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COLLUVIUM THICKNESS AND ITS RELATIONSHIPS TO VEGETATION COVER DENSITY AND SLOPE GRADIENT: AN OBSERVATION FOR PART OF MURCIA PROVINCE, SE SPAIN

ABSTRACT: OSMAN SALLEH K., *Colluvium thickness and its relationships to vegetation cover density and slope gradient: an observation for part of Murcia Province SE Spain* (IT ISSN 0391-9838, 1994).

The present study investigates widespread valleyside colluvial deposits and their relationships with their environmental settings in part of the Murcia province in SE Spain. These deposits are expressions of continuing soil loss which has taken place under present day environmental conditions. Such geomorphological responses are thought to vary in relation to slope character and its associated environmental factors which are known to influence the potential force of soil erosion processes.

KEY WORDS: Colluvial deposits, Vegetation cover, Slope gradient, Soil erosion, Murcia (Spain).

RIASSUNTO: OSMAN SALLEH K., *I depositi colluviali e le loro relazioni con la copertura vegetale e l'inclinazione dei versanti: osservazioni in una parte della Provincia di Murcia (Spagna)* (IT ISSN 0391-9838, 1994).

Lo studio affronta affronta il tema dei depositi colluviali largamente diffusi sui versanti vallivi e delle relazioni con i loro contesti ambientali in una parte della provincia di Murcia nel Sud Est della Spagna. Questi depositi sono l'espressione della continua diminuizione del suolo che ha preso a manifestarsi nelle attuali condizioni climatiche. Si ritiene che tale risposta geomorfologica varii in relazione alle caratteristiche dei versanti e ai fattori ambientali che si riconoscono influenzare il potenziale dei processi di erosione del suolo.

TERMINI-CHIAVE: Depositi colluviali, Copertura vegetale, Versanti, Erosione del suolo, Murcia (Spagna).

INTRODUCTION

The complexities of interrelationships between process and landform are manifold. To understand these relationships, experiments have been carried out to create a situation designed to lead to an explanation.

In soil erosion studies the erosion phenomenon may be completely or partially simulated in the field or in the laboratory. Such studies, consisting of post factum volumetric or synchronic-dynamic recording, may then be used to derive relationships between process and landforms (DE PLOEY & GABRIELS, 1980; DE PLOEY, 1984). Modelling laboratory and field experiments are not however without problems. There is a fundamental difficulty with equivalence control: the structure of the natural process is only partially known and cannot, therefore, be perfectly simulated (MUCHER & DE PLOEY, 1977). Changes to or the maintainance of landscape configuration through simulated experiments are often difficult to measure, primarily, because of the long time involved, irregular climatic inputs, difficult terrain, and bulky field equipments. In addition to this it is difficult to relate a process to an identifiable and measurable geomorphological response associated with the spatial and temporal variability of multiple processes. Such problems, however, may be overcome by using the ergodic hypothesis where processes are inferred by the studying relationships between response and control variables (PILGRIM, 1972).

The present study postulates that colluvium thickness as an expression of soil loss is a form of geomorphic response whose spatial and temporal variabilities are governed by the relationships between surface processes and slope character (including surficial vegetation and debris covers). The colluvium which are ill sorted, can be differentiated from eluvial deposits. The latter are «in situ» weathered materials.

STUDY AREA

The study area is located in a semi arid part of Murcia Province SE Spain (fig. 1). The area has a Mediterranean climate with marked seasonal variation in precipitation. Mean annual precipitation is about 300 mm with mean annual potential evapotranspiration in excess of 900 mm

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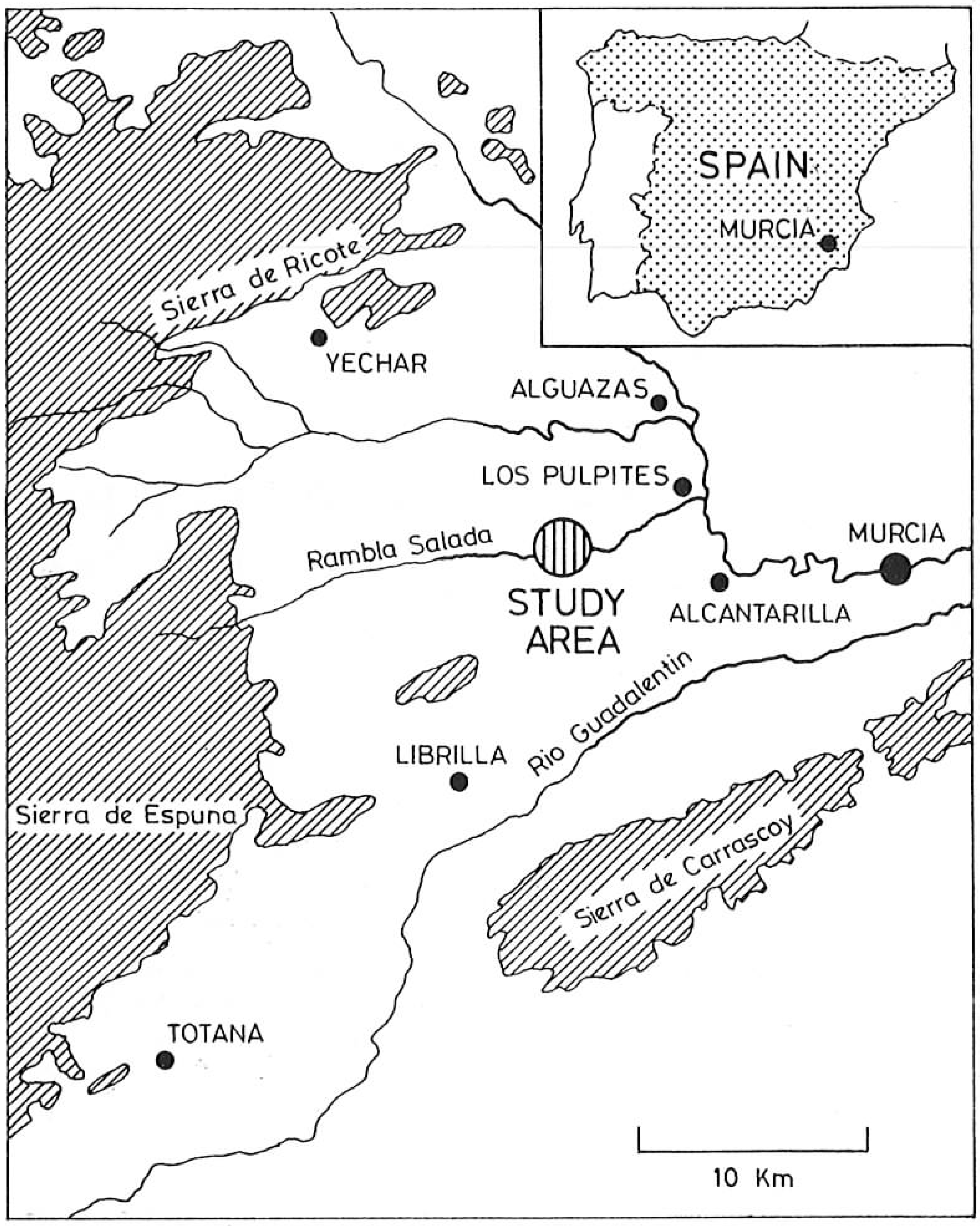


FIG. 1 - The general location of the study area.

