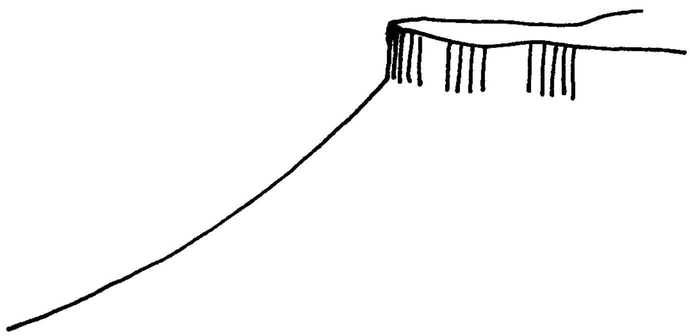

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DOWNSLOPE MOVEMENT OF ROCKS ON RED BLUFF HILL

by

Luna B. Leopold
University of California
Berkeley, California 94720

In Sublette County, Wyoming, there are large areas of table-like mesa lands representing the remnants of dissected pediments. The highest of these are seen as Mount Airy and Cora Butte, standing as much as 500 m above the adjacent valley floors. Various levels of these pediment surfaces exist. Each is characterized by a veneer of stream-rounded gravel lying on the cut surface of the local bedrock, usually Wasatch formation of Eocene age.

Broad valleys were cut into these pediment surfaces and, during the Pleistocene, the valleys were successively filled and evacuated by outwash gravels emanating from the glaciers in the mountains. As far as is presently known, all these outwash gravels lie within the valleys cut into the previous pediment surfaces and consequently, the pediments, standing as they do higher than any glacial materials, are considered of pre-Pleistocene, probably Tertiary age. Owing to the fact that the pediment is cut on Eocene beds, it is presumed that the dissection of the pediments took place in mid-Tertiary time, later than the Eocene but pre-Pleistocene.

The presence of these alluvial gravels lying at high elevations, leads to a characteristic condition of the hillslopes developed on the back-wasting slopes. The stream gravel is eroded from the nearly horizontal cover and moves with time gradually down the hillslopes, mixed with colluvium partly derived from the windblown material of presumably Pleistocene and Holocene age. A first glance at such hillslopes would lead one to believe that the whole hill is made up of gravel mixed with finer material. But in fact, the gravel is coming from discrete, nearly horizontal thin beds at the mesa top. Gravel constitutes nothing more than a veneer over the hillslopes as a result of downslope motion of the rounded, mesa-top rocks.

Another characteristic of these hillslopes is the fact that at the base of the steepest portion, the gravel cover abruptly ends. Lower on the foot slopes, the surficial material appears to be only sandy silt of colluvial origin. Why the gravel appears to abruptly end at the bottom of the hill is not entirely obvious and it was deemed worthy of investigation to elucidate, if possible, the nature of the processes on these slopes.

An experiment using painted rocks was, therefore, set up on a typical hillslope of the nature just described. This particular hill, which we have called Red Bluff Hill, is immediately south of the road known as North Cottonwood, a gravel road which heads west from U.S. Highway 189 about halfway between Daniel and Big Piney, Wyoming. Red Bluff Hill is 7.2 miles west of the Highway 189. The latitude of the site is 42°46'30"N, and its longitude is 110°12'00"W.

The experiment was laid out on a south-facing slope with contour lines that are essentially straight and oriented in an east-west direction. A topographic map of the location is shown in Figure 1.

