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No. 6.—A GEOLOGICAL EXCURSION IN THE GRAND CAÑON DISTRICT.

BY DOUGLAS WILSON JOHNSON.

Introduction.

The salient features of the Grand Cañon district have been made familiar by the classic works of Powell and Dutton, and by the more detailed local studies of later observers. An approximately parallel series of north-south faults and folds divides the district into a number of subordinate plateaus, as indicated on the accompanying sketch map (fig. A).

North of the Colorado River the several plateau blocks are called from east to west, the Marble Cañon Platform, the Kaibab Plateau, the Kanab Plateau, the Uinkaret Plateau, and the Shivwits Plateau. South of the river the displacements are less prominent, and have not been carefully traced. Hence a single name, the San Francisco Plateau, is given to this portion of the district.

The name Colorado Plateau has often been applied to this southern area, but such usage leads to confusion, inasmuch as the whole province is known as the Colorado Plateau province. It seems better to follow Powell ('**75**, pp. 186, 195; '**95**, p. 94) in his employment of the name San Francisco for this subdivision of the province. Gilbert ('**75**, p. 47) formally applies the name Colorado Plateau to this area but later speaks of it repeatedly as the San Francisco Plateau (Gilbert, '**75**, pp. 109, 116, 542). Robinson ('**07**, p. 109) has recently defined the limits of this particular subdivision of the plateau province, and employed the name San Francisco to designate it. The name is appropriate, for the district is dominated by the San Francisco Mountain group, of which San Francisco Peak is the highest point, while a large part of the area is included in the San Francisco Forest Reserve. The name Coconino Plateau is generally restricted to the higher portion of the San Francisco Plateau lying south of the Kaibab.

The following notes were made during the summer of 1906 in the course of a wagon trip from Prescott, Arizona, to Salt Lake City, Utah, and are offered as a brief contribution to our knowledge of the physiographic features of the Grand Cañon district.

In the course of this trip we followed along the western side of the Echo Cliffs Monocline for sixty miles, making three traverses across

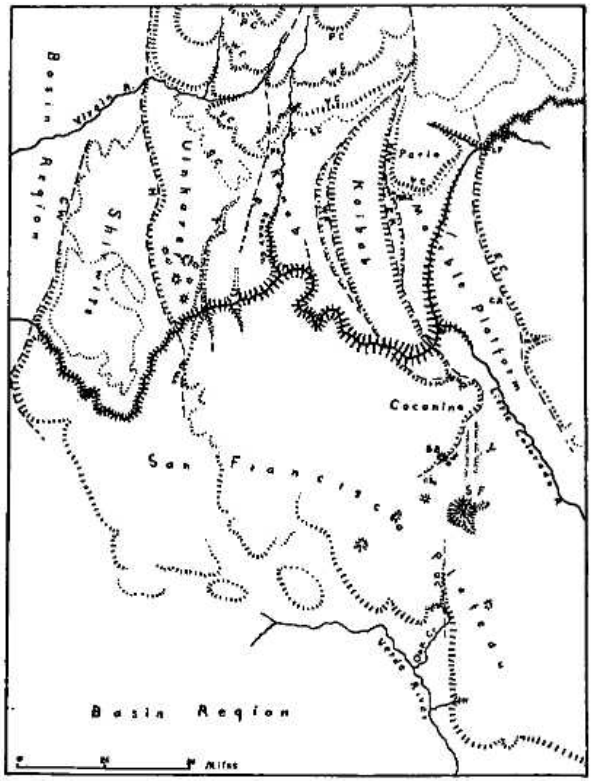

Fig. A.— Sketch map of Grand Cañon district.

the cliffs to their eastern side. We examined the East Kaibab Monocline for several miles north and south of House Rock Ranch, finally

passing up over the surface of the great double fold to the summit of the Kaibab Plateau. Passing down Jacob's Cañon we had an opportunity to see the West Kaibab Fault where this cañon opens on the Kanab Plateau at the face of the fault scarp. At Pipe Spring we encountered the Sevier Fault, and followed it southwestward for ten or twelve miles. Turning west, we reached the northern end of the Toroweap Fault and followed it southwest to a point near the Grand Cañon. Returning to Pipe Spring along the Toroweap and Sevier Faults, we next turned westward, crossing the Hurricane Fault near the Arizona-Utah line, and followed it northward into Utah.

In meeting the expenses of the excursion, we were aided by grants from the Massachusetts Institute of Technology and the Sturgis-Hooper fund of Harvard University, and by private contributions from Mr. George H. Crocker, Sr., and other friends of the Institute. Our party included Dr. H. W. Shimer of the Institute, and Mr. C. H. Decker, E. M., of Bingham Cañon, Utah.

