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SLOPE PROFILE ANALYSIS : METHODOLOGY AND TOOLS

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ABSTRACT : The study of slope has a significant place among various disciplines such as geology, botany, agriculture, pedology, engineering, hydrology and mining besides geomorphology. Various models of slope evolution have been evolved in gemorphology but without setlling the controversy on the basis of exhaustive field studies. These theoretical models can be tested by appreciating a detailed descriptive account of a slope profile followed by its genetic interpretation and conclusions. As a result, the methodology and tools for slope profile survey, its graphical representation are of paramount significance.

The present paper deals with the explanation of basic terms and methodology involved in a slop profile survey and its analysis. A review of the works, various methods of slope expression and their inter-conversion have been incorporated.

The present paper clearly explains that the slope profile survey is carried out by (a) identification of profile line on the basis of preliminary studies of topographical maps, geological maps and finding out the true slope followed by field studies and (b) locating profile stations in accordance with certain principles, measurement of lengths and angles between them.

The measurement of an accessible length is performed directly by a linen tape, an inaccessible length with a clinometer or Abney level following the principles of trignometry. The measurement of both upslope and downslope angles at a station is carried out with either Abney level, Clinometer, a light weight theodolite or Ewing's Stadi Altimeter. The data so obtained are entered in a field book and processed.

Alternatively data regarding lenghts and angles between profile stations are generated with the help of published topographical maps preferably on the scale of 1:25000 and aerial photographs. The generated lenght and height data are converted into degrees and tangents and subsequently approximated. The graphical representation of the data can be made following two methods : (a) the data of lenghts and angles obtained from field survey are converted into coordinates i.e. horizontal and vertical differences between stations, cumulatively added and marked on a paper by selecting a suitable scale. (b) the data generated from topographical maps are cumulatively added and plotted on a simple graph on a scale.

The profile is analysed on the criteria of units, sectors, unit relationship, order of discontinuities and sequences present. The complete methodology has been explained with due support of mathematical equations, tables, graphs and at the same time inherent drawbacks of methodology have also been pinpointed.

Slope has been held as a fundamental type of landscape feature which prevails all over the eath's surface. As a result, it has received the utmost attention of geomorphologists. It has rightly been remarked that no other theme in geomorphology has been discussed so exhaustively and deeply as slope, but it has continued as a focal theme of controversy. From the tremendous literature having accumulated on research with regard to the approaches of 'form-process' or 'process form' it appears that within the broad realm of geomophology, there is a subdiscipline called as slope geomorphology. The studies of slope profiles occupy significant place in the disciplines of geology, botany, agriculture, pedology, engineering, hydrology and mining each besides gemorphology, with varying objects. In fact the controversy, whether this is the form of slop which determines the functioning of processes or the processes which control the form of a slope has been a controversy no less than the 'chicken-egg' dispute.

Various models of slope decline, parallel retreat, slope replacement and dynamic equilibrium have been propounded by leading gemorphologists such as Davis (1909), Wood (1942), King (1957), Penck (1953) and Strahler (1950) respectively regarding the mode of slope evolution, but none of them is proved beyond dispute by adequate field studies. The evolution of slope must be studied as a detailed description of slope profile and genetic interpretation of the same. Since slope profile reveals a number of phases in the slope development, it offers a sound basis for testing of various hypotheses related to theoretical slope development. The present study is an attempt to provide a detailed account of methodology for slope profile analysis and the tools and equipments required for measurement of profile lenght and angles of slope between the profile stations.

REVIEW OF THE WORK

The earliest surveys of slope profiles for geomorphical purposes were conducted by Taylor (1875) and Lake (1928 Their potentialities for the study of slope olution were first fully demonstrated by F (1947, 1948) and Savigear (1952). Strahler (1950) was the pioneer in the use of profiles in conjuction with statistical analysis. By 1956 profiles had become established as a standard descriptive technique in geomorphology. Outstanding contribution with regard to the methodology of profile survey and anaysis had been made by Savigear (1956) and Pitty (1966, 1967, 1968, 1969). The main field studies employing the technique of profiling have been conducted by Fair (1947, 1948), Pallister (1956, 1956 (b)), Palmer (1956), De Bethune and Mammericks (1960, 1964); Fourneau (1960), Hack (1960), Young (1964, 1972) Clark (1965), Pissart (1966) and Lewin (1970).