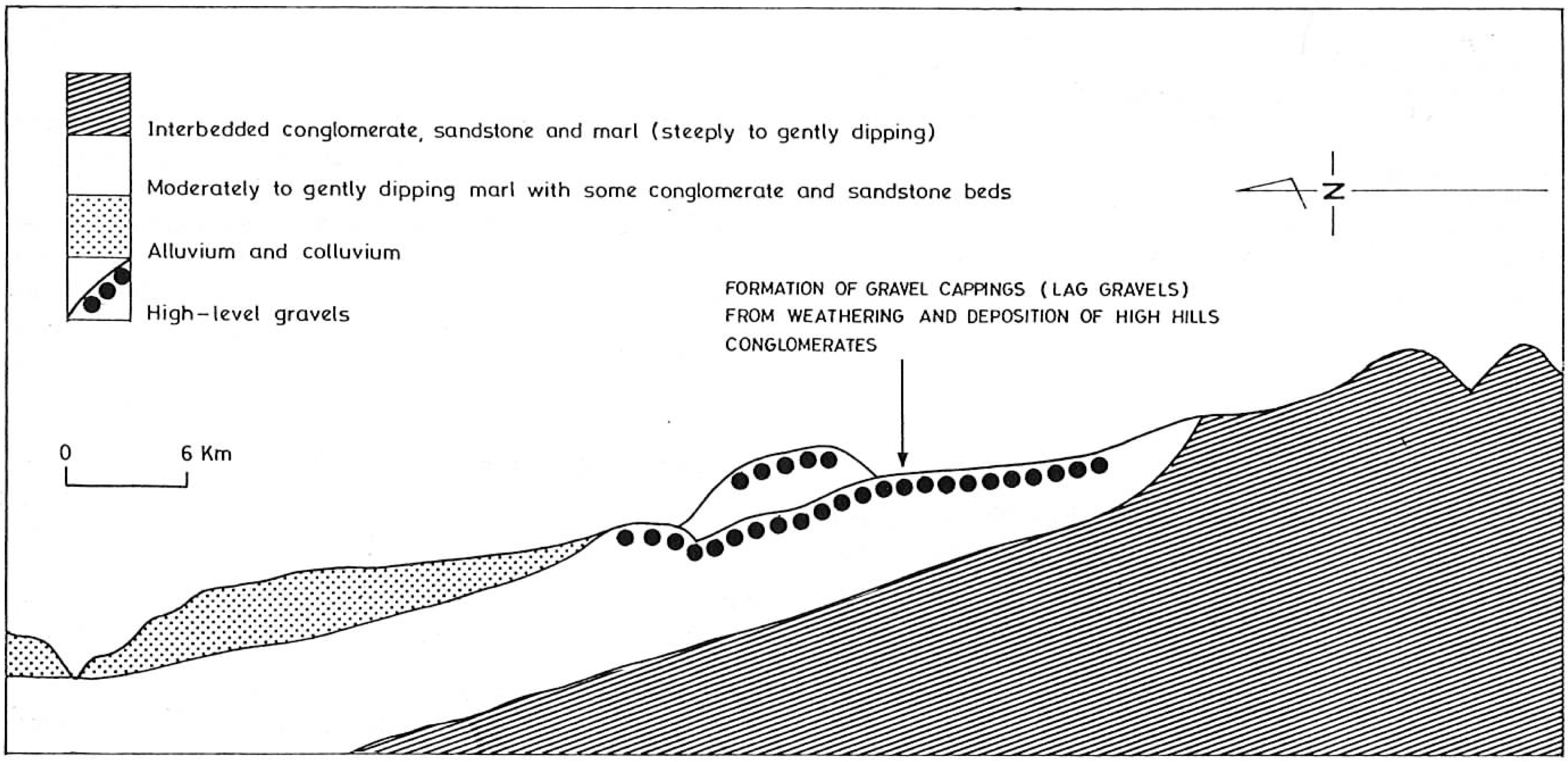
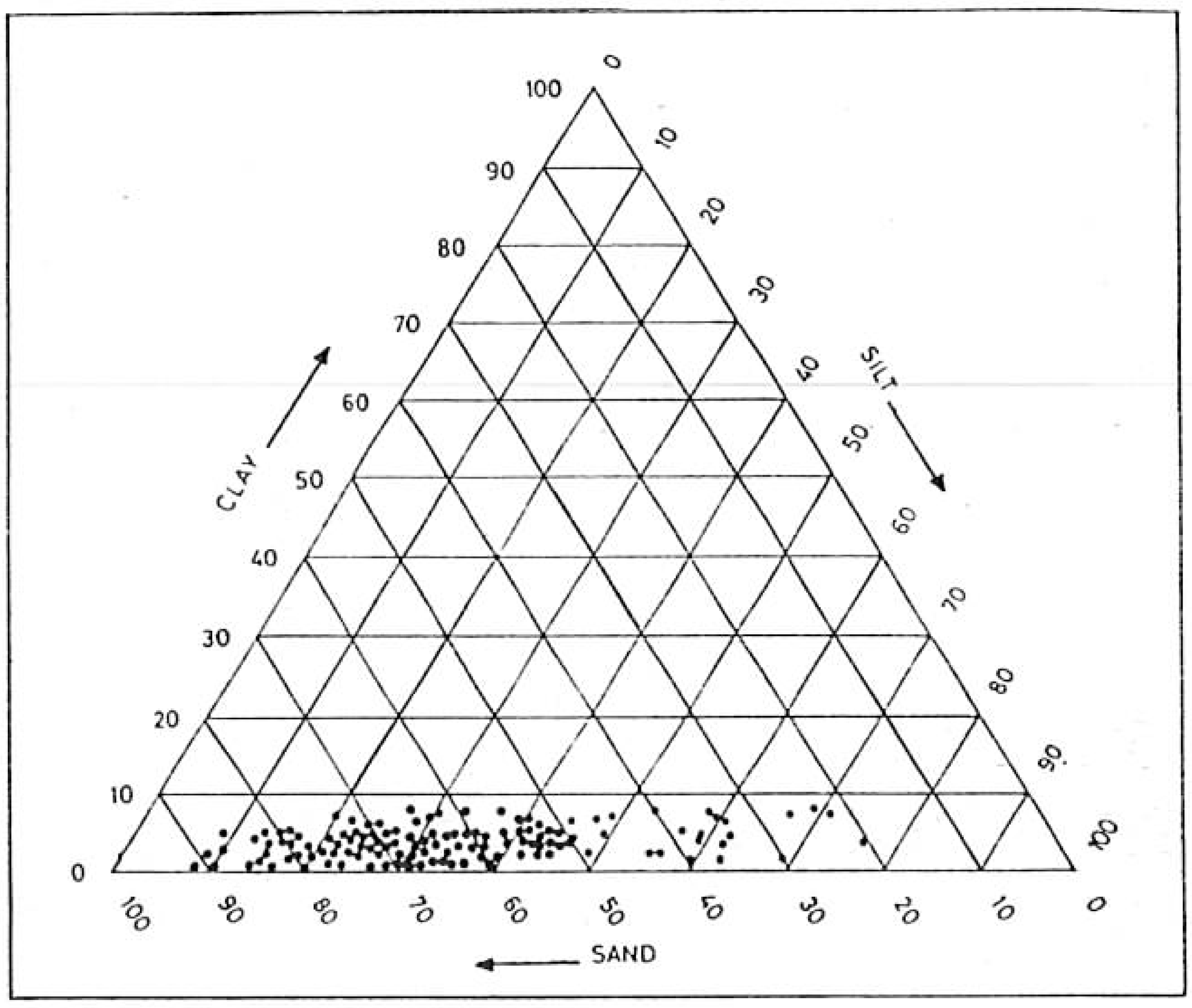


FIG. 2 - The geology and surficial materials of the study area.

FIG. 3 - The particle size distribution of the colluvium.