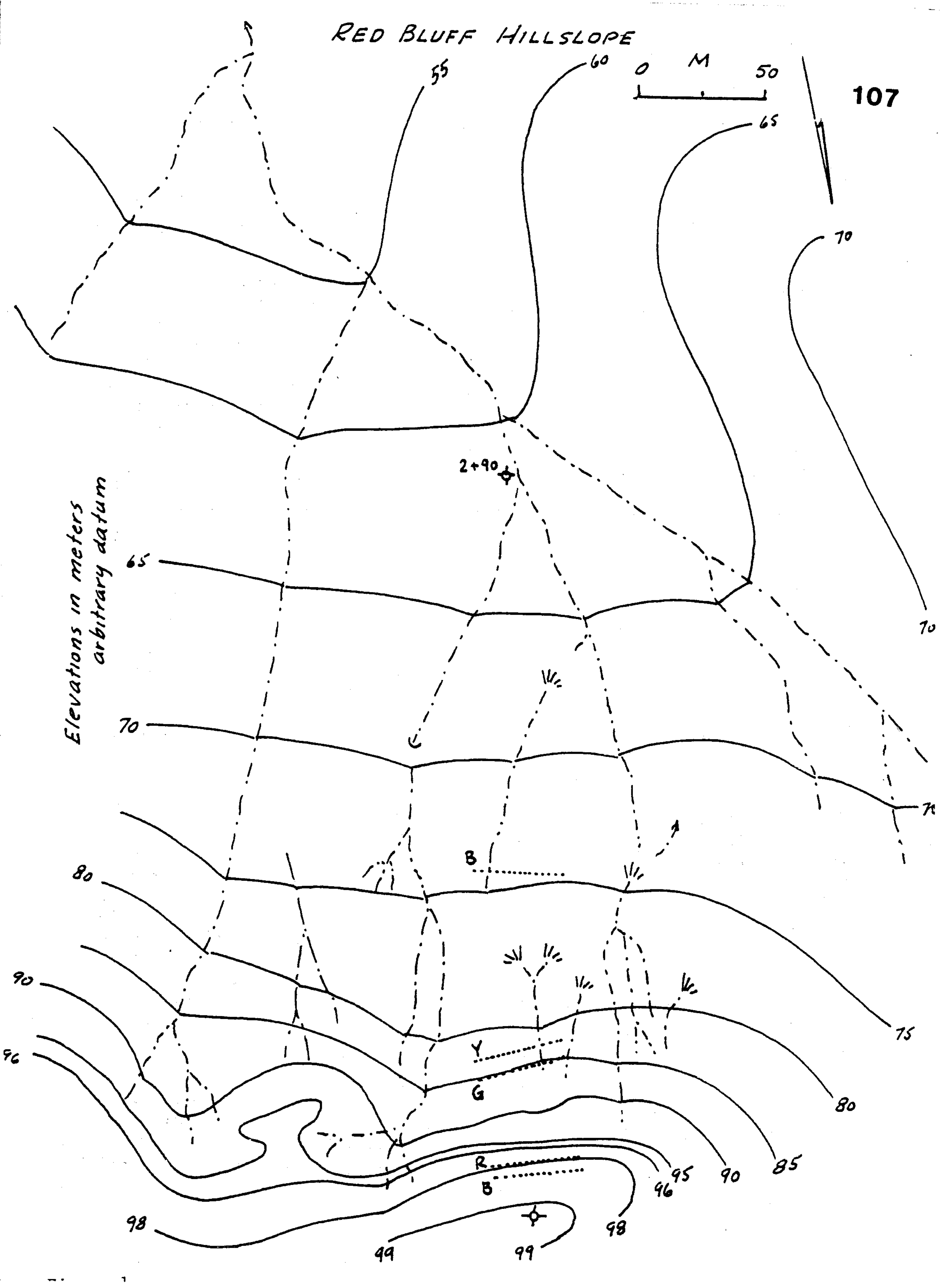
Near the upper portion of this slope, 5 lines of painted rocks were laid out essentially on contour. Each line is approximately 30 m long. Within each meter of length along the line, one rock of each of the following sizes was placed equally spaced and in the following order of size: a 90 mm rock was followed by one 16 mm in diameter, then 64 mm, 22, 45, and 32 mm, in that order. All rocks in a given line were painted the same color. The uppermost line is painted blue, and in the downslope direction the colors go red, green, yellow and black. Thus, in each line there are 30 rocks of each of six sizes or 180 rocks in each line and thus, 900 painted rocks total on the hillslope. The lines were carefully laid out between iron stakes driven as benchmarks marking the ends of the line. The procedure was to come back after a year and measure the distance each rock has moved from its original position.

