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Field Method for Hillslope Description

Luna B. Leopold and Thomas Dunne

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FIELD METHOD FOR HILLSLOPE DESCRIPTION

by

Luna B. Leopold and Thomas Dunne

for

The Commission on Present Day Processes
International Geographical Union

(Authors' address: U.S. Department of the Interior, Geological Survey, Washington, D.C. 20242, U.S.A.)

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EDITORS' PREFACE

The publication of the Technical Bulletins by the British Geomorphological Research Group arises out of a common need, expressed by the Group as a whole, to have a source of standardised information relating to increasingly sophisticated methods of data collection. The demand for such Bulletins is threefold: for comparability of results among workers in the field; for the dissemination of information concerning techniques, particularly where this speeds up and facilitates the execution of a research programme, and for manuals which stress particularly the uses and limitations of the techniques in the field of geomorphology.

The authors and editors have endeavoured to ensure accuracy and where necessary the manuscripts are being forwarded before publication to interested commercial firms for critical evaluation. In other respects the authors alone are responsible for the views expressed.

The editors would like to express their appreciation to the authors, the executive committee and the technical publications sub-committee of the B.G.R.G. for the support they have given in getting this Bulletin to press and particularly to Professor K. M. Clayton for his advice and help in publication.

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INTRODUCTION

It is recognized that one factor hindering knowledge of hillslope formation is lack of uniform data on what are the shapes of hills in various parts of the world. The Commission is taking the lead in encouraging scientists to assist in the collection of a uniform set of data which merely describe a hillslope. After such simple data are available, many more sophisticated studies will be required on process, rate of process activity, and other matters.

Some data already collected using the procedure described below give an interesting comparison of the hillslope profiles for different lithologies and different climates. These data give added impetus to further collection.

Under the auspices of the Commission, such data will be published or otherwise made available to interested scientists. The exact form and place of publication are not yet determined.

Any survey data which are collected will be gladly received by the Commission. The information compiled in a manner similar to the example enclosed should be sent to the Secretary of the Commission, Dr. Luna B. Leopold, U.S. Geological Survey, Washington, D.C. 20242.

+The Commission on Present Day Processes, International Geographical Union.

DESCRIPTION OF PROCEDURE

1) Choice and location of profiles

Slopes chosen for survey are presently confined to those with approximately straight contours and simple profiles. They may be rilled or unrilled, and may terminate at a local base level, preferably a river channel, stream, or dry channel. Special attention should be given to ensuring that the survey of the hillslope profile extends to the local base level.

To choose a slope for survey, it is desirable to inspect the variety of hillslopes occurring in the region in order to determine which slope ought to be considered typical or significant.

The profile should be permanently marked by bench marks at both ends. These are established by driving steel bars into the ground until they are almost flush with the surface. A length of at least 2 feet is necessary for stability. To ensure that they will not be disturbed, they should be as inconspicuous as possible. It is essential, therefore, to reference them to other, readily identifiable features, such as road markers, nearby peaks, or conspicuous bedrock outcrops. The bench marks may be located by the intersection of tapes, by transit or compass bearings, and taped, paced, or estimated distances. Relocation will be facilitated by the inclusion in the original field notes of any details of the hillslope and its environs which impress the surveyor. An evocative name will also establish the site in one's mind, and also facilitate reference. A sketch map of the general location of the hillslope, and an account of how to reach one of the bench marks from a nearby highway or other feature should be included. In any published description one should also include the latitude and longitude of the site. It is helpful to include its position within a township or other administrative unit, or a grid reference on a topographic map.

In preparing a file of essential facts to be published, after the details of location, the file should contain a description of the hillside itself. This might deal with the general nature of the topography of the hillslope; the presence or absence of rilling; the nature of its base level; and the general character of its vegetation cover and surficial material. The type of rock underlying the hillslope should also be described as far as possible. This description might include such details as rock classification; texture; dip and strike; and the intensity and direction of jointing. The regolith should be described with its characteristics of thickness, texture, presence of humus layer, permeability, structure, and density of roots. If possible, one or more photographs of the hillslope should be included in the file.

2) Survey of hillslope profile

The profile is surveyed from the upper bench mark (BM 1) to the local base level at BM 2. The bearing of this line should be included in the field notes. A tape is stretched along the profile and vertical relative elevations are determined with an engineering level at slope distances of 1, 3, or 5 meters (or 5, 10, or 20 feet), depending on the curvature of the profile and the regularity of the slope. Measurements at no less than 50 points are usually needed for a good profile. The slope distances are later reduced to their horizontal projection. Alternatively, hand level or Abney level measurements may be used to obtain the elevations.

To reduce the space required for filing and publishing the data, information is extracted from the field book for inclusion in a more concise description of the hillslope (Table 2). The distances tabulated in the description are reduced to the horizontal.

3) Survey of cross profiles

Three locations on the profile are chosen for the survey of detailed cross profiles. The objective of these cross profiles is to measure the rugosity or roughness of the slope, and they should be chosen with this in mind. They do not need to be equidistant along the profile, but should be located so as to show any differences of rugosity due to rilling, bedrock outcrops, etc. In the absence of other considerations, one might locate one cross profile at the approximate centers of the concave, convex, and straight portions of the hillslope. If it is felt that more than three cross profiles are necessary, they can be included. The cross profiles are surveyed during the measurement of the main profile by laying a tape at right angles to the line of the profile and measuring relative elevations at intervals along this tape. The cross profile should be either 40 feet with measurements at 2-foot intervals, or, with a tape calibrated in meters, the cross profile should be 10 meters long measured at 1/2 meter intervals. The survey data and computed elevations are entered in the fieldbook (Table 1). One disadvantage of using a hand level to survey the hillslope profile is that such an instrument is not accurate enough for the survey of microtopographical features of the cross profile. At each of the cross-profile locations quantitative descriptions are made of vegetation and of the size distribution of particles on the ground surface. (p 8-9)

Table 1

Sta. (ft)	B.S.	H.I.	F.S.	Elev.	Notes
BM1	1.92	201.92		200.00	Top of pin
0+00			2.67	199.25	Ground Surface
0+05			2.70	199.22	
0+10			2.75	199.17	
0+15			2.75	199.18	Hole Dug
0+20			2.72	199.20	
0+25			3.20	198.72	
0+30			3.38	198.54	
0+35			3.58	198.34	
0+40			3.78	198.14	
0+45			4.07	197.85	
0+50			4.34.	197.58	
0+55			4.83	197.09	

Cross profile at 0+55 ft.