The study of slope profiles has not received much attention in India. Few studies have been conducted by Pandey (1968), Subramaniam (1976), Sharma and Padmaja (1977, 1978), Rai (1981) and Gurjar (2001).

TERMINOLOGY FOR SLOPE PROFILES STUDIES

The terms used in the slope profile studies have been defined mostly by Young (1964) and King (1966). Some terms have been introduced by British Geomorphological Research Group (1959-62) also. Significant and frequently used terms are stated below :

- Profile form refers to the two dimensional shape along a vertical plane that follows the direction of maximum slope.
- Plan form refers to the shape of the ground surface viewed vertically as shown by the curvature of the contours.
- Slope profile is a line across a ground surface largely or entirely following the direction of a true slope.
- A transect is a line across a ground surface often straight that does not necessarily follow the true slope.

- True slope refers to angle of surface slope of the ground in the direction of the maximum slope i.e. perpendiculat to the contour.
- Apparent slope is the angle of surface slope in any direction other than that of a true slope.
- Aspect is the horizontal direction faced by the true slope.
- Cliff : Surface inclined at more than 40° degree is called a cliff.
- Slope Unit : A portion of a slope profile being demarcated on the basis of the extent of curvature (convexity or concavity) or angularity is termed a slope unit. A Slope unit may be either a segment, an element or an irregular unit.
- Segment : A slope unit with an approximately constant angle is called a segment. A rectilinear segment is recognised by the fact that it exhibits no systematic change of angle. The British Geomorphological Research Group (1959-62) has preferred a term 'facet' over a segment.
- Element : A slope unit with a curvature is termed as an element. A convex element has an increase in angle downslope (positive curvature) whereas a concave element has a decrease in angle (negative curvature) downslope.
- Sector : Slope sector refers to that part of a slope element on which the curvature remains constantg. An element may have one of more sectors.
- Profile curvature is defined as the rate of change of angle with distance down the true slope and expressed in degress per 100 metres.
- Maximum segment : A segment steeper in angle than the slope units above and below it is termed as maximum segment. It may also form the lowest unit on a profile having a gentler slope unit above it.
- Minimum Segment : A segment gentler in angle than the slope unit above and below is named a minimum segment.
- Crest Segment : A segment bounded by downslope in opposite directions is called a crest segment According to Young (1964) a crest requires a specific angle of 2 degress.
- Basal Segment : A segment bounded by upward slopes in opposite direction is termed a basal segment.
- Irregular Unit is a portion of a slope profile within which there are frequent changes of both angle and curvature. Thesse changes are too small to indicate to scale.
- Inflexion is a line of maximum slope between adjacent concave and convex elements.
- Convexity consists of all parts of the slope profile including a segment where there is no decrease in angle downslope, although maximum, minimum and crest segment are excluded.
- Concavity is used to describe that part of a slope profile including a segment where there is no increase of angle downslope but excluding maximum, minimum and basal segment.
- Profile intercept is defined as a uniformly inclined portion of a slope profile. Uniform inclination means average inclination does not vary more than half a degree.
- Break of slope is an angular discontinuity of the ground surface.

- Change of slope is a smoothly curved concave or convex area whose true ground horizontal equivalent is greater than the width of a line on a field map.
- Profile of consociation has only either a convex or a concave unit groups.
- Profile of association has only either a convex - concave or a concave - convex unit groups joining inflexion.
- Profile of interrupted association refers to convex - concave - convex units interrupted by rectilineariity (disconti-nuty).
- Profile of dissociation has a consociation grouped with a rectilinear form.
- Profile of nonassociation has an association grouped with a rectilinear form.

Table 1:

Conversion between methods of Expressing Slope Angle.