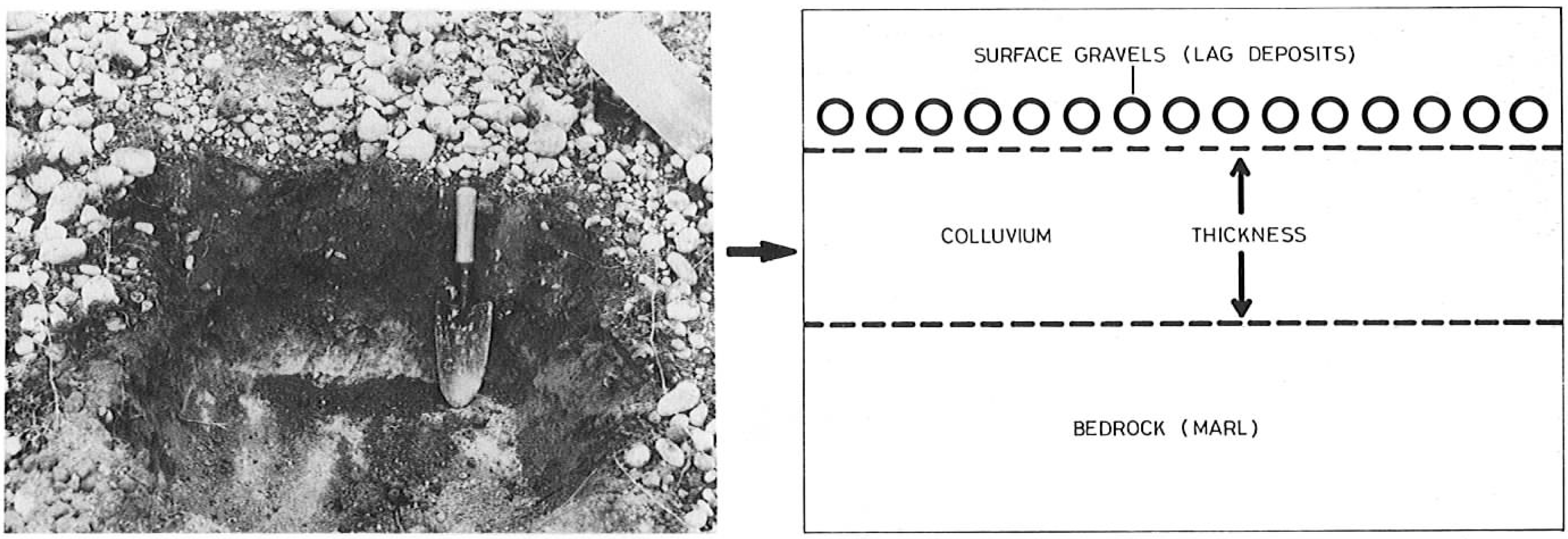


FIG. 4 - Colluvium (a), of thickness (b), overlying bedrock marl (c). 1) The concentration of gravel debris, derived from weathering of conglomerate bedrocks at crestal slopes, transported and deposited as lag - gravels on mid - and lower slopes characterised the surface of the finer colluvium, 2) The abrupt junction between the base of the colluvium and the subjacent material, which is typical of such a colluvial deposit, 3) The slightly irregular nature of this basal junction which in any section makes repeated measurements of colluvium thickness and the derivation of a mean value necessary.

(Murcia Meteorological Service, 1971; SAURA & FERRERAS, 1976). The low precipitation and high mean annual temperatures (17.6 to 18.6 °C) are thus typical of a semi arid climate.

The area is underlain by sedimentary rocks, consisting of a variety of clastic and calcareous beds with thin lenses of evaporites. The main beds are conglomerates, sandstones and marls (fig. 2). These interbedded sedimentary units characterise the undulating hills of the region. These hills form the valleyside and interfluve morphologic units of numerous ephemeral drainage basins.

The sparse vegetation cover enables rain splash and surface wash to operate with maximum vigour. Soil formation is thus limited and surface materials are characterised by a layer of colluvium. The colluvium is poorly sorted and consists of mainly sand particle size with proportions of silts and clays (fig. 3). The colluvial layer was also observed to rest on subjacent materials of bedrock and older colluvial deposits (fig. 4).

It is believed that the colluvium resulted from a reduction in vegetation cover brought about not only by drier conditions but also through the exploitation of the environment by man (BUTZER, 1974). Associated with this is the problem of accelerated erosion, typical for Mediter-

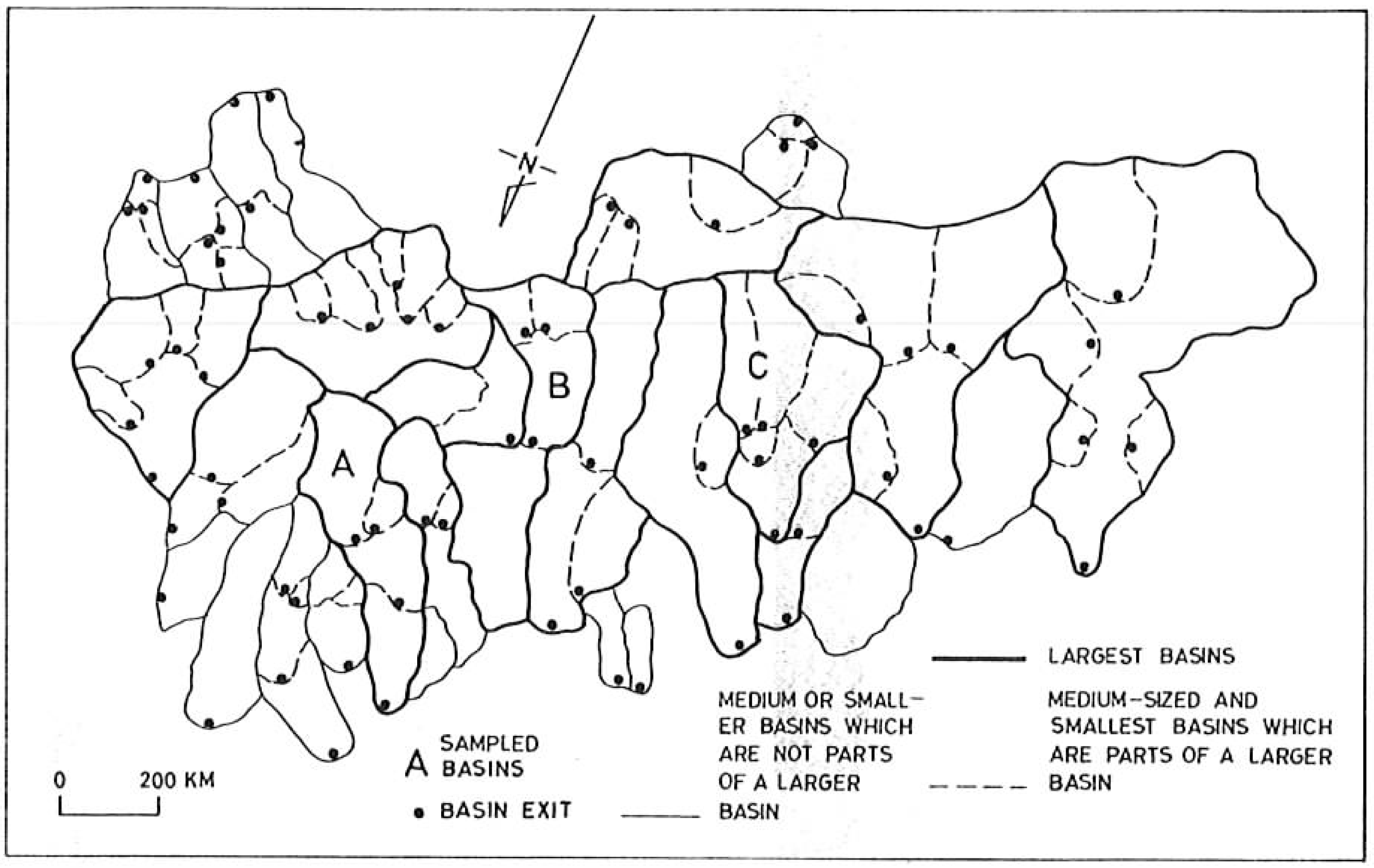
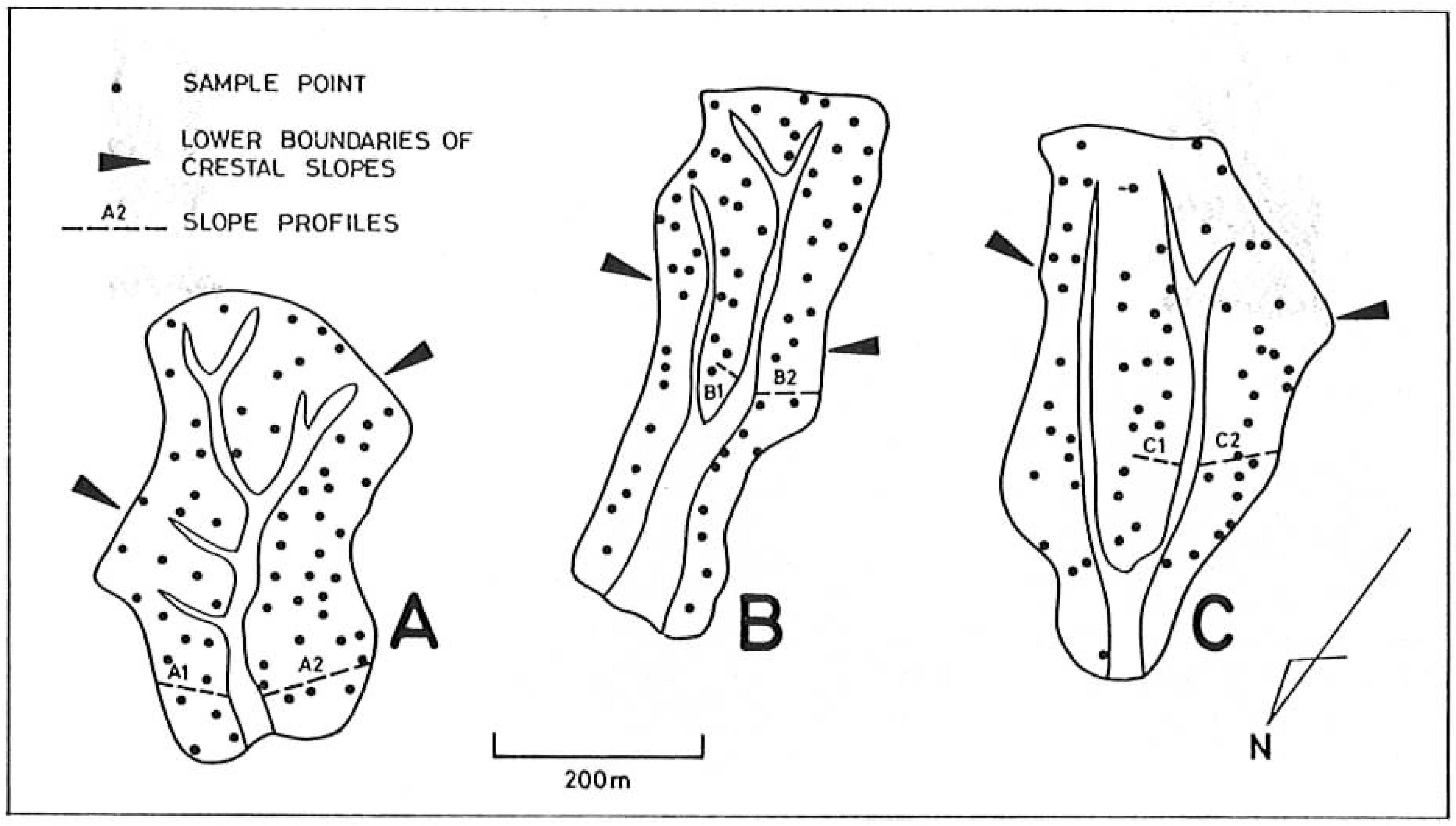