Vegetation is Phlox spp., and occasional grasses (Pea and Agropyron spp.). Hole dug at 0+15 ft; rim elevation 199.47. Upper 0.2 feet - compact, unstructured, chocolate brown silty sand. 0.2 to 1.5 ft. - grayish fine sandy silt. No rocks at all. Small amount of clay. Roots penetrate 0.2 ft. Auger encountered impenetrable layer at 2.5 ft. - i.e. elevation of 196.97 ft. on profile. Gravel layer begins at 0+40 ft. on profile (elev. 198.14).

Explanations

Sta. - Station; 0+15 means 15 feet from beginning point; 1+20 = 120 feet.
B.S. - Backsight, in which rod is placed on a point of known elevation.
H.I. - Height of instrument (line of sight) above datum.
F.S. - Foresight in which rod is placed on a point whose elevation is to be measured.
Elev. - Elevation of the point above datum.
% Veg. - Percentage of ground covered by vegetation.

Table 1 (continued)

Cross profile at 0+55 ft-
H. I. = 201. 92 ft. Depth to bedrock approx. 1. 0 ft.

Sta. (ft)	F. S.	Elev.	% Veg.	Surficial Material
0	6. 04	195. 88	5	Bedrock 0
2	6. 09	195. 83	30	mm.
4	6. 18	195. 74	20	90 /
6	6. 08	195. 84	20	64 //
8	6. 06	195. 86	15	45 //
10	6. 13	195. 79	40	32 𝍸 /
12	6. 14	195. 78	50	22 𝍸 𝍸
14	6. 02	195. 90	30	16 𝍸 𝍸 𝍸 𝍸
16	6. 08	195. 84	20	
18	6. 23	195. 69	5	11. 𝍸 𝍸 𝍸 𝍸
20	6. 27	195. 65	5	
22	6. 29	195. 63	5	8 𝍸 𝍸 ///
24	6. 28	195. 64	10	5. 6 ///
26	6. 27	195. 65	25	4
28	6. 19	195. 73	25	<4 𝍸 //
30	6. 28	195. 64	20	
32	6. 26	195. 66	35	Soil Sample No. 1
34	6. 21	195. 71	45	
36	6. 26	195. 66	30	Surface rocks are subangular
38	6. 35	195. 57	45	to subrounded. Much quartzite.
40	6. 29	195. 63	25	Variety of colors and types.
			505	Stream deposits.
			21	
			= 24%	

Table 1. Abstract of two pages from a field book, showing the format used for recording data on a hillslope survey.

4) Description of vegetation

Vegetation is described by using the tape already laid out for the survey of the cross profile. If the tape is in feet, the vegetation cover is estimated along 2-foot increments of the tape, centered on each point used for the cross profile survey. Each tenth of a foot represents 5 percent of the 2-foot increment. The number of tenths of a foot underlain by vegetation are counted to give a measure of the cover for the 2-foot increment expressed as a percentage. If the tape is in centimeters, 50 cm would be an appropriate distance within which the number of 5 cm units underlain by vegetation would be counted. The percentage vegetated is entered into the field book under the column entitled '% Veg.' (Table 1). This is done for all the 2-foot increments (or 50 cm increments). An average figure for the cover density is then computed (Table 1). In deciding how to measure the cover density, the investigator must make a judgment about his particular area. For example, in a semi-arid environment, one might judge that in considering hillslope erosion the most important vegetative characteristic is crown density of plants providing shelter against raindrop energy. In a humid grassland or forest environment, on the other hand, one might consider that the density of stems and roots is the more important variable because of its effect upon the shear strength of the soil and its susceptibility to mass movement. Whichever measure of vegetation cover is used, it should be clearly indicated in the field book and in the description.

5) Surficial material

The size distribution of the surficial material is measured by sieve analysis if the material is fine. If a significant proportion of the surface is covered by gravel and boulders, the size distribution is measured by a combination of sieve analysis and pebble counting. Data are collected in the manner first described by Wolman (1954) for river gravels. In the vicinity of the surveyed cross profile, the investigator walks along several parallel lines, picking up a rock at each pace.

Averting his eyes, he reaches down over the toe of his boot and picks up the first rock touched by his outstretched middle finger. Each rock chosen in this way is measured across its intermediate axis (b-axis) with a scale on which are marked class intervals in millimeters. Class intervals of rock size are, in millimeters, <4, 4, 5.6, 8, 11, 16, 22, 32, 45, 64, 90, 128, etc. The class intervals differ by $\sqrt{2}$. In the field, the size is recorded opposite the appropriate lower class limit (Table 1). This makes the tabulation consistent with that for sieve analysis where the amount held on a particular sieve is tabulated against the size of the sieve opening. If the operator touches material which is less than four millimeters in diameter, he simply records one rock in a class designated 'less than four millimeters.' Rocks too large to be lifted have their b axes measured in place. The sample is considered complete when 100 rocks have been measured. If a sampling point falls on bedrock, this occurrence is noted in the field book (Table 1), but this is not counted in the size distribution. The latter consists only of discrete rock and soil particles. Later, however, the area covered by bedrock can be estimated by counting up the frequency of occurrence of bedrock in 100 'trials'. When 100 rocks have been measured, a sample is taken from the upper 2 inches of soil in the locality. This is later sieved to provide information on the size distribution of material less than 4 millimeters in diameter. If the proportion of material less than 4 millimeters is considered insignificant, sieve analysis of the fine fraction may be unnecessary.