Degrees and minutes	Degress and decimals of a degress	Tangent	Percentage Grade	Gradient or unit rise 1 in	Degrees and minutes	Degress and decimals of a degress	Tangent	Percentage Grade	Gradient or unit rise 1 in
0°00'	0.00	0.00	0.0	∞	20	20	0.364	36.4	2.8
0° 06'	0.10	0.02	0.2	573	21	21	0.384	38.4	2.6
0° 10'	0°17'	0.03	0.3	344	22	22	0.404	40.4	2.5
0°12'	0.20	0.04	0.4	287	23	23	0.425	42.5	2.4
0°18'	0.30	0.05	0.5	191	24	24	0.445	44.5	2.2
0°20'	0.33	0.3	0.6	172	25	25	0.466	46.6	2.1
0°24'	0.40	0.07	0.7	143	26	26	0.488	48.8	2.1
0°30'	0.50	0.09	0.9	115	27	27	0.510	51.0	2.1
0°36'	0.60	0.11	1.1	95.5	28	28	0.532	53.2	1.9
0°42'	0.70	0.12	1.2	81.9	29	29	0.554	55.4	1.8
0°48'	0.80	0.14	1.4	71.6	30	30	0.557	57.7	1.7
0°54'	0.90	0.16	1.6	63.7	31	31	0.601	60.1	1.7
1	1.00	0.18	1.8	57.3	32	32	0.625	62.5	1.6
2	2	0.35	3.5	28.6	33	33	0.649	64.9	1.5
3	3	0.52	5.2	19.1	34	34	0.675	67.5	1.5
4	4	0.70	7.0	14.3	35	35	0.700	70.0	1.4
5	5	0.88	8.8	11.4	36	36	0.727	72.7	1.4
6	6	0.105	10.5	9.5	37	37	0.754	75.4	1.3
7	7	0.123	12.3	8.1	38	38	0.781	78.1	1.3
8	8	0.158	14.1	7.1	39	39	0.810	81.0	1.3
9	9	0.158	15.8	6.3	40	40	0.839	83.9	1.2
10	10	0.176	17.6	5.7	41	41	0.869	86.9	1.2
11	11	0.194	19.4	5.1	42	42	0.900	90.0	1.1
12	12	0.213	21.3	4.7	43	43	0.933	93.3	1.1
13	13	0.231	23.1	4.3	44	44	0.966	96.6	1.0
14	14	0.249	24.9	4.0	45	45	1.0	100.0	1.0
15	15	0.268	26.8	3.7	50	50	1.192	119.2	0.84
16	16	0.287	28.7	3.5	60	60	1.732	173.2	0.58
17.	17	0.306	30.6	3.3	70	70	2.748	274.8	0.36
18	18	0.325	32.5	3.1	80	80	5.671	571.1	0.18
19	19	0.344	34.3	2.9	90	90	-	-	0.00

- Primary profile has only one type of slope unit i.e. either an element or a segment.
- Secondary profile comprises two types of units such as convex-concave or convex-rectilinear or rectilinear-concave units.
- Tertiary profile consists of three types of units viz. convex, rectilinear (maximum segment) and concave.
- Profile sequence is a portion of a slope profile consisting successively of a convexity, a maximum segment and a concavity.

METHODS OF EXPRESSION OF SLOPE READINGS

Readings of slope may be expressed in terms of degree and minutes, degrees and decimals of a degree, tangents, percetage grade and unit rise.

Readings in degress and minutes are obtained directly from the theodolite, abney level and Brunto's compass. Indian pattern clinometer provides the reading in tangnet. Percentage grade is obtained through multiplication of tangent by 100 i.e. $\tan \theta \times 100$.

Unit rise or gradient is expressed in terms of height changes per measured length. The unit for measurement of height and the lenght must be preferably in the same unit either yard or metre.

The aforesaid expression of readings can be converted into each other. A model for conversion between methods of expressing slope angles is gives in Table 1.

TOOLS FOR SLOPE PROFILE SURVEY

The tools to be employed in a slope profile survey are of two types :

(A) Published Maps :

Geological Survey of India, Survey of India and National Remote Sensing Agency, Hyderabad respectively are generally taken as base maps for indentification of profile line or generation of data base for length and angle of slope between profile stations.

(B) Equipments :

Ranging rods are used for fixing the profile stations and linen tape is used for measurement of distances. Slope 'pantometer' is suitable for obtaining large number of short (1-2 metre) and equal mesured lenghts. A 'profile recorder', which is wheeled across the ground, reproduces a continuous scale record of the surface with a local accuracy of 5 centimeters may also be used. Distance measurement can also be done with a theodilite applying the principles of techometry.

For the measurement of slope angles, the most convenient and widely used instrument is Abney level which gives the readings upto 10' accuracy and is also rapid to use and at the same time needs only one observer. An alternative instrument convenient if a series of measurements of angle are to be taken from a single stations, is a light weight theodolite. With the use of a Ewing Stadi-Altimeter, horizontal distances and vertical height difference for over 30 stations per hour can be obtained. Brounton's compass and Indian pattern clinometer are also used for measurement of slope angles.