FIG. 5 - The location of the three drainage basins sampled.

FIG. 6 - The location of sampling points within the sampled basins.



ranean semi, arid areas over the last 500 years (VITA FINZI, 1969).

There is no data to determine precisely what factors have led to colluviation in the study area. The colluvium is interpreted as lag deposits whose formation could have been attributed to various slope processes of the present climate. Colluvial movement must thus be dependent on factors influencing the vigour of these processes (KWAAD, 1976; IMESON & JUNGERIUS, 1976; WATSON & *alii*; 1984).

DATA COLLECTION

The main objective of the study was to relate colluvium thickness (response variable) to various environmental factors (control variables). These being slope gradient, curvature and length, surface plant and debris covers, colluvial particle size characteristics and organic matter content.

On the basis of air photo interpretation and detailed field checking and mapping, a study area covering about 10 km^2 was map on an air photo base (1:6000) into its constituent basins which varied considerably in size and drainage order but not in terms of their environmental settings (fig. 5). To investigate the study objectives three basins of the same order and approximately the same size were selected for sampling purposes. The basins selected were large enough to avoid the overcrowding of sample points. They were designated as basins A, B and C respectively. Careful mapping of the colluvial layer whose upper boundaries were defined by crestal slopes (FAIRBRIDGE, 1968) was then carried out.

A sample size of 180 sites (60 sites in each basin) was considered sufficient to portray the study objectives. The sites were randomly determined for each basin by consulting

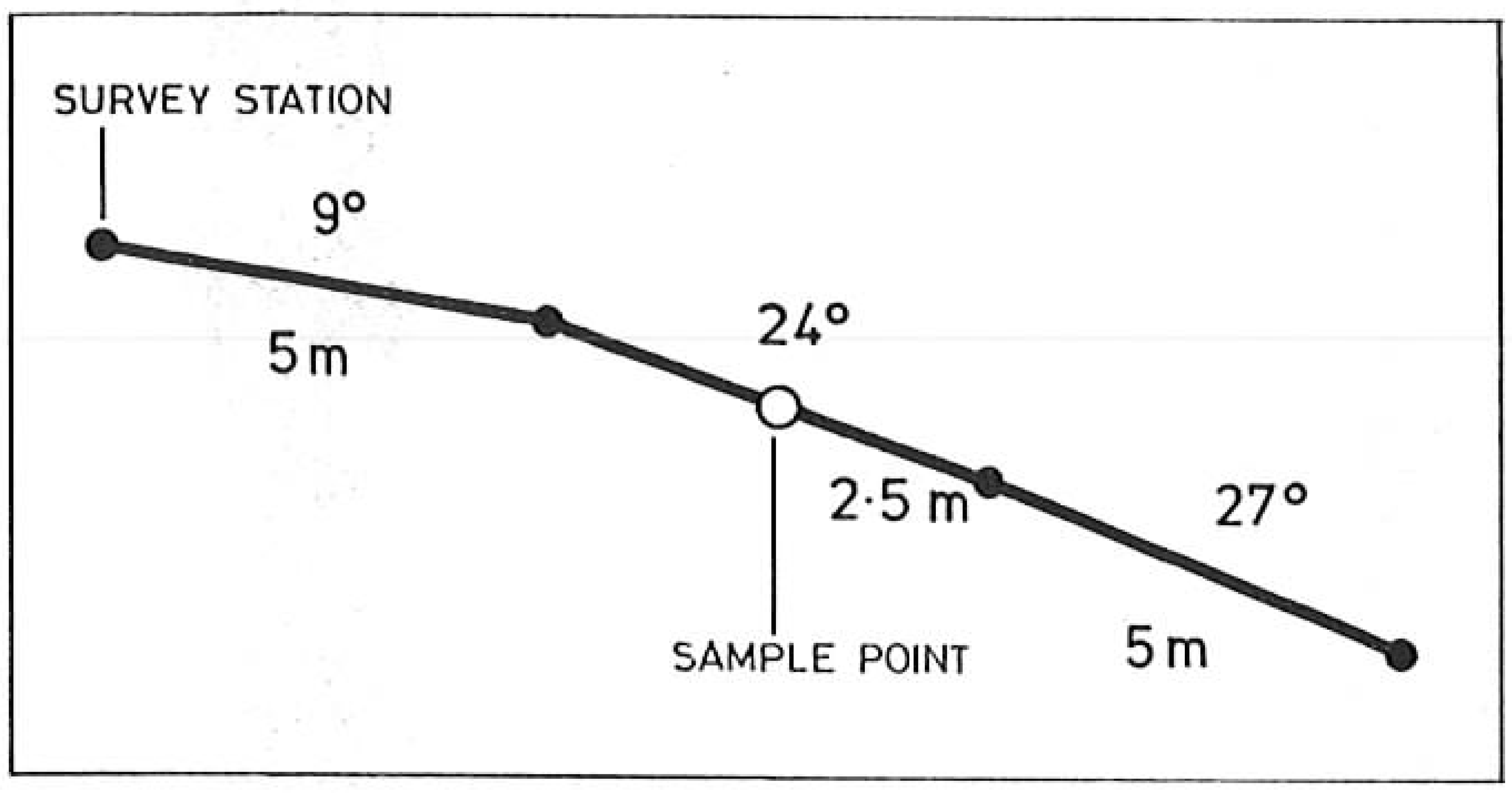


FIG. 7 - A typical sample transect at an individual sampling point.