In addition to the nature of the surficial material, an estimate of the depth to bedrock should be included for each cross profile. If necessary, the investigator may also add a description of the soil profile at each locality.

A SAMPLE OF SURVEY DATA FOR ONE HILLSLOPE 1/

Name of site: Painted Rock Slope near Red Butte, Daniel, Wyoming, U.S.A.

Painted Rock Slope near Red Butte lies 7.2 miles from U.S. Highway 189 between Daniel and Big Piney, Wyoming, on the road leading west to an entrance of the Bridger National Forest in the Wyoming Range, along the southern edge of the valley of Cottonwood Creek. (Fig. 1). It forms part of the southwestern edge of a high river terrace upon which the road is situated. The slope is approximately one-quarter of a mile north-northwest of a conspicuous conical butte formed in strongly banded red shaley material. The road makes a sharp turn to the southwest 100 feet beyond the slope, which is located approximately three-quarters of a mile northwest of a small radio station on the south side of the road.

The upper bench mark (BM 1) is a steel bar protruding 0.75 foot above ground level approximately 50 feet south of the road near the remains of an Indian campsite, marked by fractured fireplace rocks. It lies approximately 50 feet from the edge of the terrace. From this bench mark, the profile stretches downslope for a distance of 1,041 feet along a bearing of 180° Mag. to the lower bench mark (BM 2) which is a large flat rock in the more northerly of two small channels whose confluence lies 18 feet east of the bench mark (Fig. 1).

The latitude of the site is 42° 46' 30" N., and its longitude is 110° 12' 00" W. It lies within the topographic map entitled Big

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1/ This description, tables and maps, is typical of what would be published in the Catalogue of Slopes.

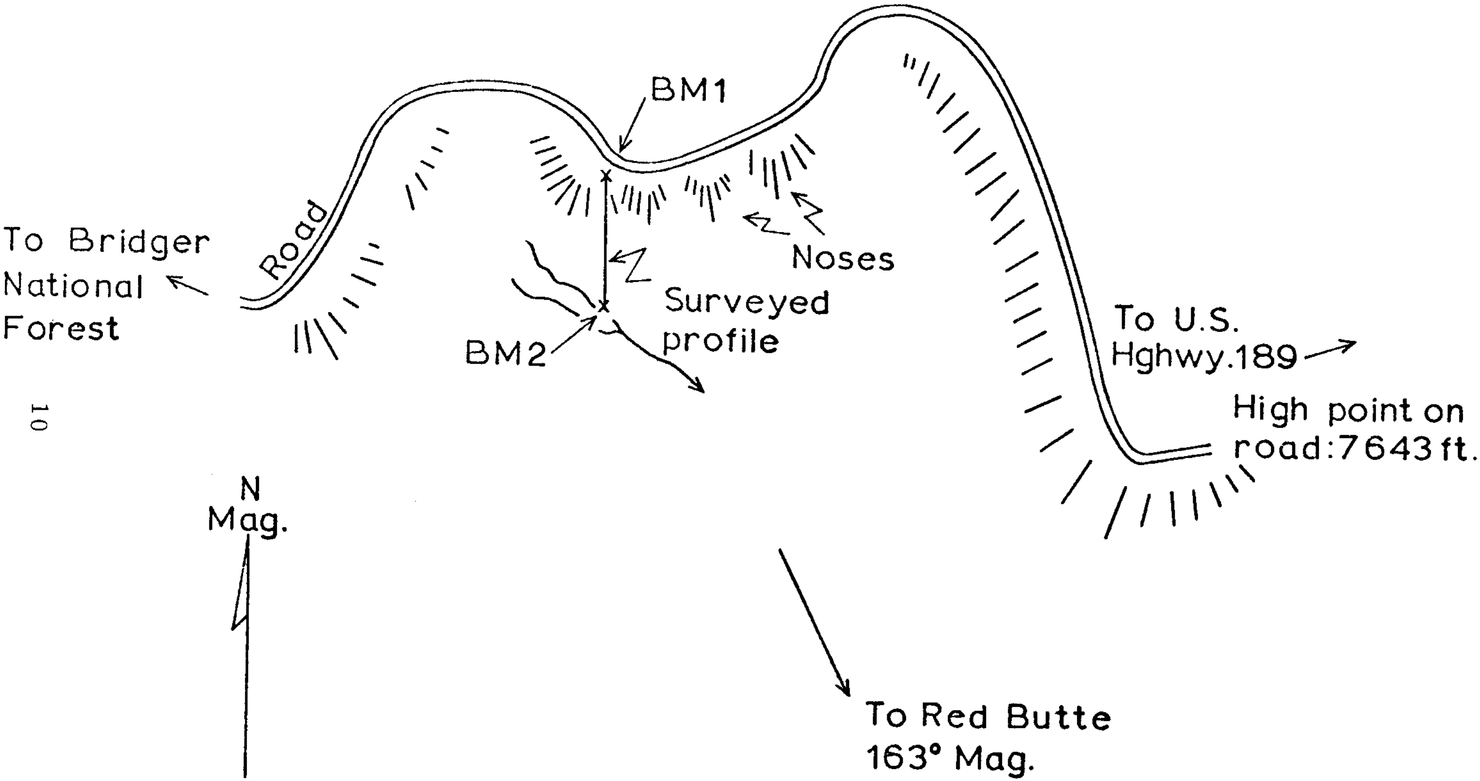

BM1
Road
To Bridger National Forest
Noses
Surveyed profile
BM2
To U.S. Hghwy.189
High point on road:7643 ft.
N Mag.
To Red Butte 163° Mag.