METHODOLOGY FOR SLOPE PROFILE SURVEY

The analysis of a slope profile involves survey followed by interpretations and conclusions. The profile survey is carried out by (a) identification of slope profile line and measurement of length between stations and (b) measurement of angles.

(A) Indentification of slope profile line and measurement of Length

The first and the foremost task in conducting profile survey is to identify the true slope of the terrain. This can be done with the help of the geological maps being published by geological survey of India. The tentative profile line so identified can be finally decided through the field visit and identifying the dip of the terrain.

In deciding the location of profiles, most of the studies have used purposive sampling i.e. deliberate selection of the line of profile by the surveyor. Purposive sampling has been critizied as subjective and therefore open to the selection consciously or otherwise, of profiles that may demonstrate some preconceived hypothesis. The surveyor may also adopt a random or a controlled sampling as required for the purpose of such studies.

In selecting the positions of profile stations during the field survey, two different practices can be followed :

(a) In one case, stations are sited where the slope is judged visually to change, giving unequal measured lengths. One drawback in this method is that only those changes in angle that are visually identifiable are selected as profile stations, others that are equal in amount but not seen, may fall between stations causing irregularity in the record.

(b) The profile stations can also be sited by adopting a standard unit of length eliminating any subjectivity. The main disadvantage in using a standard unit length arises from the nature of slopes having long section in which changes in angle are small and gradual in addition to shorter sections of rapidly changing slopes. If a long unit length is used, breaks of slopes visibly apparent to the surveyor are recorded with inaccuracy. If the unit length is made short enough to record such breaks, the time needed to survey the smooth sections is greatly increased.

The choice of the best method depends on the aims and circumstances of the survey. If methodological investigations into the nature of slope profile form are intended, then a standard length is preferable. If a record of the shape of a landform, for interpretation in geomorphological terms is required, the subjective choice of profile stations is desirable.

The following two working rules are employed in a profile survey with greater details :

i) No measured length shall be more than 20 metre or less than 2 metre.

ii) The difference between the two adjacent measured lengths shall not exceed 2° on slopes of less than 20° or 4° on slops exceeding 40° unless both measured langths are reduced to 2 metre.

The suggested values of 20 metre, 2 metre 2° are for topography of normal scale and can be varied with unusually high or low drainage density or with very gentle slopes. The field procedure for determining measured lengths may be illustrated by an example. Let P, Q and R be successive stations. Measured length PQ is measured as 10 metre at 6°, and QR as 8 metre at 9°. Since the difference exceeds 2°, R must be moved back until QR is 8° or less. If QR still exceeds 8° when reduced to 2 metre, both previous measurements must be abandoned and Q moved back, re-locating P by backward measurement. New values are thus obtained for the shortened PQ. With experience the need to move Q should rarely arise. The use of a 'profile recorder' permits the selection and comparison of a range of alternative measured lenghts subsequent to field survey.

During the profile survey the following supplementary measurements should also be recorded :

i) The longitudinal slope of the interfluve crest or the other crest of the profile.

ii) The longitudinal slope of the talweg or the base of the profile.

iii) The plan curvature' at the steepest point on the profile.

iv) The 'aspect' of the slope at the steepest point on the profile and at other points if the direction changes substantially.

The measurement of length between two profile stations can be done with a tape in the case of an accessible ground surface. There may be a possibility that the ground surface between two profile stations is inaccessible. In such a case the surveyor can take three successive profile stations on a profile line into consideration out of which the first two stations must have accessible ground surface for direct measurement with a tape. The angle of the third station can be measured with a clinometer or abney level from the first and the second stations. The measurements of angles and lengths so obtained can be arranged in form of an right angle triangle (Fig.1) and the inaccessible length between the second and the third stations can be generated following the formulae illustrated below :

$$D_2 = \frac{D_1 \tan \theta_1}{\tan \theta_2 - \tan \theta_1}$$

where D_2 is an unaccessible distance between stations b and c along profile line.

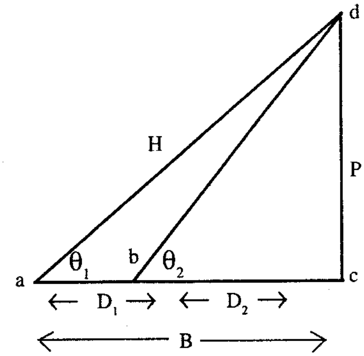


Fig. 1

D_1 is an accessible distance between station a and b along the profile line, θ_1 and θ_2 are the angles in ∠ cad and ∠ cbd respectively.