It is not necessary to preface these notes with any extensive review of the literature. A short summary of observations made by previous workers in the Grand Cañon district, together with a fairly full bibliography will be found in one of Davis's ('01) papers cited below. It is sufficient to note in the present connection that two theories have been entertained regarding the relative ages of the displacements and the main drainage lines of the district. According to Dutton, the courses of the Colorado River and its main tributaries were established before the faults and folds came into existence. The development of the displacements at a much later period was so gradual that these main drainage lines were able to maintain their courses, cutting their channels downward as fast as uplift occurred, wherever barriers were raised across their paths. In other words, the drainage lines are older than the lines of displacement; the Colorado, with its main tributaries, is an antecedent river system. The same conclusion had been reached by Powell ('75, p. 198) some years earlier.

An alternative theory has been advanced by Davis ('01, '03). According to his interpretation the displacements are much older than supposed by Powell or Dutton. After the displacements occurred, the region was reduced to a peneplain. Across this surface of faint relief the Colorado river system found its way, its course having been determined in part by a series of complex adjustments during the cycle which ended in the peneplanation, while in places the stream

courses came to lie across the lines of displacement because the base-levelling process had often reduced hard and soft rocks on the two sides of a displacement to much the same level. Subsequent elevation permitted the river to entrench itself. Weak rock areas were quickly swept away, leaving resistant areas as higher plateaus, the lines of displacement usually marking the boundaries between the two. According to this theory the displacements are older than the river's course. From the standpoint of the present cycle, the Colorado is a structurally superposed river system, having been let down from the surface of the former peneplain.

One object which our party had in view was to test the above theories by personal observation in the field.

Faults of the San Francisco Plateau.

Under this heading are briefly considered several fault lines which we encountered on our way across the San Francisco Plateau, from the termination of the plateau in the great escarpment overlooking the valley of the Verde River, to the crossing of the Little Colorado River. These fault lines we could not trace far, nor study carefully, because of limited time. They are of minor importance when compared with the great displacements farther north, but indicate a more strongly faulted condition of the San Francisco Plateau than is usually ascribed to this part of the district.

Our approach to the San Francisco Plateau from the Basin region was by a road which follows up the valley of Oak Creek until near the escarpment; here we entered Bear Wallow Gulch (pl. 17, fig. 1), a small tributary cañon, and made the ascent of the escarpment near the head of the gulch. As seen from the Basin region, the scarp is wonderfully abrupt, and the angular changes in direction of the cliff line suggest the influence of faulting. In the face of the scarp, minor faults are occasionally seen. Bear Wallow Gulch, a tributary to Oak Creek, appears to be developed along a northeast-southwest fault line, and the contact between the Lower Aubrey red beds and the overlying crossbedded sandstone is somewhat higher on the northwest side than on the southeast. The wagon road makes the steep ascent of the escarpment, or the Mogollon Rim as it is locally called, by a series of zigzags, near the head of the gulch. At the first of the westernmost

bends in the road the red beds are seen dipping steeply to the southwest where they are dragged up along a fault plane. Farther up, the grey crossbedded sandstone is similarly affected. The continuation of this fault toward the southeast is distinctly visible on the southeast wall of the valley, where the lava capping the crossbedded sandstone abuts against the sandstone at the contact, indicating a considerable displacement. It would appear that the general trend of the displacement where it crosses Oak Creek is northwest-southeast.

From the first western bend in the road, above referred to, one has a splendid view of a prominent fault in one of the outlying mesas (pl. 17, fig. 2, *F*), where the lava-capped crossbedded sandstone on the eastern side of the displacement has dropped down 800 or 1,000 feet (estimated). This fault (which appears to be independent of the one just described) has a north-south trend and coincides with Oak Creek for an unknown distance northward, and may be called the Oak Creek Fault (fig. A, *O. C.*). The eastern side of Oak Creek is thus distinctly lower than the western side. Near the outlying mesa, however, the creek swings to the east of the fault line, leaving a fragment of the downfaulted block west of the creek, and affording the precise contact visible in the end of the mesa. It is evident that the lava is older than the faulting, and from the character of the contact between the lava and underlying sandstone it appears that the lava was outpoured upon a surface at least somewhat diversified, with a valley several hundred feet deep near the present location of Oak Creek.