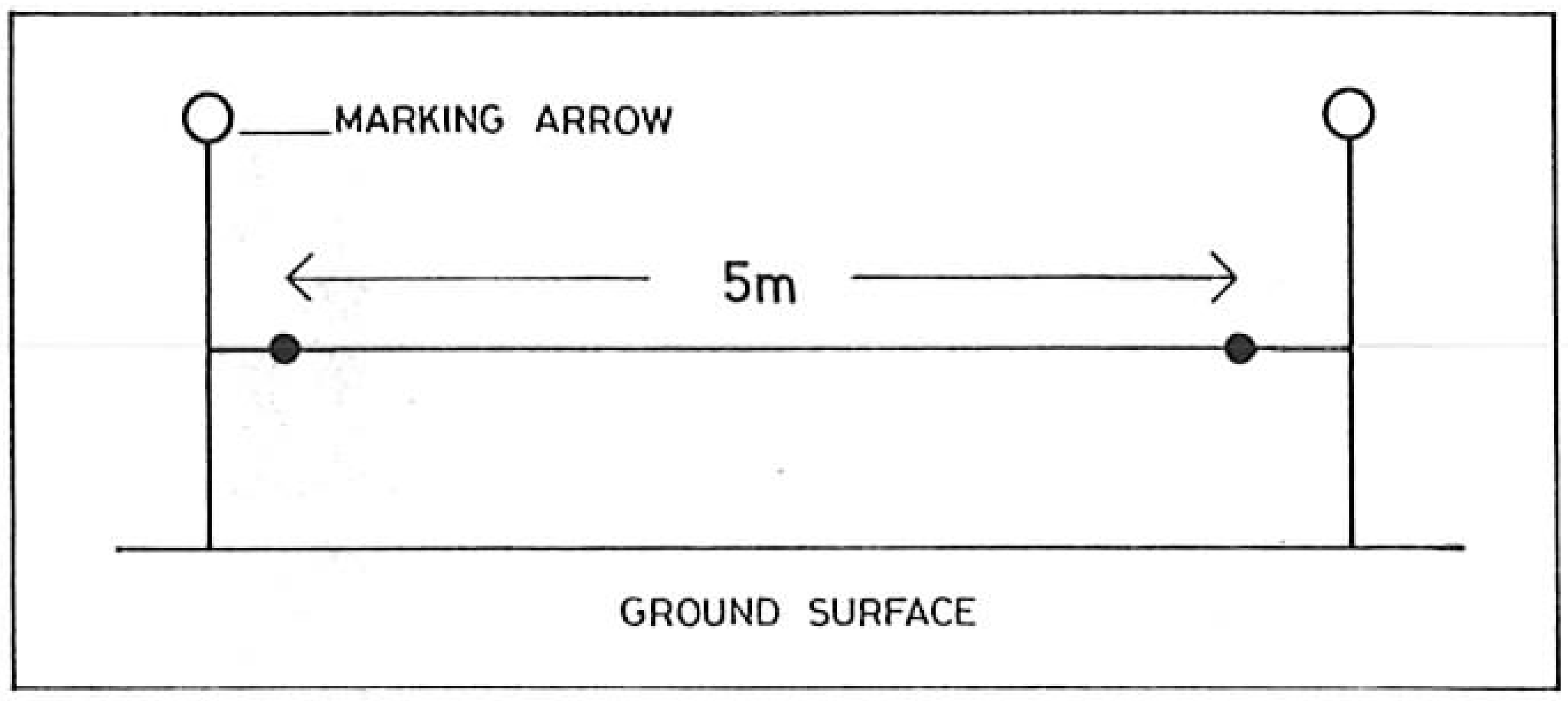


FIG. 8 - Measuring percentage vegetation and debris cover based on the line intercept method.

random number tables and carefully marking them on the base map by reference to a superimposed 1 mm grid (fig. 6). At each site a transect of 3x5 m intervals was aligned to the true slope with its mid - point at the 7.5 m mark. A pit (0.5 m^2) was then dug to observe and measure the thickness of the colluvium (fig. 7). Samples of colluvium were then collected for subsequent laboratory analysis.

In this study, the pipette method was used for fractionation of finer particles and wet sieving for sand particles. The loss on ignition technique suitable for sediments of low organic content was used to calculate organic matter content. Slope gradient and curvature were then measured along the transect (fig. 6).

The line — intercept method (MUELLER-DOMBOIS & ELLENBERG, 1974) was used to measure per centage vegetation and debris covers over a distance of 5 m (fig. 8). The line intercept was positioned with its mid-point on the mid-point of the transect and orientated in a random fashion. The calculation for percentage vegetation or debris cover was as follows:

$$\frac{\text{Total length of vegetation/debris intercepted (cm)} \times 100}{500}$$

Slope profiles were also constructed to provide a morphological context within which the results derived from statistical analysis could be viewed. Two slope profiles were recorded in each basin (see fig. 6). In each case the slope profiles were positioned to show the range of environmental characteristics on the slopes.

SPATIAL CONTROLS OF COLLUVIUM THICKNESS

The statistical analyses revealed significant relationships between colluvium thickness, and slope gradient ($r = -0.7$) and vegetation cover ($r = 0.8$) (fig. 10a and 10b, respectively). The relationships with other control variables were very low however and were discarded from the Hultiple Regression Model (MRM). The MRM identified vegetation cover and slope gradient in order of importance, as influences on colluvium thickness (tab. 1). Vegetation cover was specially notable in providing 68% explanation in the variance of colluvium thickness. The inclusion of slope gradient increases R^2 to only 38%, leaving only 11% of the variance in the response variable unaccounted for.

The slope profile analyses also reinforced these findings, indicating that along the profiles vegetation cover and slope gradient accounted for more than 55% explanation in colluvium thickness -r = 0.69 and -0.53 respectively (fig. 9 and tab. 2).

DISCUSSIONS AND CONCLUSIONS

Interpretation of the relationships between colluvium thickness with vegetation cover and slope gradient were not as simple as the MRM had shown. The colluvium may be a relict depositional feature or an abandoned cultivation site and being more stable and thicker, would facilitate greater vegetation cover. Furthermore, vegetation cover-process relationships might also be interpreted in the following manner, that is, it is vegetation cover density on the upper slopes which through regulating the force of surface wash processes, may influence colluvium thickness on lower slopes.

The relationship between vegetation cover and colluvium thickness is thus complex. The main problem is to determine whether vegetation cover influences colluvium thickness or vice versa. In the absence of detailed soil analyses including moisture availability and soil chemical contents, not much could be said of the colluvium thickness influencing vegetation cover situation. However, it should be known that vegetation has always been sensitive to en-

TABLE 1 - Multiple linear regression parameters for the regression of colluvium thickness (X1) and its control factors, slope gradient (X1) and plant cover (X2)

Constant	Regression coefficients			Critical value of F at 0.05 level	F-value
B_0	B_1X_1	B_2X_2	SE_Y		
0.891	- 0.486	0.725	0.098	2.37	316.15

Standard error at origin of			t-value for				
B_0	B_1X_1	B_2X_2	B_0	B_1X_1	B_2X_2	r	R^2 (X)
0.105	0.057	0.058	8.50	8.56	12.54	0.88	78

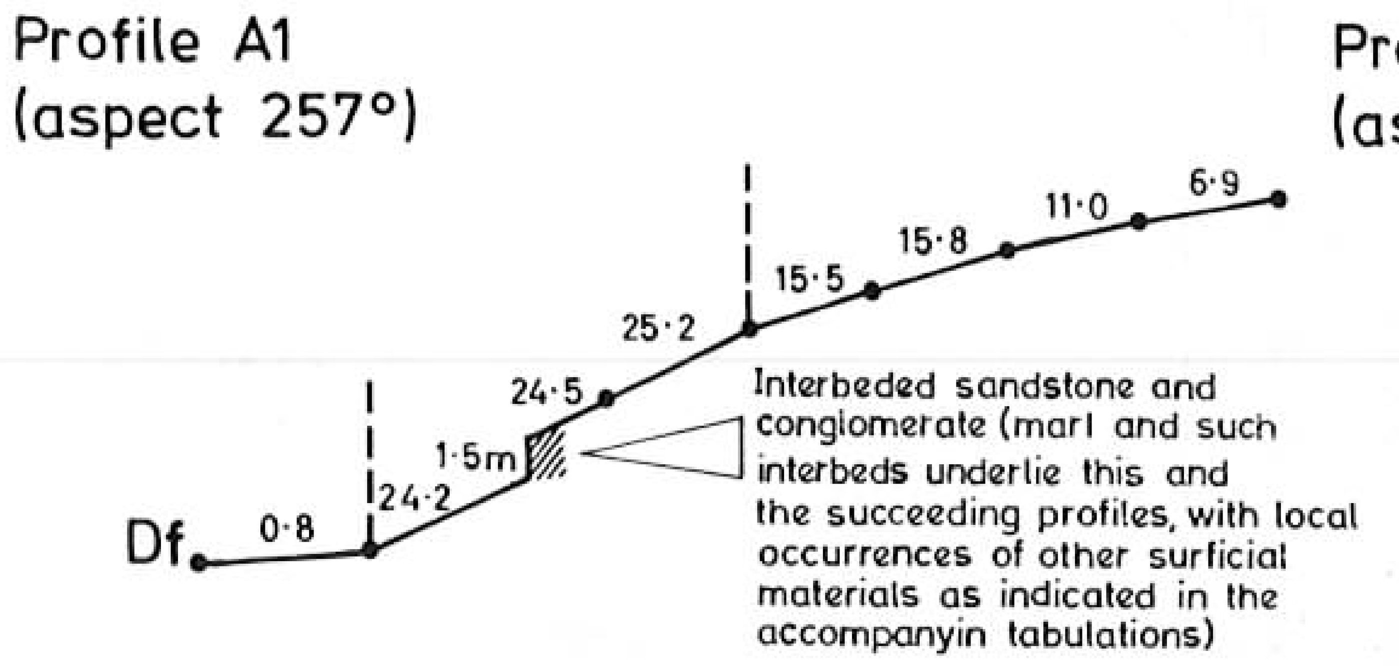
Multiple linear regression equation, $\log Y - 0.891 - 0.486 \log X1 + 0.725 \log X2 \pm 0.098$

