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RELATIONSHIPS AMONG SELECTED GEOLOGICAL AND GEOMORPHOLOGICAL PROPERTIES OF VALLEY NETWORKS IN A PART OF MERSA MATRUH AREA , NORTHWEST EGYPT

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SUMMARY :

A part of the valley systems of Mersa Matruh area Northwest Egypt, called Wadi El-Raml , has been studied in an attempt to relate the structure function to the geomorphic properties , and to investigate the relationships between the geomorphic forms of valley network . Based entirely on field measured data , the comparisons and relationships between variables have been recognised with the aid of four types of statistical analysis: the poisson distribution function, analysis of variance, correlation coefficient , and linear regression analysis . The structure control and morphological properties , as observed in the field and revealed from the analysis , has been demonstrated and discussed . The results seem to suggest that geologic structure exert , to some extent , a strong effect on the relationships between geomorphological properties in this particular area .

1- INTRODUCTION

The interpretation of landforms requires that forms and processes be related : how they differ spatially and what factors control them . In other words , however, form is a function not only of processes but also of environmental factors such as geologic lithology and structure , climate , soil , and vegetation ,

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The functional relationships between forms and their controlling factors are not the only ones used in the interpretation of landforms , but an understanding of these relationships is often regarded as a central issue in modern geomorphology.

The influence of geologic structure on landforms is widely acknowledged . Not only are the major phenomena on the earth surface predominantly of structural origin , but many of the minor landforms are controlled by geologic structure (bedding , folds , faults , and joints) through the action of agents of degradation processes on complex rock masses (Thornbury , 1954 ; Melton , 1959 ; Hills , 1972) . Such structurally related features have been ascribed as " drainage anomalies " (Tator , 1954) . In this contex , however , the greatest aid that geomorphology offers to structure geology is from various features of drainage pattern such as " preferred orientation " of stream channel , segments of norrowing or local widening of valley as well as the whole drainage pattern itself may imply strong structural control (Desjardins , 1952 ; Haward , 1967 ; Aghossy , 1970) . Moreover , many investigations , in the field of structural geomorphology , have emphasised the significance of drainage patterns as sensitive indicators of local geologic structures (Tator , 1960) . In the processes of drainage development on an area undergoing dissection , the streams , in general , become adjusted to structures through the differential influence of resistant and non-resistant rocks . In this connection the stage of development of valley network is an important factor govering the extent to which underlying structures affect the drainage pattern properties (Thornbury , 1954) . As in the main drainage lines , structural relationships may also be prominent in tributary valleys . However , in spite of the important role assigned to the element of geologic structure in influencing valley - network development , relatively few attempts have been made to determine this relationship quantitatively , and were partly based on field observations or chiefly based on measurements derived from aerial photographs (Parvis , 1950; Henderson , 1960) .

On the other hand , much impetus was given to fluvial morphometry by Horton's (1945) suggested methods of quantitative analysis of the various measurable drainage - network porperties . Following Horton's lead , many workers have applied methods of statistical analysis to quantitative geomorphic parameters of fluvially - eroded terrain to discover new morphometric relations . Much of that work has been carried out in semi-arid , and arid environments (Strahler, 1950 , 1952 , 1958 ; Schumm , 1958 ; Schumm and Hadely , 1957 ;

Melton , 1957 ; Smith , (1958) . From such work it is acknowledged that the analysis of morphological features , for example : network topology and slope form , may be extremely helpful in the interpretation of the morphology of valleys , and it is essectial to an understanding of the structural control of drainage evolution (Abou-Raddy , 1989) .

The present paper attempts to establish statistical relationships and comparisons between quantitative geologic structure parameters and geomorphic properties of drainage network besed entirely on field measurements and observations . The statistical analysis of data collected has been selected with the aim of furthering the understanding of the geometric of land classification , in this case that of fluvially - eroded " badland " terrain .