In case of an inaccessible ground surface or otherwise distance measurement can also be done with the help of a theodolite applying the principle of techometry.

(B) Measurement of Angles

The angle of slope between two profile stations can be obtained directly by a field survey with the help of a theodilite, abney level or a clinormeter. In this process an upslope reading of a station is taken from the preceding station and thereafter a downslope reading of the preceding station is also obtained. Thus two readings (upslope and downslope readings) are taken simultaneously for a stations.

(C) Calculation of profile curvature

To obtain a profile curvature at a point on the ground surface, measured length 'a' and 'b' are set out upslope and downslope respectively from a profile station, their angles θ a and θb and ground surface distance Da and Db are recorded. The profile curvature can be ontained by a formulae illustrated below :

$$Cab = \frac{\theta a - \theta b}{05.\ (Da+Db)} \times 100 = 200 \frac{\theta a - \theta b}{Da+Db}$$

where θa and θb are upslope and downslope angles of stations, 'a' and 'b' from the common station along a profile on the ground surface.

Da and Db are the ground surfaces distance of 'a' and station 'b' from the common station.

0.5 is an empirical constant and 100 is a constant for 100 metre length.

Thus if successive measured lengths, in a downslope direction, are 10 metre at -3° and 10 metre at -4.5°, the curvature at the point between them is 200 (1.5/20) = 15°/100 metre. On a slope profile an estimate of the curvature of the measured length itself may be required. This can be taken as the mean of the curvature of the two points bounding it. Alternatively, if a, b and c are successive measured lengths (in a downslope direction), the curvature of b is given by

$$Cb = 100.\frac{\theta a-\theta c}{_{0.5}Da+Db+_{0.5}Dc}$$

The degrees of convex or concave curvature are marked on the elements of a profile as X 30 and V 30 respectively in the case of curvature being 30° per 100 metre.

GENERATION OF DATA BASE FROM SECONDARY SOURCES

Data base can be generated from the available aerial photographs and topographical maps on the scale of 1.25,000 also particularly for profiles which do not require very microlevel details. Any profile line may be drawn on the basis of geological and topographical maps in the direction of true slope. The points representing the contonur or benchmark may be marked on the profile line and thereafter the length between these points can be measured on the basis of scales of the maps. The height between two stations can be obtained on the basis of difference between contours, bench marks or spot heights.

Accurate, closely-contoured maps would in theory provide the necessary information to

Table - 2 :

Generation of Data & Their Approximation

Station	Generated Data				Data Approximated			
	Measured length in metre	Height in metre	Inclination Tangent	Inclination Degress	Profile intercept in metre	Cumulative Measured lengths	Cumulative Height	Inclination approximated to half degree
1	50	8	0.16	9°30'	125	125	20	9°30'
2	75.2	12	0.16	9°30'				
3	75.2	20	0.266	11°30'	75	200	40	11°30'
4	75	40	0.533	28°	75	275	80	28°
5	125	100	0.8	39°	125	400	180	39°
6	50	60	1.2	50°	50	450	240	50°
7	20	10	0.5	27°	20	470	250	27°
8	30	10	0.33	18°	30	500	260	18°

construct slope profiles but comparisons of profiles drawn from maps with those surveyed in the field have repeatedly shown that the former are very inaccurate. Contours can be used to obtain the mean angle of a slope more than 100 metre height but are unsatisfactory for obtaining the local slope angle at a point. In the case of the maximum steepness of a slope, the estimate from contours tends to be substatially too low, but by a variable amount so that the value obtained by applying, correction factor is subject to a large error. An example of data generation from the ropographical maps is illustrated in Table-2.

The slope angles can also be obtained from air photographs. The parallax difference between two points on a stereoscopic pair of photographs is measured by a stereometer. Slope angles can be obtained using the following formulae :

$$\text{Tan } \theta = \frac{fp}{cw}$$

where, f is focal length of camera lens in milimetre (mm).

p is difference in parallax between the points in milimatre (mm).

c is mean horizontal distance between two points as measured from air photographs in milimetre.

w is mean of the distance between the principle point and the transferred principal point in milimetre.

Generation of data base for heights from air photographs can be carried out to the nearest 1 metre but even in such cases profiles using measured length of 20 metre would be subject to an error of 3°. This is why the measurement of angles is always preferable through a field study.