The critical value of t at greater than 150 degrees of freedom is 1.98 at the 0.5 level, and 2.61 at the 0.01 level.

TABLE 2 - The summary of the main features of the slope profiles.

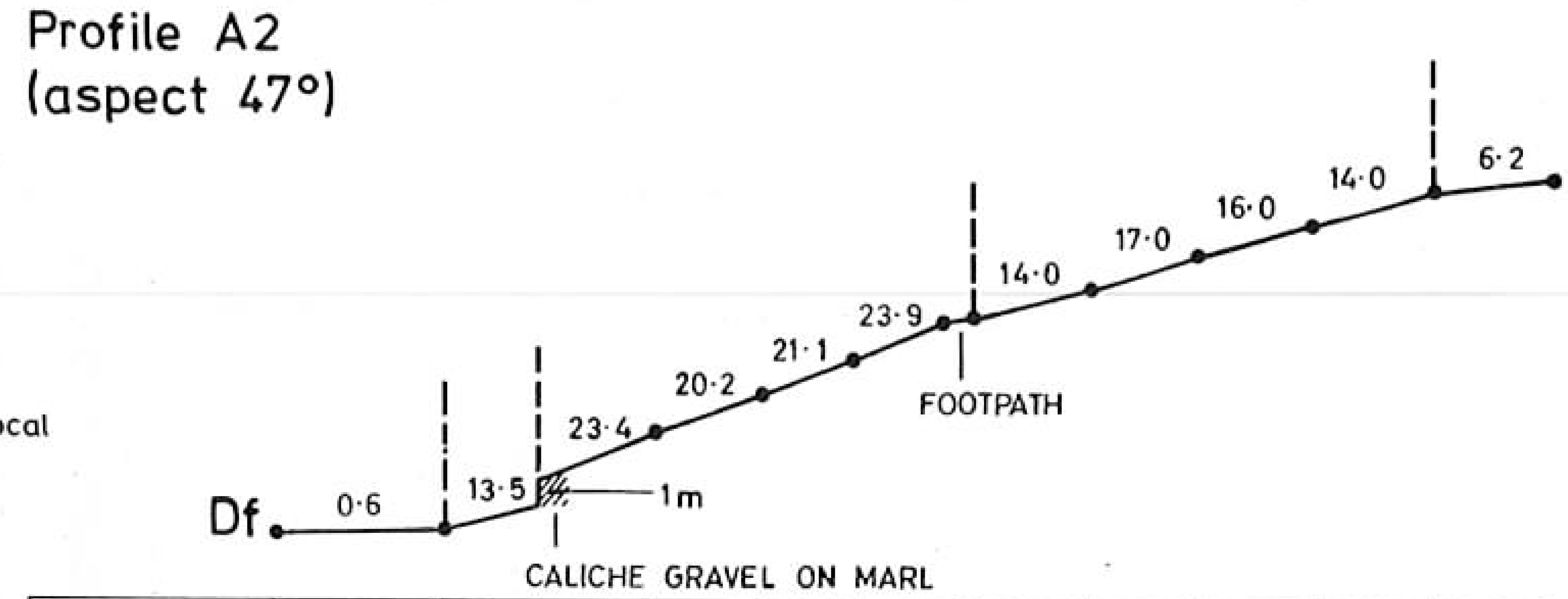
Profile	Aspect	Lenght (m)	Slope Form	Gradient (degree)	Vegetation Cover (%)	Vegetation Species	Colluvium Thickness (cm)	Surface Gravels (%)	Subjacent Materials
A1	237	40	1. concave upperslopes 2. near-planar midslope 3. planar basal slope	7-15.5 25 24	3-10 3-5 3-5	Thymus hyemalis Thymelaea hirsuta	7.5-12.0 3-5	60-80	loose gravels calcrete/ marl
A2	47	45	1. near-planar crestal slope 2. convexo-concave upperslope 3. convexo-concave lowerslope 4. planar basal slope	6 14-17 20-24 13.5	11-12 4-7 10-13.5	Thymus hyemalis	10-16 3.7-8.5	60-75	marl/ calcrete gravel/ marl
B1	238	40	1. convex upperslope 2. convex midslope 3. concave lowerslope	10-16 25-32 4-18	6.5-8.5 2-4 2	Thymus hyemalis	7.5-14 4.5 14-15	60-80	sandstone conglome-rate/marl marl
B2	66	40	overall moderately inclined convex slope	9-18	11-18	Thymus hyemalis Plantago albicans Asphodelus fistolusus	8-17	50-75	calcrete
C1	35	30	1. overall convex slopes 2. basal steepening	10-18 27	5-37 4-5	Thymus hyemalis Fumana thymifolia	7-15 20-37	60-70	partly cemented gravels with marl and sand-stone
C2	237	99	1. near-planar crest 2. near-planar slope	9-10 19-21.5	3-7	Thymus hyemalis Thymelacea hirsuta	10-14 5-8	45-75	partly cemented gravels with some marls

Profile A1 (aspect 257°)



Vc	Tda	3·5	3·8	3·4	5·6	9·8	4·8	7·6
Ct	Tda	3·0	4·5	5·0	10·5	11·8	7·5	12·3
Sm	Tda	marl	calcrete		loose gravels			
	There is much surface gravel throughout the slope with small rock outcrops.							

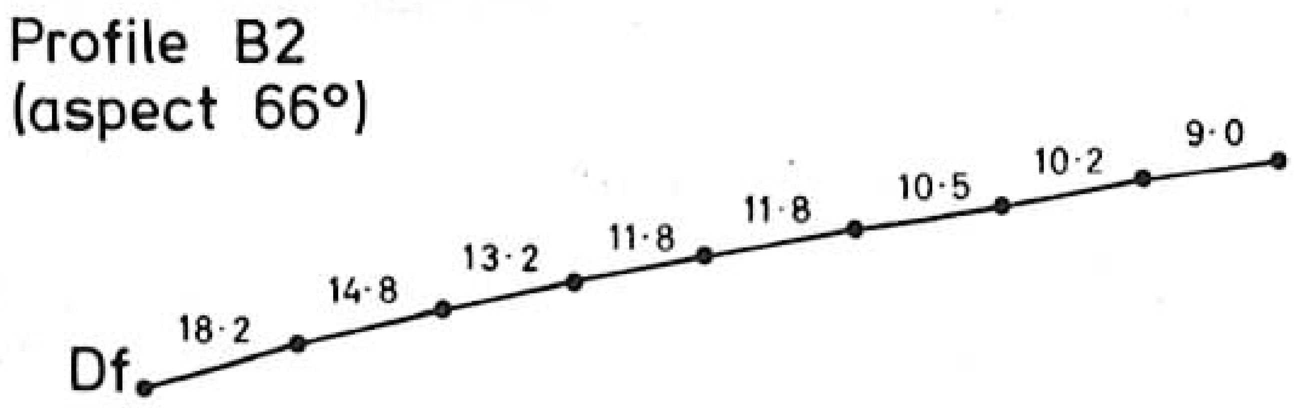
Profile A2 (aspect 47°)



Vc	Tda	13·5	10·2	13·0	10·0	Ae	4·0	6·6	11·0	11·2	11·8
Ct	Tda	3·7	3·7	8·5	8·2	Ae	15·8	10·1	13·8	14·8	11·7
Sm	Tda	marl	loose gravels	loose gravels	Wcg	Ae	Wcg	Ca	Wcg	marl	loose gravels
	There is surface gravel throughout the slope. The steepening (13·5°) at the base of slope, a result of cultivation of the drainage floor, consists of loam colluvium with pebbles and grit on caliche gravel (40 – 90 cm) underlain by marl.										