Figure 1.

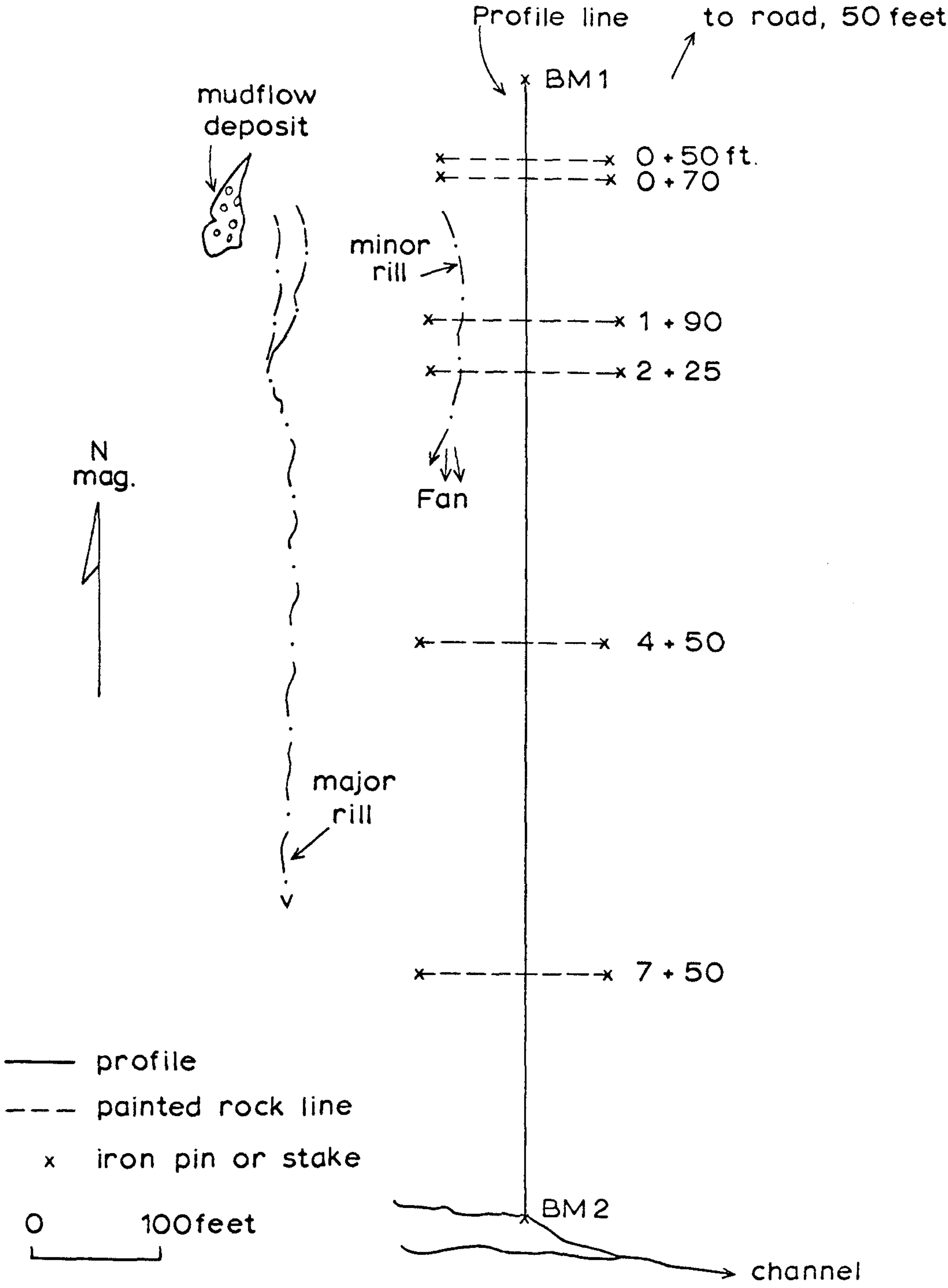
Piney, Wyoming, published by the U.S. Geological Survey in 1939, at a scale of 1 : 125,000.

The hillside forms part of the edge of a high terrace of Muddy Creek, cut on reddish-grey clayey shale of the Wasatch Formation. Its flat upper portion is covered with silty sand containing occasional subangular cobbles. A layer of gravel occurs 2.5 feet below the terrace surface. Beginning 40 feet along the surveyed profile, the ground surface is completely covered with stream-laid gravels and a small amount of weathered silty sand. Below these, at a depth varying from 3 to 18 inches, lies the clayey shale bedrock. The gravel cover stretches downslope to the 200-foot station on the profile. Beyond this, the gravel cover thins rapidly. The hillslope is drained by several small rills (Fig. 2) graded to the small channel in which BM 2 is located. This channel forms the local base level for the slope. Several small fans were observed on the hillslope studied, and in its immediate vicinity. The internal structure of these features strongly suggests their origin as mudflow deposits. One of these deposits within a quarter of a mile of Painted Rock slope contains bottles, cans, and other modern debris. The vegetation of the slope is thin. The upper terrace surface has a sparse cover of Phlox spp., fringe sage (Artemisia filifolia), and occasional grasses. Below the terrace surface, big sage (Artemisia tridenta) dominates, but Phlox spp. and various grasses are also present.

At this location, elevation 7,000 feet msl, the annual precipitation is about 10 inches 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.

Survey made by L. B. Leopold and T. Dunne, 1969. Data computed and description written by Dunne.