The topographic features along this portion of the great escarpment terminating the Plateau Province show a fairly pronounced angularity, while segments of the escarpment and portions of the stream courses are relatively straight for considerable distances (see Verde sheet, U. S. topographic atlas). The location of Upper Oak Creek has evidently been determined by the Oak Creek Fault. In like manner, Bear Wallow Gulch appears to have been eroded along a fault line. There is thus a suggestion that faulting has exerted an important control over erosion in this region. More field work will be necessary before the evidence in favor of general fault-control can be regarded as conclusive.

In the vicinity of Oak Creek the beds of the plateau series dip gently northward, thus preserving the general dip observed in other parts of the San Francisco Plateau. Farther north the dip has carried the crossbedded sandstone below the surface, and the overlying Aubrey

limestones constitute the upper member of the sedimentary series. The surface remains fairly uniform, so far as we could judge, and it is for the most part covered by basalt flows (whose appearance indicates that they should be classed with the recent rather than with the ancient basaltic outpourings recognized elsewhere in the Plateau region). These relations suggest a peneplain surface bevelling the underlying inclined sediments and covered with sheets of lava. Robinson ('07, p. 109–129) has recently presented evidence from other localities pointing to the same conclusion. The displacement of the lava along the Oak Creek Fault indicates a relatively recent date for the fault, and it is probably correlated in time with the more recent movements along the Hurricane Ledge in the vicinity of the Virgin River, described below.

From Cedar Spring, (fig. A, *C. S.*) northwest of San Francisco Mountain, a broad valley or wash, known as Hull Wash (fig. A, *H. W.*) runs northeast to the Little Colorado. The northwestern side of this wash is bounded by a rather prominent line of cliffs. For long distances the cliff-line is remarkably straight, and small valleys often debouch from the face of the cliffs into the broad wash through sharply cut V-shaped openings, rather than by gradually widening valley mouths. It is believed that the cliffs have been developed along a fault line trending northeast-southwest. Baker's Butte (fig. A, *B. B.*), a volcano six miles northeast of Cedar Spring, was apparently formed across the line of displacement.

A short distance west of Lockett's Tank (fig. A, *L.*) there is a north-south line of cliffs several miles in extent, due either to a faulting movement that dropped the area west of the fault line, or to erosion on a faulted mass. The face of the cliff is of lava, as is also the floor of the valley just west. But limestone appears a short distance back of the cliff face. No time was available for careful study, but the features seemed to indicate that a broad north and south valley, possibly related to an early fault line, had been floored with lava, while a recent uplift along the eastern side of the valley had developed the west-facing scarp. A narrow gorge passes from the broad valley eastward through the scarp. Lava flowed through this gorge, and for several miles along its continuation eastward across the plateau. Much of the lava has been removed from the eastern part of this channel, but toward its western end the lava is still in place in the bottom of the gorge. Lockett's Tank is a pool developed where the run-off

from occasional heavy rains drops from the surface of the lava down to the bottom of the limestone gorge from which the lava has been largely removed (Davis, '01, fig. 13).

A few miles farther west is another north and south line of cliffs, developed in limestone, and dissected by small ravines which open on steep alluvial cones well up the face of the cliff. This line of cliffs faces east, and forms the west side of a valley which has less regular limestone cliffs, of less altitude, on its eastern side. The relations suggest a north-south fault with a downthrow toward the east. Toward the northern end of the east-facing scarp there is a low hill in front of the cliffs which seems to be a down-faulted block. Toward the southern end a side valley from the west enters through the cliffs. From this side valley lava has entered the main valley and floored it with igneous rock in very recent geological time. Lava has also entered the main valley through shallow ravines cut in the face of the cliffs. The amount of displacement in both of these north-south faults is small.

If our observations are correctly interpreted, there are displacements south of the Grand Cañon in greater number than has generally been supposed, but less extensive and much more irregularly developed than the great displacements north of the Cañon. Careful field work will be necessary before the detailed relations can be ascertained.

Echo Cliffs Monocline.

Of our observations along the Echo Cliffs Monocline, only those which bear on the origin of the peculiar form of certain parts of the cliffs need be noted here. Brief mention, however, may be made of the remarkable landslides which begin toward the northern end of the cliffs and continue around the base of the Paria Plateau to House Rock Valley, a distance of some fifty miles (pl. 18, fig. 1). These landslides have been described by Davis ('01, p. 121–126) who believes them to be the result of a revival of erosive activity following the uplift of the region which permitted the incision of the present Cañon. We did not observe the slides until we reached a point south of Bitter Spring, where a branch of the Colorado River first reaches eastward to the foot of the cliffs. The sudden development of landslide topography at this point is in accordance with the interpretation quoted above.