark gray, coarse grained, friable, nonresistant; fossiliferous	5
Limestone, gray, thin bedded, with nodules of chert	4
Gypsum, pinkish, with a 5-foot bed of dark limestone 10 feet above base	215
Limestone, gray, filled with fragments of chert that breaks into plates	5
Concealed interval	5
Limestone, soft, gray, with well-preserved silicified fossils	5
Thickness of Harrisburg member	272

Kaibab limestone—Continued.

	Feet.
Limestone, gray, massive, resistant, with much dark chert; contains *Batostomella* sp., *Fenestella* sp., *Polypora* sp., *Septopora* sp., *Productus ivesi*, *Pustula subhorrida*, *Pustula* aff. *P. irginae*, *Pseudomonotis?* sp., *Aviculipecten*, 3 sp., *Acanthopecten coloradoensis*, *Acanthopecten?* sp	100±

17. *Section just off the St. George-Wolf Hole road about 7 miles north of Wolf Hole, Ariz.*

Top of hill.

Kaibab limestone:

	Feet.
Harrisburg gypsiferous member (some of this unit may be basal part of Moenkopi formation):	
Gypsum, red, in thin layers	15
Gypsum, white	18
Gypsum, red, with a little red shale	5
Gypsum, white to pink	10
Limestone, white, with little or no chert	2
Sandstone, brown to yellow, soft, and gypsum	7
Limestone, yellowish, filled with white platy chert	15
Gypsum	15
Limestone, white, earthy to sandy; white on a fresh surface, yellow to white on weathered surface; chert nodules abundant in lower part	17
Gypsum, white to pink, with a little limestone	148
Limestone thickly set with white platy chert; has a peculiar brown fibrous surface	3
Concealed interval	4
Thickness of Harrisburg member	259
Limestone, gray, with many nodules of dark chert that are brown or black on a weathered surface	315
Limestone, sandy; weathers white and contains little chert; not very resistant to weather	15
Gypsum, with some shale and limestone	270
Limestone, cherty, gray; exposed	150
Thickness of part of Kaibab limestone exposed	1,009

18. *Section near Black Rock Spring, Ariz., 25 miles south of St. George, Utah.*

Moenkopi formation:

Middle red beds.

Virgin limestone member:	Feet.
Limestone, earthy, yellow	9
Shale, red	36
Limestone, earthy yellow	5
Shale, red	26
Limestone, earthy yellow, containing *Isocrinus* sp., *Myalina* sp., *Bakewellia* n. sp., *Monotis?* sp	24
Thickness of Virgin limestone member	100
Shale, red	113

Moenkopi formation—Continued.

	Feet.
Shale, red, with prominent beds of bluish gypsum	22
Shale, red	8
Shale, red, with much gypsum	10
Gypsum, reddish	17
Gypsum, impure, yellowish brown	10
Thickness of part of Moenkopi formation measured	280

Unconformity.

Kaibab limestone:

Harrisburg gypsiferous member:	Feet.
Limestone, gray, filled with nodules of white chert that breaks with a platy fracture	25
Concealed interval, less resistant beds	10
Limestone, granular; weathers white with a very hackly surface; contains *Chonetes hillanus*, *Squamularia guadalupensis*	7
Limestone, soft; weathers yellowish and contains many nodules of light-colored chert which does not break into plates	8
Gypsum, in part pinkish	43
Limestone, dark; weathers rough and has fetid odor when broken	4
Concealed interval, probably gypsum	8
Limestone, gray, with much platy chert	4
Concealed interval	1
Thickness of Harrisburg member	110
Limestone, gray, with much dark-colored chert that shows as black or brown excrescences on weathered surfaces	250

19. *Section in narrows of Virgin River below Bloomington, Utah.*

Kaibab limestone:

Harrisburg gypsiferous member:	Feet.
Limestone, hackly, very light gray to almost white, with small dark-colored chert nodules showing on weathered surfaces	7
Limestone, white on both fresh and weathered surfaces	5
Concealed interval	3
Limestone, yellowish, filled with white or light-gray chert which breaks into plates; a very characteristic rock	15
Concealed interval	10
Limestone, light blue-gray, with some chert nodules that stand out upon weathered surfaces; fossiliferous; upper part particularly "flinty"	15
Concealed interval	12
Limestone, porous, white, gypsiferous	1½
Shale, red	10
Conglomerate and breccia of limestone with red earthy gypsiferous matrix	14
Shale, red and yellow, soft, sandy	7
Limestone and shale, earthy, gray, gypsiferous	4
Shale, red and yellow, soft, sandy	8