(The Commission report would also include a topographic map, as Fig. 1 of the report and a photograph as Fig. 4. They are, however, omitted from this example).



Profile line
to road, 50 feet
BM 1
mudflow
deposit
0 + 50 ft.
0 + 70
minor
rill
1 + 90
2 + 25
N
mag.
Fan
4 + 50
major
rill
7 + 50
profile
painted rock line
x iron pin or stake
0 100 feet
BM 2
channel

Figure 2.

In feet - Note: Distances are horizontal

Distance	Elevation	Distance	Elevation	Distance	Elevation	Distance	Elevation	Distance	Elevation
0+00	199.2	2+01.8	149.6	4+10.4	118.6	6+21.6	102.0	8+29.5	85.3
0+10	199.2	2+11.7	148.2	4+20.3	117.3	6+31.5	101.0	8+39.4	84.7
0+20	199.2	2+22.6	146.6	4+30.2	116.1	6+41.4	100.3	8+49.3	83.7
0+29.9	198.5	2+32.5	145.1	4+44.1	115.3	6+51.3	99.7	8+59.4	83.2
0+39.9	198.1	2+42.4	143.6	4+53.0	114.2	6+61.2	98.9	8+69.2	82.5
0+49.9	197.6	2+52.3	142.0	4+62.9	113.3	6+71.1	97.9	8+79.1	81.6
0+59.9	196.1	2+62.2	140.7	4+72.8	112.3	6+81.0	97.0	8+89.1	81.2
0+69.3	192.8	2+72.0	138.9	4+82.7	111.3	6+90.9	96.4	8+99.0	80.4
0+78.4	188.7	2+81.9	137.3	4+92.6	110.4	7+00.8	95.6	9+08.9	79.7
0+87.6	184.8	2+91.8	135.7	5+02.5	109.6	7+10.7	94.8	9+18.8	78.8
0+96.9	181.2	3+01.7	134.2	5+12.5	109.9	7+20.6	93.9	9+28.7	78.2
1+06.0	177.1	3+11.6	132.7	5+22.4	109.0	7+30.5	93.2	9+38.6	77.5
1+15.4	173.8	3+21.4	131.0	5+32.3	108.1	7+40.4	92.4	9+48.6	77.1
1+24.7	170.2	3+33.3	129.5	5+42.2	106.6	7+50.3	91.6	9+58.5	76.5
1+34.2	167.2	3+41.2	128.1	5+52.2	106.6	7+60.2	90.7	9+68.4	75.9
1+43.6	163.7	3+51.1	126.6	5+62.1	105.8	7+70.1	89.8	9+78.4	75.4
1+53.1	160.7	3+61.0	125.2	5+72.1	105.4	7+80.0	89.0	9+88.3	74.8
1+62.6	157.7	3+70.9	123.7	5+82.0	104.8	7+89.9	88.2	9+98.3	74.5
1+72.3	155.4	3+80.8	122.4	5+91.9	104.2	7+99.8	87.4	10+08.2	73.8
1+82.1	153.2	3+90.7	121.4	6+01.8	103.6	8+09.7	86.8	10+18.2	73.7
1+91.9	152.2	4+00.5	119.7	6+11.7	102.7	8+19.6	86.0	10+28.2	73.1

Table 2 Sample Tabulation: Distances and elevations for the profile of Painted Rock slope near Red Butte

Table 3

Cross profile at 0+55 feet

Sta.	Elev.
0	197.15
2	197.13
4	197.13
6	197.12
8	197.02
10	197.05
12	197.04
14	197.15
16	197.12
18	197.14
20	197.13
22	196.90
24	196.94
26	196.84
28	196.77
30	196.60
32	196.39
34	196.29
36	196.07
38	195.81
40	195.48

Vegetation Cover 24 % (Crown density)

Cover consists of Phlox spp., and various grasses (Pea and Agropyron).

Area of Bedrock Outcrops (%) 0

Depth to Bedrock 1.0 feet

Surficial Material (lower class limits)

mm.	90	64	45	32	22	16	11
%wt.	6.1	8.2	5.9	13.2	16.4	21.9	17.6

mm.	8	5.6	4	<4
%wt.	7.8	1.2	0.5	1.7

Surface rocks are subangular to subrounded, mostly quartzite, in a variety of colours and types. Stream laid. Bottom side of virtually all rocks covered with caliche. Surface gravel layer begins at 0+40 feet on the hillslope profile and is found at a depth of 2.5 feet in a pit at 0+15 feet on the profile. Above the gravel layer at 0+15 feet lies a layer of silty sand, containing no rocks.

Table 3 (continued)

Cross profile at 1+00 feet

Sta.	Elev.
0	181.22
2	181.20
4	181.20
6	181.19
8	181.09
10	181.12
12	181.11
14	181.22
16	181.19
18	181.21
20	181.20
22	181.12
24	181.01
26	180.91
28	180.84
30	180.67
32	180.46
34	180.36
36	180.14
38	179.88
40	179.75

Vegetation Cover 33% (Crown density)

Cover consists of Phlox spp., various grasses (Pea and Agropyron spp.), and big sage (Artemesia tridenta). The upper limit of sage occurs at this station.

Area of Bedrock Outcrops (%) 0

Depth to Bedrock 0.25 feet

Surficial Material (lower class limits)

mm.	90	64	45	32	22	16
%wt.	5.4	7.3	13.0	17.5	23.2	18.4
mm.	11	8	5.6	4	< 4	
% wt.	8.6	4.8	1.7	0.6	0.1	

Soil Profile at 1+00 feet

0 - 0.1 ft. Medium gravel to small cobbles.

0.1 - 0.25 ft. fine tan-coloured, silty sand with some 4-8 mm. gravel.