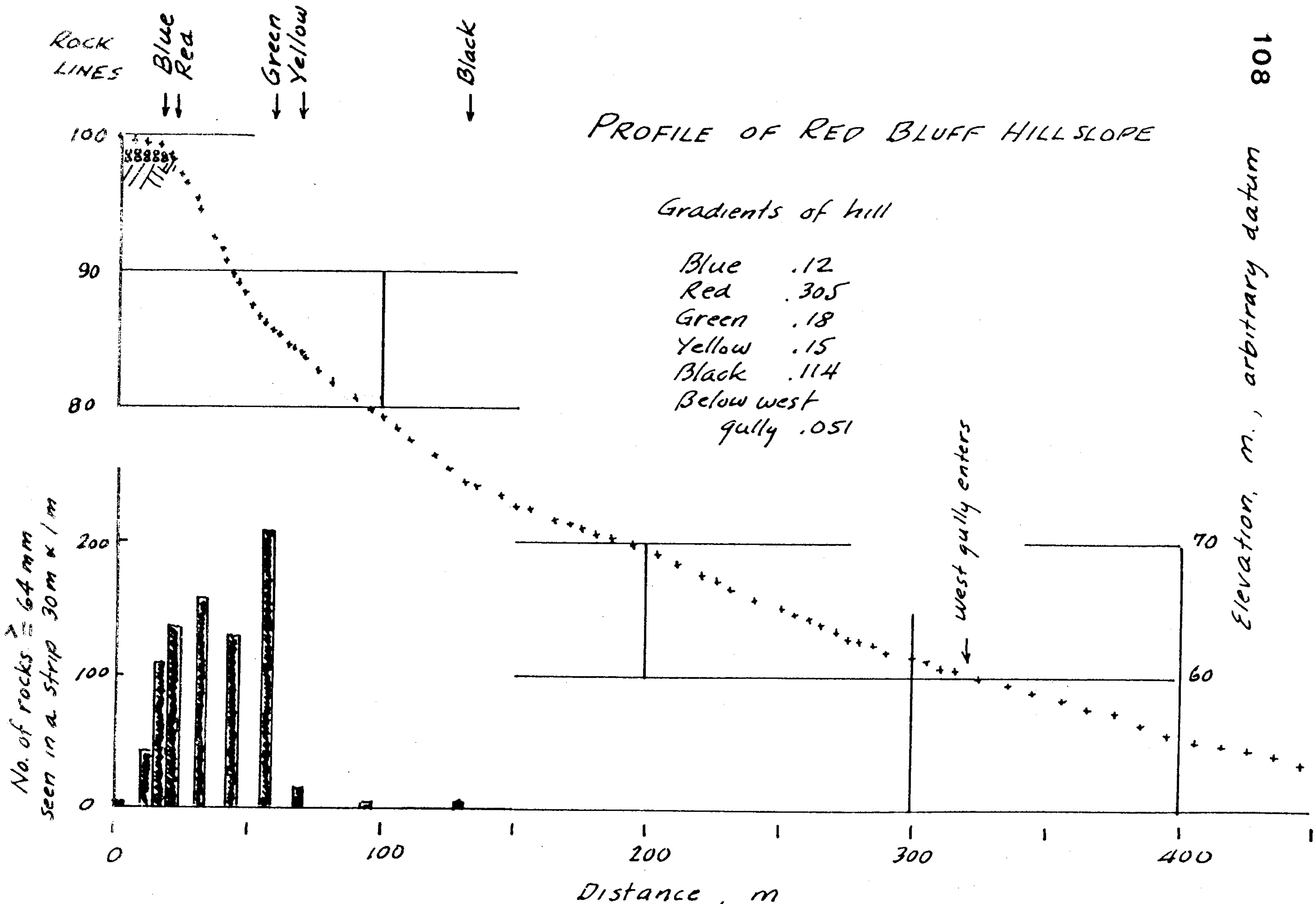
The results described here came from the placement in August 1980, measured again in 1981, and the measurements here reported were made in July of 1982.

A profile of the hillslope is presented in Figure 2. Diagramatically, the location of the layer of stream-laid rounded rocks is shown between elevation 98 and 99 on the vertical scale. On this profile, the location of the 5 painted rock lines is indicated, and on that sheet in tabular form, the gradient of the hill at each of the rock lines, also, is noted (Figure 2).

To quantitatively describe the natural occurrence of rocks on this surface, a graph is placed in the lower lefthand corner of Figure 2 which shows a count of the number of rocks ≥64 mm in diameter found along a strip, 1 m wide and 30 m long, along the contour. It can be seen at the very top of the hill, at distance zero, only a negligible number of rocks of this size were counted. Between distance zero and 60 m from the top of the hill, the number of such large rocks increases more or less progressively and reaches a maximum near the line of painted green rocks at 60 m from the top of the hill. As can be seen on the bar graph, this accumulation of rocks at the surface ends abruptly at about 70 m. At a distance of 130 m from the hilltop near the black painted rock line at the base of the steep portion, very few rocks of this size are found.