Table 3

Field Book and Data Approximation

Station	Field data		Field data approximation		
	Measured Length in Metres	**Inclination (upslope and down slope angle readings in degree and minutes)**	**Mean of upslope and downslope readings approximated to 0.5 degree**	**Profile intercepts in metre**	**Average inclination in degree**
1	20.4	6° 30' 6° 30'	6° 30'	20.5	6° 30'
2	30.6	20° 30' 20°40'	20°30'	56.0	20°30'
3	25.5	20° 35' 20° 30'	20°30'		
4	15.4	40° 30' 40° 40'	40° 30'	15.5	40°30'
5	25.3	42° 30' 42° 30'	42° 30'	25.5	42° 30'
6	30.4	37° 35' 37° 35'	37° 30'	30.5	37° 30'

Table 4

Conversion of Angle and Distance into Rectangular Coordinates

Measured Length	Distance in metres	θ angle in degrees	Cosine θ	Sine θ	Horizontal difference = D Cosine θ	Vertical difference = D Sine θ	Coordinates: Horizontal in metres (Cummu-lative)	Coordinates: Vertical in metres (Cummu-lative)
1.	20.4	6° 30'	.994	.111	20.28	2.26	20.28	2.26
2.	56.0	20° 30'	.937	.350	52.47	19.60	72.75	21.86
3.	15.5	40° 30'	.760	649	11.78	10.06	84.53	31.92
4.	25.5	42° 30'	.749	.676	19.09	17.24	103.62	49.16
5.	30.5	37° 30'	.804	.609	24.52	18.57	128.14	67.73

FIELD DATA AND THEIR APPROXIMATION

Data obtained directly from the field survey are arranged and approximated. The measured lengths ›nd the angles can be noted in a field book. Firs.'y, the upslope and downslope angle readings of : station are approximated to the nearest half degree. If the angles measured from the two or more successive stations and thereafter approximated do not vary more than 0.5°, the measured lenghts between them is amalgmated and the entire length is treated as one intercept. A model of a field book and approximation of readings both angles and lengths is given in Table 3.

GRAPHICAL REPRESENTATION

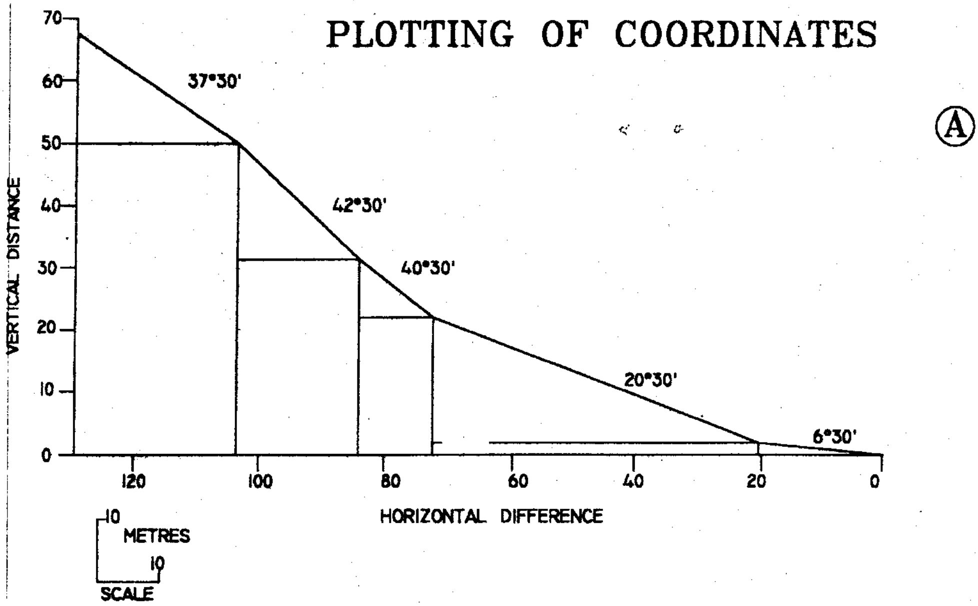
To plot a profile, angle and distance measurements are converted into rectangular co-ordinates. For convenient plotting these borizontal vertical differences are added cumulatively. In order to obtain the coordinates, horizontal and vertical distances are multiplied by horizontal difference (D Cosine θ) and vertical difference (D Sine θ) respectively, where 0 is the slope angle at a respective station. The conversion of angle and distance measurements into rectangular coordinates is being illustrated into Table-4. Thereafter the co-ordinate values are plotted on a scale to be adopted by a surveyor (Fig. 2 [A]).