0.25 - 1.0 ft. and beyond - grey, friable clay. Breaks into 2 mm. angular clods. This is local bedrock.

Table 3 (continued)

Cross profile at 1+50 feet

Sta.	Elev.
0	163.58
2	163.75
4	163.54
6	163.73
8	163.87
10	163.79
12	163.97
14	163.03
16	163.97
18	164.03
20	163.82
22	164.10
24	163.99
26	164.14
28	164.21
30	164.35
32	164.39
34	164.42
36	164.40
38	164.45
40	164.54

Vegetation Cover 37% (Crown density)

Cover consists mainly of big sage (Artemisia tridenta) and various grasses (Pea and Agropyron spp.).

Area of Bedrock Outcrops (%) 0

Depth to Bedrock 1.5 feet

Surficial Material (lower class limits)

mm.	92	64	45	32	22	16
% wt.	10.5	10.8	12.7	15.5	18.0	16.0

mm.	11	8	5.6	4	< 4
% wt.	7.6	4.9	0.7	0.9	2.4

Surface rocks depleted of caliche coating compared with those at station 0+55 ft. Two thirds by count are without caliche. Some were found which retain a remnant of caliche as if originally coated on bottom. Suggests motion, instablity and wear.

Soil Profile at 1+50 feet

0 - 1.5 ft. - Tan-coloured, stony, fine sand and silt with numerous stones. Largest stones 32-45 mm; average size 16 mm. Most stones covered with resistant caliche on one side only, indicating surface deposition. No caliche in matrix. No soil structure or profile development. Interpreted as a mudflow. Rocks in soil similar to those on surface. Roots penetrate to 1.25 ft. 1.5 ft. - clay bedrock.

Station 2+00 feet

No cross profile

Vegetation Cover Same as at 1+50 feet

Area of Bedrock Outcrops (%) 0

Depth to Bedrock 1.0 feet

Surficial material (lower class limits)

mm.	22	16	11	8	5.6	4	< 4
% wt.	6.0	4.2	9.7	8.9	12.5	8.4	50.3

Table 3 Sample tabulation: Data from surveys of cross profiles, vegetation, and surficial material.

ADDITIONAL MEASUREMENTS

In addition to the profiles and cross profiles which are descriptive, the Commission recommends installation of two kinds of simple observation to record, by successive resurvey, effects of processes through time. These observations are simple, but if various investigators use the same methods over a period of time, then the observations become more useful and understandable.

It is recommended that on each surveyed hillslope three lines of painted rocks be placed and their distances of movement be recorded at least two times a year. Where additional observations are possible, such as movements resulting from a single rainstorm, these additional observations are of course useful.

And on each surveyed hillslope, the Commission recommends one mass-movement pit, usually placed near the center of the surveyed profile. The pit should be excavated and movement recorded once a year. Additional pits are desirable but if one is placed on each surveyed hillslope, much useful information of a uniform type would be available in only a few years.

The following pages describe how to lay out and observe both the painted rock lines and the pits.

1) Painted rock lines

If three painted rock lines are to be installed on a hillslope, two paint colors should be used. The rocks typical of the surveyed hillslope should be collected, sizes varying from 5.6 mm to 64 mm if this range occurs. For each line of about 100 feet (or 30 meters) long, a total of 20 replications of the rock groups occur along the line. So for three rock lines there will be needed 60 rocks of each of the size classes: 60 rocks of intermediate (b axis) diameter 64 mm, 60 rocks of 45 mm, etc. The size classes vary by the square root of 2, and thus are 64, 45, 32, 22, 16, 11, 8, and 5.6 mm. Thus the three rock lines include a total of 480 painted rocks. (Fig. 3).

The painted rocks in a line are set in a straight line approximately along a contour as shown in the diagram which shows the size of rock and spacing between rocks. The spacing interval is 6 times the mean diameter of the larger of the two rocks separated by the interval. The 6 diameter spacing is chosen to ensure that the adjacent rocks do not interact or affect each other.

The recommended procedure is to pick up at random several sacks or shoulder-packs full of rocks, and bring them to a central place near the location chosen for the rock line. Rocks are picked out of the bag one at a time. Each is measured with a mm rule and put into a pile of rocks of similar size. The b axis is measured and the rock put into the pile designated by the lower end

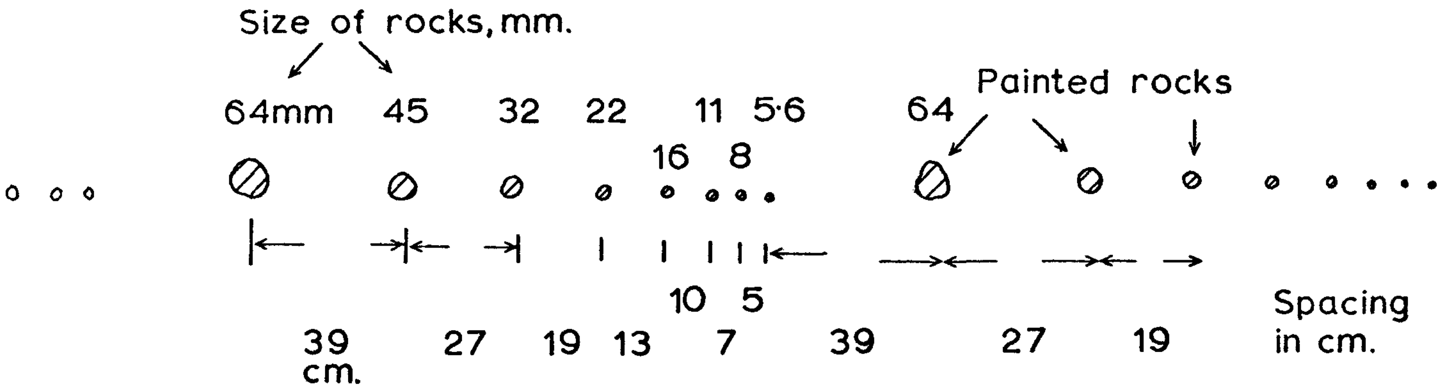

Size of rocks, mm.
64mm
45
32
22
11
5·6
16
8
Painted rocks
64
10
5
39 cm.
27
19
13
7
39
27
19
Spacing in cm.