Before discussing the quantitative results of rock movement, some statements should be made concerning the probable processes involved in the movement itself. At this location, elevation about 2300 m, mean sea level, the annual precipitation is about 25 cm, more or less uniformly distributed through the year. It has a frost-free season of less than 4 months and a long period of winter snow cover. Summer precipitation after mid-June is in the form of thunderstorms which can be severe.


RED BLUFF HILLSLOPE
0 M 50
Elevations in meters
arbitrary datum
55
60
65
70
75
80
85
90
95
96
98
99
2+90
B
Y
G
R


PROFILE OF RED BLUFF HILLSLOPE
Gradients of hill
Blue .12
Red .305
Green .18
Yellow .15
Black .114
Below west gully .051
ROCK LINES
Blue
Red
Green
Yellow
Black
West gully enters
100
90
80
70
60
Elevation, m., arbitrary datum
No. of rocks ≥ 64 mm seen in a strip 30m × 1m
200
100
0
0
100
200
300
400
Distance, m

The hillslopes bordering the mesas are relatively free of rills. On Red Bluff Hillslope a few minor rills can be seen. Their location is shown on Figure 1 and most are only 1 or 2 dm deep and seldom as much as half a meter wide. Many rills terminate in a small fan as shown on the figure. In the area mapped, only 1 headcut was noted and it can be seen near the center of the page of Figure 1. These surfaces are more or less covered with sage (Artemesia tridentata). Inspection of the small fans found on the lower slope may show an internal structure that strongly suggests their origin as mudflow deposits, but gravel cropping out on the margin of the rills that do exist and in the small fans is surprisingly sparse. The material would be described as silty sand with a minor admixture of gravel.

The relative paucity of rills implies that most of the movement of the larger rocks must take place by sheetflow, by downslope motion due to wetting and drying, and to some minor extent frost action. Movement by gravitational sliding, by sheetwash, and by wetting and drying could occur both during the spring snowmelt season and during thunderstorm runoff in summer.