Kaibab limestone—Continued.	Feet.
Harrisburg gypsiferous member—Continued.	
Limestone breccia, hackly on weathered surface, pinkish locally but light blue-gray in general tone; sun-cracked on weathered surfaces; a very characteristic rock	7
Lime shale, gray to yellow, sandy, with a little white chert in bands	4
Limestone, soft, porous, pink, yellow, and gray in color; weathers to a hackly or cavernous surface	7
Limestone breccia, dark blue-gray, with hackly surface, more resistant than unit above	5
Limestone breccia, relatively soft; matrix a yellow limestone. Fragments in breccia as large as 4 inches in diameter	2
Thickness of Harrisburg member	137
[Remainder of section measured farther down canyon.]	
Limestone, thin bedded, ash-gray, with some layers of chert breccia and calcareous shale. Possibly duplicates part of the beds described above	70
Limestone, massive, uniform, fine grained, gray on fresh surface and brownish on weathered surface; filled with layers and nodules of brown chert; fossiliferous throughout	275
Breccia of limestone and chert in a limy matrix; whole mass weathers to a yellow-brown color	110
Gypsum and red shale	50
Breccia of limestone and white chert in limy matrix	20
Shale, soft, gray, and gypsum	10
Limestone, very massive, gray to light gray on weathered surface, cherty, fossiliferous	220
Sandstone, soft, yellow, gypsiferous	8
Limestone, gray to brown, very cherty, thin bedded	32
Limestone, arenaceous, light gray to white, cherty	25
Thickness of Kaibab limestone	957
Coconino sandstone (?):	
Sandstone, coarse grained, cross-bedded, brown on weathered surface, buff on fresh surface	15
Sandstone, white on fresh surface, dark gray or blackish on weathered surface, cross-bedded; variable along strike	5
Sandstone, white to cream-colored, earthy, fine grained; locally upper part of unit whiter than lower part	25
Thickness of Coconino sandstone (?)	45
Supai formation (?): Sandstone, medium grained, cross-bedded, very massive; lower part yellow and brown, with a little irregular red staining; middle part similar but with much red staining and a few thin soft red sandstones; upper part in some places a uniform red but usually a clean yellow-brown. The unit is so uniform that it can not be subdivided. No fossils observed.	1,490
Redwall limestone: Limestone, siliceous, and sandstone, mostly heavy bedded, light gray on fresh surface, red-brown to dark gray on weathered surface. About 200 feet below the top of the exposure a marked dark-gray layer 20 feet thick looks as if it might be stained by hydrocarbons but shows none on a test. Fragments of fossils observed	500+

20. *Section in Beaver Dam Mountains near Arrowhead Trail from Salt Lake City to Los Angeles, about 20 miles northwest of St. George, Utah.*

	Feet
Moenkopi formation.	
Unconformity.	
Kaibab limestone:	
Harrisburg gypsiferous member (some of this unit may be basal part of Moenkopi formation):	
Limestone, very light gray, almost white	4
Limestone, hackly, darker than overlying layer	4
Limestone, dark gray, with a few fossils	6
Concealed interval; fragments of gray limestone on surface	9
Concealed interval; fragments of platy quartz and chert on surface	15
Limestone, filled with platy chert of very light color	17
Limestone, pink and gray, with hackly surface, fossiliferous	11
Limestone, yellowish, thin bedded	10
Limestone, gray to pinkish, with hackly surface, fossiliferous	8
Concealed interval	12
Limestone and platy white chert, in equal amounts. Weathered surface has a peculiar brown, fibrous appearance	16
Concealed interval	39
Limestone, gray, with hackly surface	5
Concealed interval	28
Thickness of Harrisburg member	184
Limestone, gray, cherty, massive	195
Interval mostly concealed but with some fossiliferous limestone showing; probably much of it gypsum	260
Limestone, massive, gray, cherty	170
Limestone, yellowish to white, very sandy; some nodules of calcite present. Lower part especially friable where exposed to weather	40
Concealed	75
Thickness of Kaibab limestone	924