In the case of data base generated from topographical maps, the values of distance and height between two profile points are plotted by selecting a common scale. For instance the data stated in Table-2 have been plotted in figure 2 (b).

In the above cases, initially the profile points marked are joined by straight lines and the angle written above each length. After careful examination of the profile line, slope units i.e. elements (concave or convex), segments or irregular units are demarcated. Subsequently the profile units are smoothened.

PROFILE ANALYSIS

The first step in a profile analysis is to divide the slope profile into a number of smaller divisions called units each possessing certain properties of forms such as convexity. concavity or rectilinearity. A unit is further divieded on the basis of angualarity and curvature. A unit having a straight form (uniformly inclined and distinctive from the unit above and below) is termed as a rectilinear



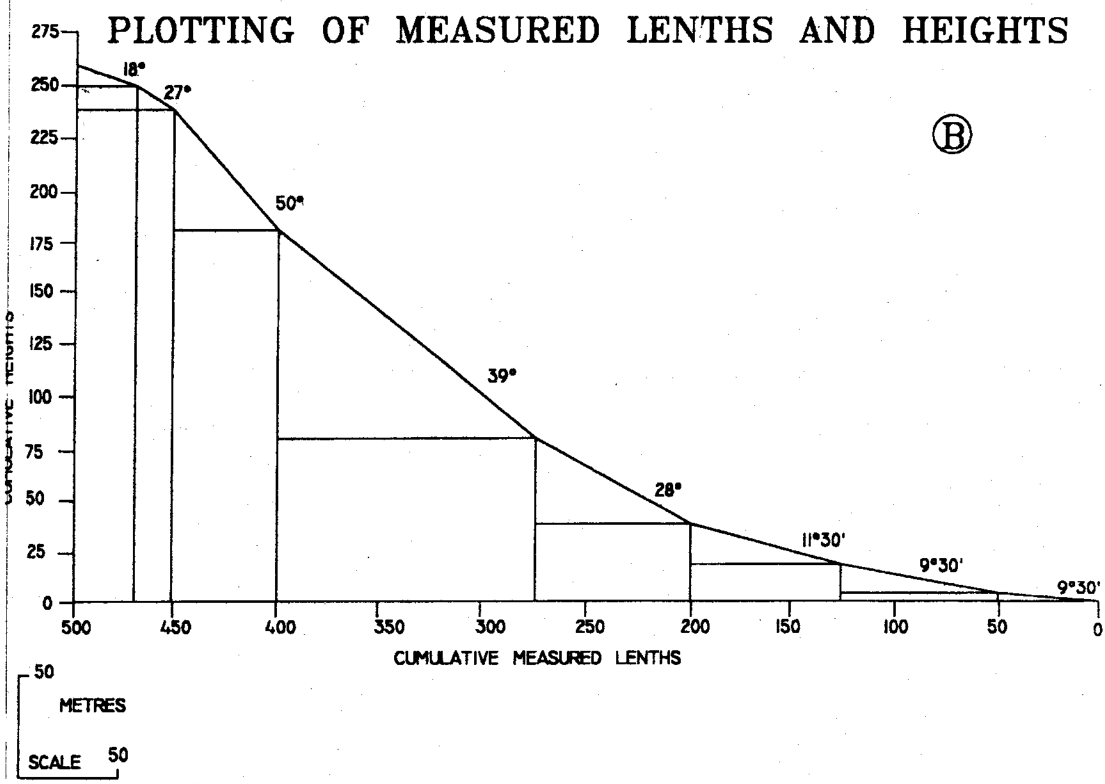


Fig. 2 : (A) Plotting of Coordinates **(B)** Plotting of Measured Lengths and Heights