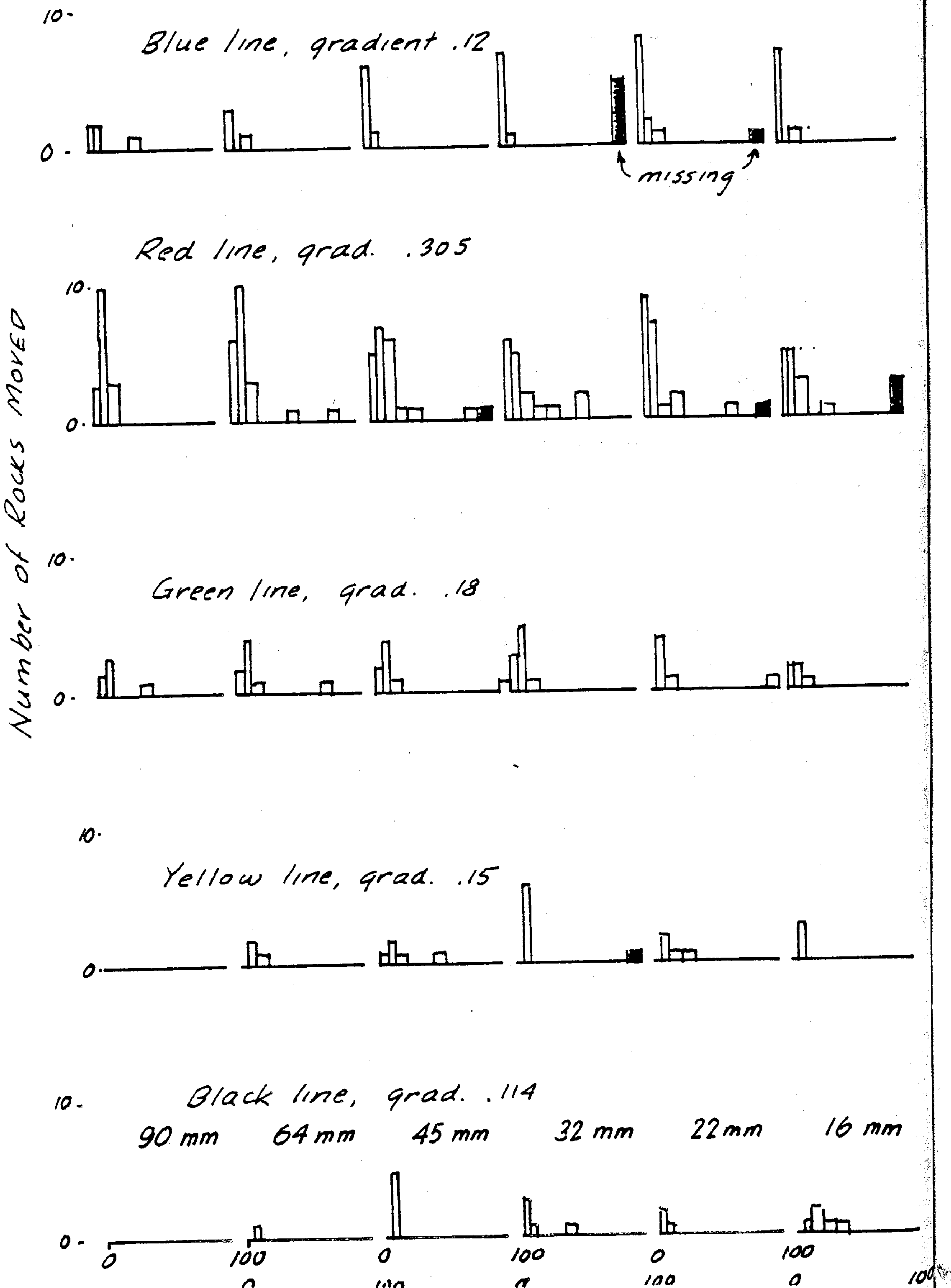
The distance and number of rocks moved in the two-year period of observation is shown in Figure 3. Separate graphs are drawn for each rock size and for each rock line. Only in the line of blue rocks, where the hillslope has a gradient of .12, does there seem to be any indication that small rocks are more likely to move than large ones. On the red line, which has a gradient of .305, there is certainly no tendency for small rocks to move more than large ones. In the three lower rock lines, rocks of intermediate size seem to move somewhat more often than rocks of either small or large size. One might have expected that small rocks would move both farther and in greater number than large ones but this does not seem to be shown by the data presently available.

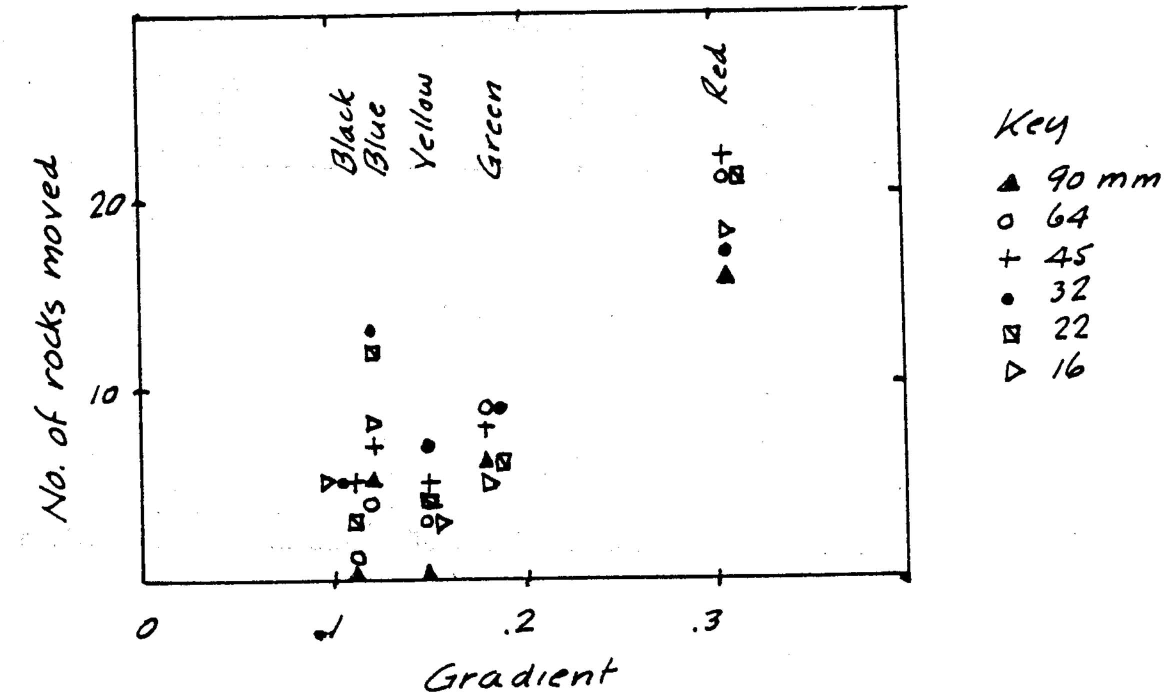
There is certainly some relation between the number of rocks moved (quite apart from distance) and the local gradient. This is shown on Figure 4. A larger number of rocks move on the high gradient portions of the hillslope than on the low gradient portions. Figure 4 differentiates the rocks by size and one might again suppose that small rocks would move in larger number than large ones but that supposition is not sustained by the data.