	Feet.
Coconino and Supai formations: Sandstone, very massive but not hard, medium grained, predominantly pale yellow but locally pinkish. Through much of it there are specks of iron oxide that stand out over the weathered surface in brown pimples. The upper part of the sandstone is a lighter yellow and has very little pink coloring; the lower part is darker, has more pink coloring, and is thinner bedded	1,420
Redwell limestone: Limestone, gray, earthy, porous; reddish or brownish on weathering. Only fossils collected are *Chaetetes milleporaceus*, at about 1,000 feet beneath top of formation, and *Marginifera* aff. *M. splendens*, at 650 to 700 feet beneath top of formation.	1,500+

21. *Section on north side of Diamond Valley, 15 miles north of St. George, Utah.*

	Feet.
Tertiary or Quaternary: Basalt flow.	
Tertiary (?) sandstone: Sandstone in massive beds, medium grained, yellow with some red staining, separated by soft sandstone, much of it red, and red shale. As a mass viewed from a distance this series is pink and contrasts with the yellow sandstone below. No fossils seen. Thickness of part visible (estimated)	1,500

[The exposure of the pinkish sandstone unit described above lies 3 miles south of the exposures described below, but viewed from a distance and considering isolated exposures between it seems to succeed the lower beds with very little interval or overlapping.]

Cretaceous (?) sandstone:	
Sandstone, heavy bedded, medium grained, buff	300±
Sandstone, red and purplish, with some shaly layers	55
Sandstone, buff and white, heavy bedded	115
Sandstone, buff to white, medium grained; in heavy beds with soft sandstone and shale between. Lowest bed has dark limonitic joint surfaces	290
Shale, gray, clayey, and gray carbonaceous sandstone that contains plant fragments	30
Quartzite, dense, reddish and gray, fine grained	3
Sandstone, light gray to brown, dense, with intercalated gray and purple shale. Some of the sandstone has carbonaceous matter, and much of it is soft, though hard layers stand out here and there	90
Thickness of Cretaceous (?) sandstone.	883±
Cretaceous (?) shale:	
Shale, steel-gray "gumbo"	40
Shale, brick-red, with some thin layers of white limestone	55

Cretaceous (?) shale—Continued.	Feet.
Shale, greenish gray, sandy and platy sandstone	45
Thickness of Cretaceous (?) shale	140
Jurassic limestone and shale:	
Limestone, platy, brownish gray, crystalline; oolitic in part; *Pentacrinus* and *Ostrea* scattered over surface	2
Shale and platy limestone, light gray with greenish cast; some of it oolitic, some sandy. The limestone is dense and hard. *Trigonia* and other pelecypods present sparingly	145
Limestone, brownish, dense, platy	5
Limestone, laminated, dense, light gray; fossils very scarce	20
Limestone, soft, earthy, cream-colored; might perhaps be called a calcareous shale	35
Limestone, dense, cream-colored; breaks with conchoidal fracture and is very fine grained	15
Limestone, soft, earthy, cream-colored	10
Limestone, dense, hard, cream-colored; with conchoidal fracture	10
Limestone, hard and soft, alternating in thin beds	15
Gypsum, with some bluish-gray shale	20
Shale, cream-colored, calcareous	15
Limestone, dense, hard, cream-colored; a few poorly preserved pelecypods observed	5
Shale, greenish gray	15
Shale, brick-red	5
Gypsum	10
Shale, brick-red; exposed	50
Interval, mostly concealed, probably red shale and sandstone	100±
Thickness of Jurassic limestone and shale	477±
Jurassic sandstone: Sandstone, white, coarse grained, with marked eolian cross-bedding. Thickness not determined.	

22. *Section through basal beds of Moenkopi formation at head of Virgin Narrows, 3 miles southwest of Bloomington, Utah.*

	Feet.
Moenkopi formation:	
Rock Canyon conglomeratic member:	
Conglomerate of pebbles and angular fragments of limestone and chert as much as 1 inch in diameter	2
Concealed interval	8
Conglomeratic sandstone, grayish brown.	3
Conglomerate of chert pebbles with some limestone pebbles; limestone cement. Pebbles as much as 5 inches in diameter. Individual beds 5 feet thick	60
Kaibab limestone:	
Harrisburg gypsiferous member absent.	
Limestone, hard, cherty, gray.	