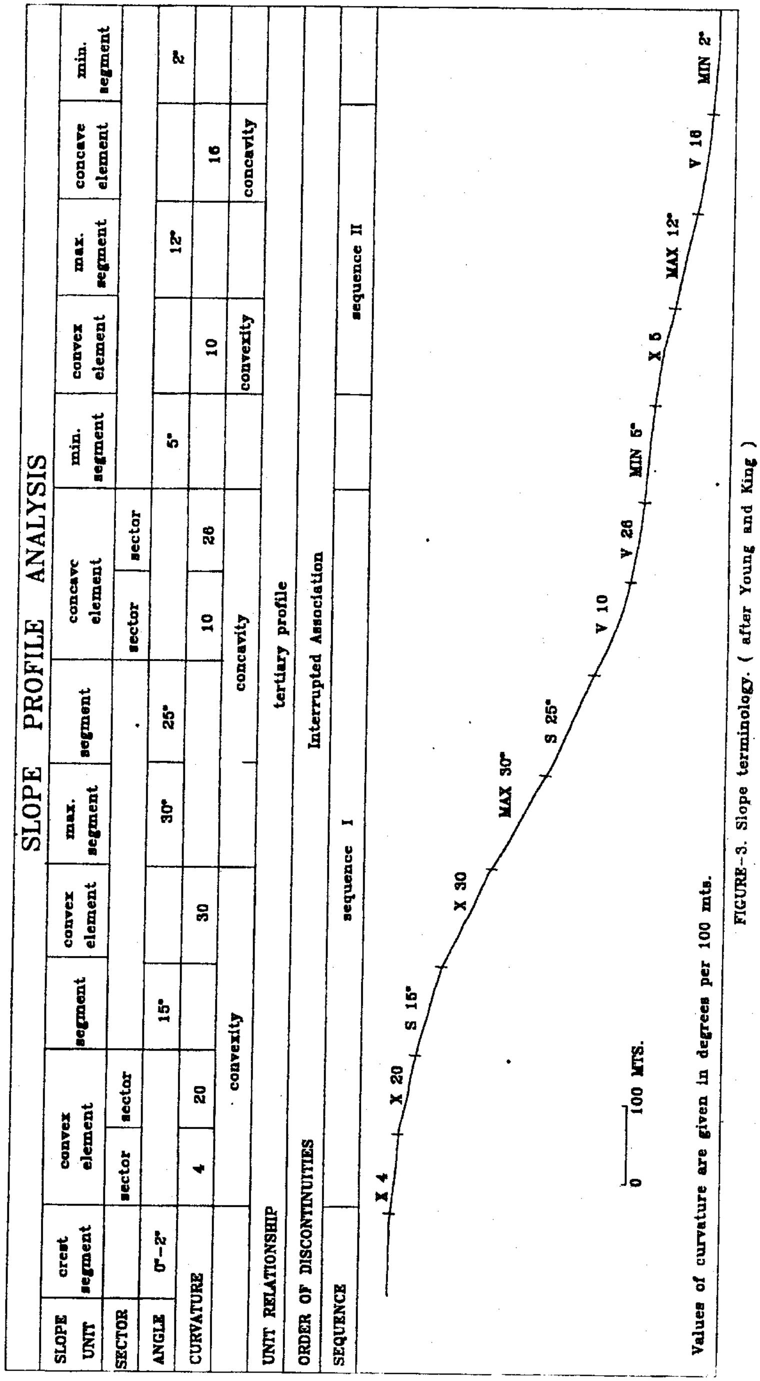


Fig. 3 : Slop Profile Analysis - Slop terminology (after Young and King)

unit or a segment. A segment has also been called a facet. A unit having curvature is termed as an element. An element can be identified either as a concave or as a convex element.

As defined herein above, convexity of a profile consists of a convex element as well as a segment but excluding maximum., minimum and crest segment. Similarly concavity consists of a concave element as well as a segment but exculding maximum, minimum and basal segment. The convexity and concavity of a slope profile include even the rectitinear parts. The elements are further divided into 'sectors'. A portion of an element whether concave or convex having uniform curvature is called as sector. There is a possibility that an element may have one or more sectors or the whole element may have constant curvature and therefore may have a single sector.

Thereafter the profile is classified as primary, secondary and tertiary profile on the basis of presence of a number of slope units i. e. unit relationship. A profile comprising only one type of unit (concave or convex or rectilinear) is identified as a primary profile. Profiles consisting of two types of units concave - convex or convex - rectilinear or concave - rectilinear) and three types of units (convex - rectilinear and concave) are identified as secondary and tertiary profiles respectively.

The profile is further classified on the basis of order of discontinuities present therein. Accordingly profile is identified as one of the profiles of consociation, association, interrupted association, dissociation and non-association etc. These terms have already been defined above. Finally a profile is analysed on the basis of sequences available. Accordingly a profile is divided into I sequence or II sequence and so on. All illustration of various stepsd involved in a profile analysis is given if figure-3.

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