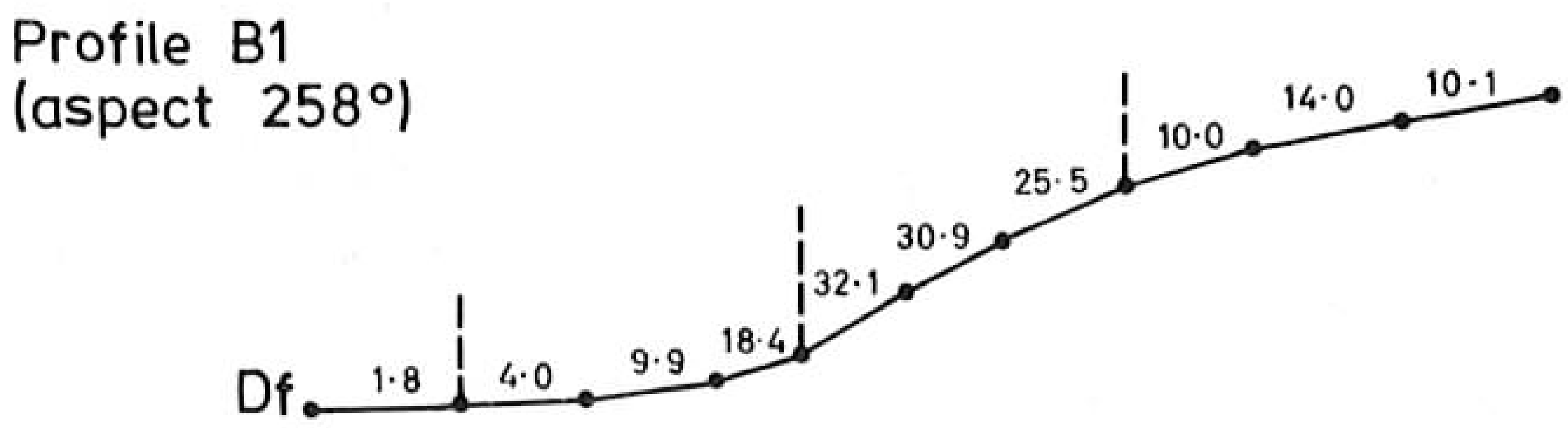
Df — Drainage floor Vc — Vegetation cover (%) Ct — Colluvium thickness (cm) Sm — Subjacent materials
Tda — Terraced dryland cultivation Wcg — Weakly cemented gravels Ae — Artificial embankment Ca — Calcrete — — — Main slope segments

Profile B2 (aspect 66°)



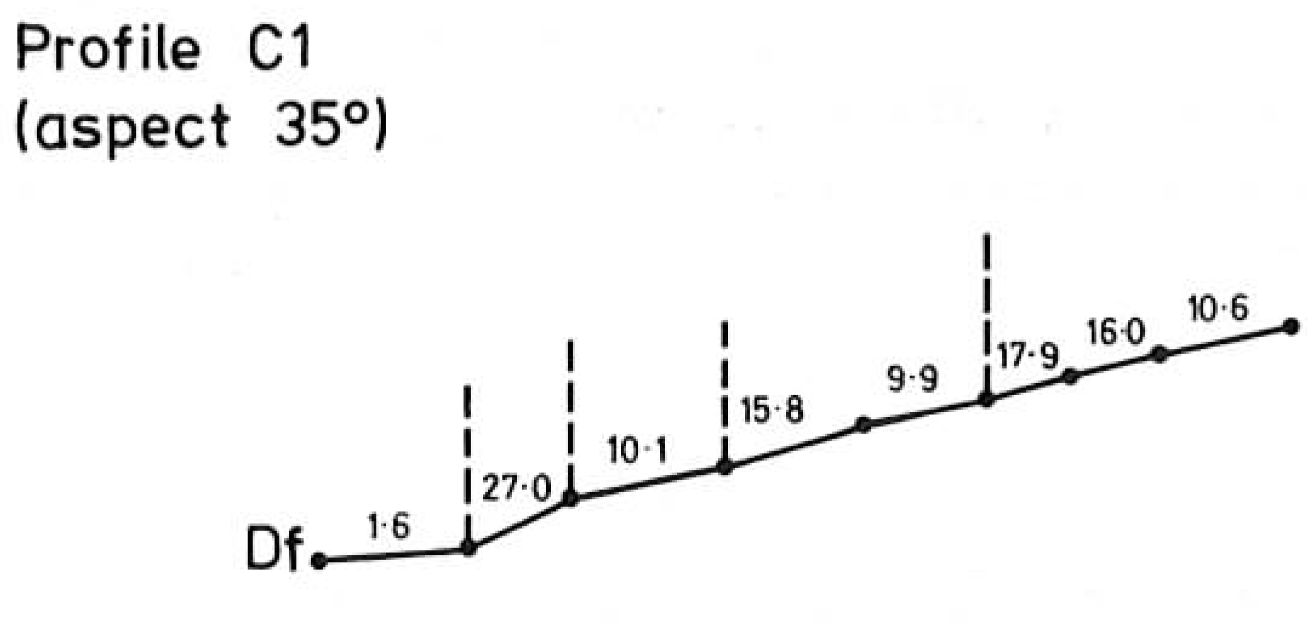
Vc	16·0	18·4	8·0	11·2	16·0	8·6	14·2	10·6
Ct	13·6	16·7	7·5	13·4	13·6	8·3	11·2	11·9
Sm	loose gravels	calcrete						
	There is much caliche debris throughout the slope. The northerly aspect of the slope is reflected in certain northern species such as BRACHYPODIUM RETUSUM							

Profile B1 (aspect 258°)



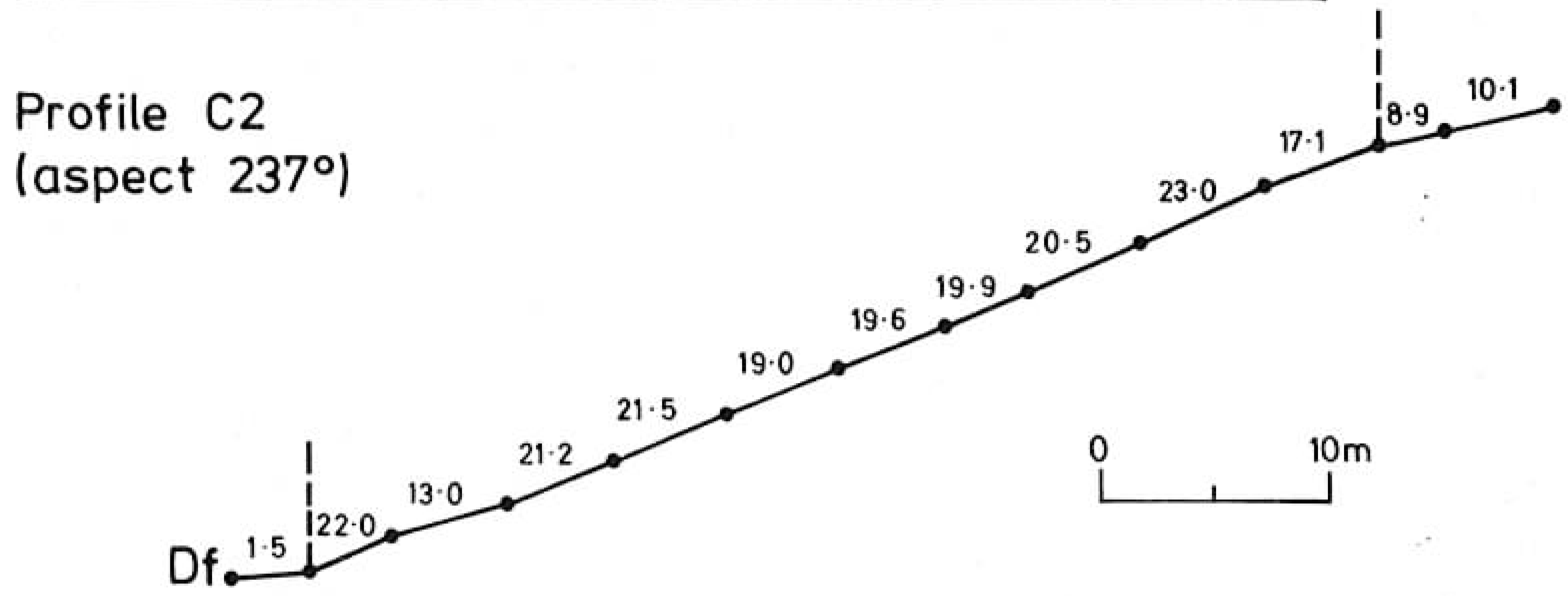
Vc	10·4	7·6	6·8	2·2	1·8	4·0	2·0	7·6	6·5	8·4
Ct	25·0	14·8	14·0	14·8	2·0	4·5	4·4	13·9	7·4	11·3
Sm	marl			weathered conglomerate				loose gravels		Ws
	There is surface gravel throughout, but no rock outcrops, with mostly semi-natural vegetation, of low shrubs, except for terraced dryland cultivation in the drainage floor. Ws = weathered sandstone									