Figure 3.

of the size interval. For example, any rock between 45 and 63 mm diameter is called 45 mm, as if it were held on a sieve of 45 mm opening.

For three rock lines, the upper and lower lines may be the same color but the intermediate line is another color.

When one has a pile of about 60 rocks of a given size, the pile is divided into two parts, 40 rocks in one part and 20 in the other. They are spread out on the ground in a layer about one rock thick, and painted, the 40 painted one color and the 20 another color.

When dry, the rocks are aligned along the outstretched tape on contour, in the sequence of size and distance as shown in the sketch (Fig. 3). A wooden stick marked with the distance intervals makes it easy to space the rocks along the tape. The two ends of each painted rock line are marked with a metal rod driven in the ground, so that the original position of the line is not lost.

When complete, there will be three lines of rocks on contour at or near the surveyed profile. Each line will probably be on a different ground slope and at different distance from the hill crest.

It can be seen that after a given rainstorm or a season, the distance each rock moved can be recorded by stretching a line between the metal rods and from that line measuring downhill to the position of each rock.

The spacing pattern gives a random position for each rock and there are 20 replications. The data may therefore be analysed to determine the effect of rock size on distance moved. Comparison between rock lines allows effect of slope (or position on the profile) to be analyzed.

Unless an individual rock has moved 2 cm or more, the movement is recorded as 'no movement' or 'less than 2 cm'.

It is recommended that rock lines of the same color be located en echelon so that movement from the upper line will not confuse the line downslope.

The accompanying table shows the field notes recording the rock lines of the hillslope of the example.

Painted rock line at 0+55 feet

Colour	Red
Location	50 ft. west of surveyed hillslope profile to 50 ft. east of it.
Sequence of sizes	From west to east rocks held on sieves of the following sizes: 64 mm, 45 mm, 32 mm, 22 mm, 16 mm, 11 mm, 8 mm, 5.6 mm. Distance between rocks is six times the geometric mean diameter of the larger size class.
Number of rocks	Eighteen sequences of eight rocks.

Painted rock line at 0+70 feet

Colour	Green
Location	50 ft. west of the surveyed hillslope profile to 50 ft. east of it.
Sequence of sizes	As at 0+55 feet.
Number of rocks	As at 0+55 feet.

Painted rock line at 1+90 feet

Colour	Red
Location	65 ft. west of surveyed hillslope to 35 ft. east of it.
Sequence of sizes	As at 0+55 feet.
Number of rocks	As at 0+55 feet

Painted rock line at 2+25 feet

Colour	Green
Location	65 ft. west of the surveyed hillslope profile to 35 ft. east of it.
Sequence of sizes	As at 0+55 feet.
Number of rocks	As at 0+55 feet.

Painted rock line at 4+50 feet

Colour	Red
Location	50 ft. west of the surveyed hillslope profile to 50 ft. east of it.
Sequence of sizes	As at 0+55 feet.
Number of rocks	Nineteen sequences of eight rocks.

Painted rock line at 7+50 feet

Colour	Green
Location	50 ft. west of the surveyed hillslope profile to 50 ft. east of it.
Sequence of sizes	As at 0+55 feet.
Number of rocks	Eighteen sequences of eight rocks.

Table 4. Sample Tabulation: Painted rock lines installed on Painted Rock Slope near Red Butte, Daniel, Wyoming, U.S.A., on July 31st 1969.

2) Mass-movement pits (Young pits)

For his work on mass movement in England, Young described a pit into the side of which, in the undisturbed soil, were driven horizontal rods. The rods were arranged one above the other in a vertical plane and the plane went to a benchmark consisting of a steel rod driven into undisturbed soil at the base of the pit. With the passage of time, the deviation of the emplaced rods from a vertical alignment gives some indication of the amount and rate of movement at various distances from the soil surface. (Young 1960, 1963).

After the initial emplacement of the rods the pit is refilled and after an interval of time (6 months or a year) the pit is re-excavated and, digging carefully up to ends of the rods, their vertical alignment is re-surveyed.

The Commission recommends that round rods should not be used. Some data indicate that either because the rods were too small or perhaps because they were too smooth, the soil was moved around them as if they were the roots of a tree. (Leopold, 1967). It is recommended that metal plates be substituted for the rods.

Digging a notch carefully into the undisturbed side of the open pit, a metal strip is inserted in a vertical position. The metal may be aluminum, thin brass, or copper. The strip is about 30 cm long and 5 cm wide. Before placement the long strip has been cut into small rectangles 2.5 cm high and all the rectangles put back into their original alignment by the use of sticky transparent tape which holds them together during the time that the rods are inserted into the side of the pit. The metal rectangles should be separated slightly when they are taped together in a strip by the sticky tape. If they actually touch each other, they may influence each other or one may prevent its neighbors from being displaced. With time, the sticky tape is destroyed by weathering and the plates then can move downhill independently of each other. (Fig. 4).

The original survey and re-surveys are made with an engineer's transit or theodolite set up about 10 feet from the pit and about on the same contour, as shown in the accompanying diagram. The transit is set up over a bench mark consisting of an iron rod at least 1 meter long driven vertically into the soil. The theodolite is oriented on a similar bench mark about 7 meters away on the opposite side of the pit. To make sure that the alignment of those two bench marks is not disturbed by downslope motion, a third bench mark may be driven vertically into the ground at the bottom of the pit and thus the top of that bench mark should be free of any downslope motion. (Fig. 4). This is strongly recommended.