Because there does not appear to be any definite relationship between the distance or the number of rocks moved and their size, it is justifiable to examine the total movement including all rocks and all lines. If the distance each rock moved is tabulated and the total distance of all rock movements summed, one obtains a total movement for the 900 rocks of 3,654 cm. Thus, the average movement of rock was 4.1 cm in two years.

Although the amount of data available for extrapolation is very modest, some orders of magnitude might be obtained by the following assumptions. If the thickness of the gravel layer providing the source of rocks is 1 m and its face stands at a slope angle of .31, the slope distance the topmost rock must move before it leaves the outcrop is 1.1 m. The grain size distribution of the source material is as follows: 90 mm, 5.4%; 64 mm, 7.3%; 45 mm, 13.0%; 32 mm, 17.5%; 22 mm, 23.2%; 16 mm, 18.4%; 11 mm, 8.6%; 5.6 mm, 1.7%; 4 mm, .6%; and <4 mm, .1%. The modal size, which is, also,

DISTANCE & NUMBER OF ROCKS MOVED IN 2 YRS, 1980-82
Red Bluff Hill, 30 rocks of each size in each line





ROCK MOVEMENT AS FUNCTION OF HILLSLOPE GRADIENT

RED BLUFF HILL 1980-82

Figure 4.

approximately the median size, is thus 22 mm. Taking the median rock diameter of 22 mm and assuming that it has to move a distance of 1.1 m at a rate of 2 cm per year, it would traverse the length of the outcrop in about 50 years. Assuming that the outcrop recedes at the rate of 1 rock diameter or 22 mm per 50 years, the outcrop would recede at about .4 m per thousand years, in the present climate under the present processes.

Knowing that present processes would not necessarily be applicable for long periods of geologic time, one can nevertheless get some general impressions by noting that at the rate at which the rocks were observed to move, an outcrop such as the one on Red Bluff Hill would recede approximaterly 1 km in about 2 million years.

The width of many valleys between the residual mesas is 1 to 2 km. It is possible to imagine that the valleys observed could have been develope in the last quarter of Tertiary time before the glacial outwash material came from the mountains to be deposited in the cut valleys.

Previously, it was noted that the surface rocks abruptly disappear about 70 m from the hilltop. The data do not provide, in themselves, an explanation for this observed fact. Two explanations have been considered. First, the present processes lead to sufficient production of colluvial material from the bedrock to cover up those rocks that reach the lower part of the hillslope. If this were true, pits dug into the surficial material in the lower portion of the hill, would either expose layers of rocks derived from upslope, or, at least, reveal such rocks scattered through the colluvial material. To the extent that we have dug such pits to test this hypothesis, surprisingly few rocks have been found in the top half meter. There were so few rocks found in these pits that one is lead to consider an alternative hypothesis. Secondly, it is possible that discharge increases downstream or downhill on an unrilled hillslope in proportion to the distance from the hilltop. Therefore, the depth of flow will, also, increase progressively downslope. If such is the case, and recalling that there are very few rills on the hillslope, it might be supposed that the increased depth would provide sufficient bed shear stress to move rocks lying at the surface and carry them down to the major channels in the valley bottom a kilometer or so downstream. If this were the case, it would mean that the increased depth of water downslope gradually overcompensates for the flattening of gradient and the rocks on the lower footslope, are more likely to be carried away than on the steeper portion of the upper hill where the flow depth is very small.