Profile C1 (aspect 35°)



Vc	20·8	5·4	16·4	26·6	36·6	6·8	5·0	9·6
Ct	18·6	21·3	15·6	19·3	37·2	7·1	9·4	14·8
Sm	loose gravels	marl	partly cemented gravel					
	An irregular slope profile, probably a result of past cultivation practices involving terracing. There is much surface gravel throughout.							

Profile C2 (aspect 237°)



Vc	15·5	3·0	2·6	5·2	10·8	6·6	5·6	4·0	13·0	3·0	5·2	6·6	6·6
Ct	18·2	5·0	7·0	7·6	8·1	13·9	10·7	10·7	14·3	4·6	6·6	12·3	12·2
Sm	marl	Cg	marl	loose gravels		marl	loose gravels	marl	loose gravels				
	There are much surface gravels throughout the slope. Cg = Conglomerate												

FIG. 9 - Slope profile analyses to reinforce the relationships of colluvium thickness with slope gradient and plant cover.

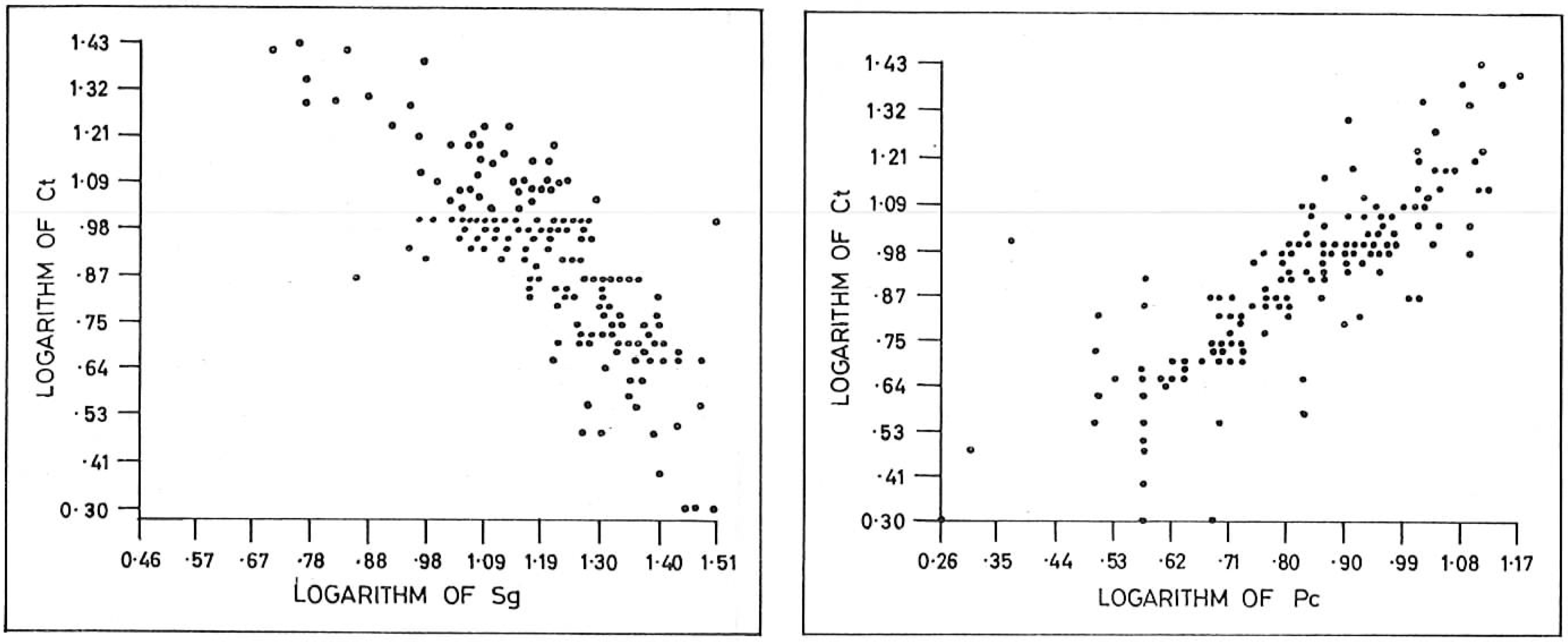


FIG. 10 - The relationship between slope gradient and colluvium thickness (10a) and between plant cover and colluvium thickness (10b).

vironmental conditions. Differences in colluvium thickness could be one of the variables influencing species colonisation. Thicker depths of colluvial soils promote vegetation growth where the necessary chemical elements are made available. These statements are highly speculative and more data is needed to validate such assumptions.

In the case of vegetation cover controlling colluvium thickness, there could in fact be two explainations. Vegetation may control the rate of erosional processes on upper slopes through which the effect of erosion influences colluvium thickness on lower slopes. Thicker vegetation cover on lower slopes may help cause deposition (ie. inhibit movement furhter downslope) and/or inhibit further movement after initial deposition. Alternatively, a more plausible explanation suggests that the random nature of the relationship between vegetation and colluvium thickness indicates that colluvium thickness does not show any particular trend on the slopes. Its random nature must be attributed solely to the random distribution of vegetation cover densities. Under a common set of soil erosion processes, therefore, vegetation cover and its attributes, canopy cover, root density etc., would act as opposing forces to the shearing effects of erosion (COOK, 1936; THORNES, 1976; SCOGING, 1982).

The relationship between slope gradient and colluvium thickness should also be intrepreted cautiously. The linear model ($Y = \alpha + \beta X$, where Y is the response variable and X the control variable and α and β are the intercept and slope constants) was used to relate slope gradient and colluvium thickness.

The model shows that steeper slopes are associated with thinner colluvium inferring an increase in the erosional potential of run-off due to the increased downslope component of gravity (CARSON & KIRKBY, 1972). However, studies have shown that the general relationship between erosion and slope can be expressed by the equation:

$$Qs \sim\sim \tan^m \Theta\ L^n$$

where Qs is amount of soil loss, Θ is the gradient angle and L is slope length (EMMETT, 1978; MORGAN, 1979). This model took into account an intervening factor (s) ie. L (MUSGRAVE, 1947; KIRKBY, 1969). Other studies also show that the values are sensitive to the interaction of other factors in the erosion - slope relationship (GABRIELS & *alii*, 1975). D'SOUZA & MORGAN (1976) for example showed that the erosion model could be expanded by including slope curvature.

Although few studies have examined the effect of vegetation densities on the exponent values, the MRM confirms that colluvium thickness is controlled by vegetation densities and slope gradient. However vegetation cover does have an overiding effect on slope gradient. A steeper slope of less vegetation cover would experience more erosion than if the same slope were covered with denser vegetation.

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