The procedure is as follows. Approximately on contour of the chosen pit site, iron rods are driven as bench marks about 3.5 meters on each side of the chosen site. A pit is dug along one side of the column of soil to be observed, one side of the pit being vertical, the other side sloping toward the bench mark over which

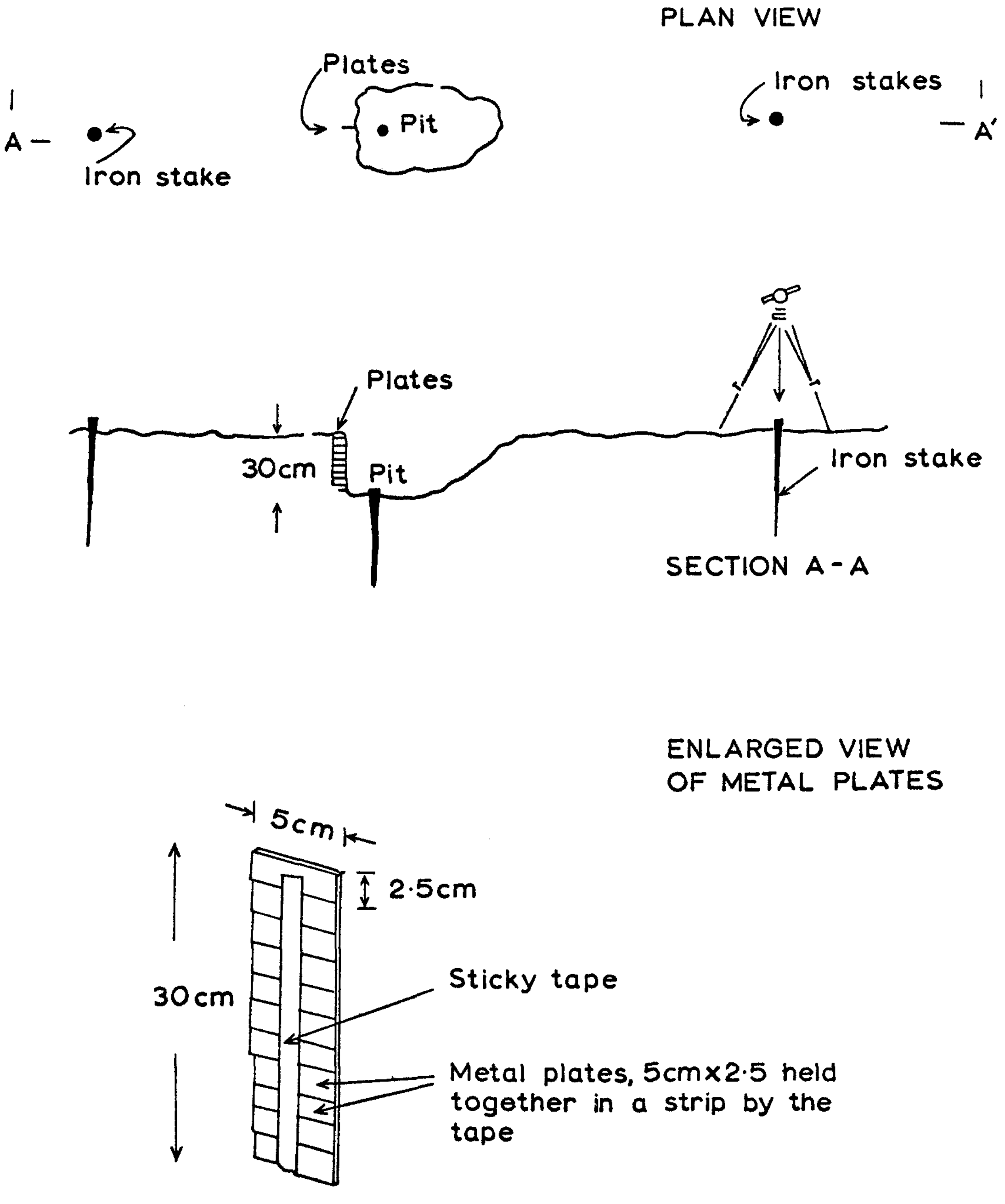

PLAN VIEW
Plates
Pit
Iron stakes
A
A'
Iron stake
Plates
30cm
Pit
Iron stake
SECTION A-A
ENLARGED VIEW
OF METAL PLATES
5cm
2·5cm
30cm
Sticky tape
Metal plates, 5cm x 2·5 held together in a strip by the tape

Figure 4.

the theodolite is set up. This allows the telescope to look down into the bottom of the pit with the minimum amount of excavation.

The theodolite is oriented on the far bench mark and in the vertical plane defined by the two bench marks, a notch is cut into the undisturbed soil of the vertical wall of the pit.

When the metal strip is installed firmly in the notch, a millimeter rule is held horizontal at the top and bottom corner of each metal plate. The reading of the theodolite vertical cross hair on the rule is recorded, showing thus the original position of each metal plate relative to the plane of the line of sight.

When the readings are complete, the pit is carefully re-filled with attention paid to not disturbing the installed plates.

On re-survey, the approximate position of the metal plates is determined by tape measurement from the bench marks. A pit is dug a little distance away from the plates and only gradually and with care excavated toward the plates so they will be found before they are disturbed with the trowel or shovel.

The programme is completed by the repetition of the original measurement procedure.

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Wolman M.G. (1954) A method of sampling coarse river-bed material. Trans. Amer. Geophysical Union, 35 (6), 951-956.

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