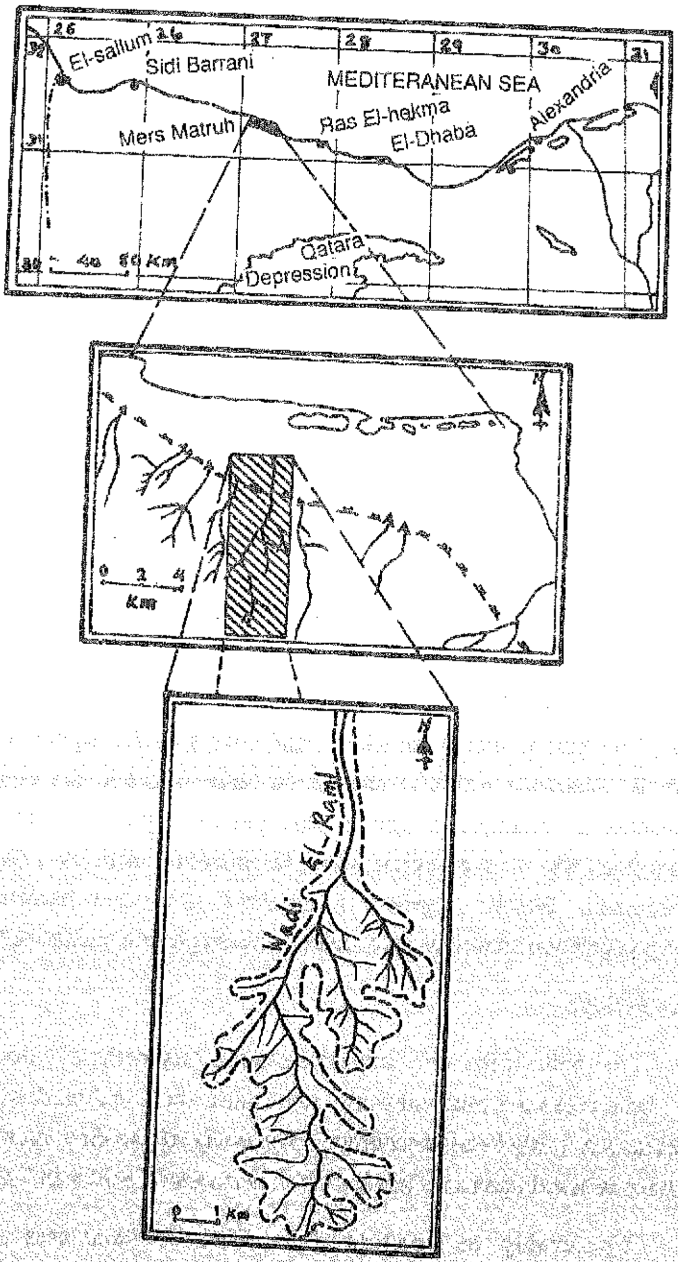
2- REGIONAL SETTING

The area under study lies southwest of Mersa Matruh (Fig. 1) , and it was readily accessible using the Matruh - Siwa Highway . It is delimited by latitudes 31° 36′ N. and 31° 50′ 30′′ N, and longitudes 27° 12′ 30′′ E and 27° 17′ 30′′ E. The area , oriented on an approximately north-south axis , is 11.25 kms long , 1.93 kms in maximum width , and covers 21.725 sq.kms to the west of Wadi El Kharruba which is one of the large wadis in the area . It is also represents an example of geomorphic pattern typical of fluvialley-eroded badland terrain , or a region of rapid erosional activity , in a semi-arid environment . Besides , a general uniformity in its climate characteristics , and a scanty vegetation as well as bare valley - side slopes are maintained .

2.1. *Geology*

The bulk of the area comprises sedimentary rocks of Miocene age (Fig. 2). These rocks are predominantly limestones, shale and marl which are intercalated in a thinly bedded sequence . The study of the lithotypes and structural features is based upon stratigraphy which is reviewed briefly in Table 1 .

Concerning the structure of the Wadi El Raml area , the beds are apparently horizontal , but the dip measurements indicate a regional inclination in the north - east direction . Local south dips are also detected , with the development of a flat structure having a N.E- S.W. trend (Mersal , 1982) . Towards the escarpment bounding " Ghot Rabah Plain " , steep north dips are known .

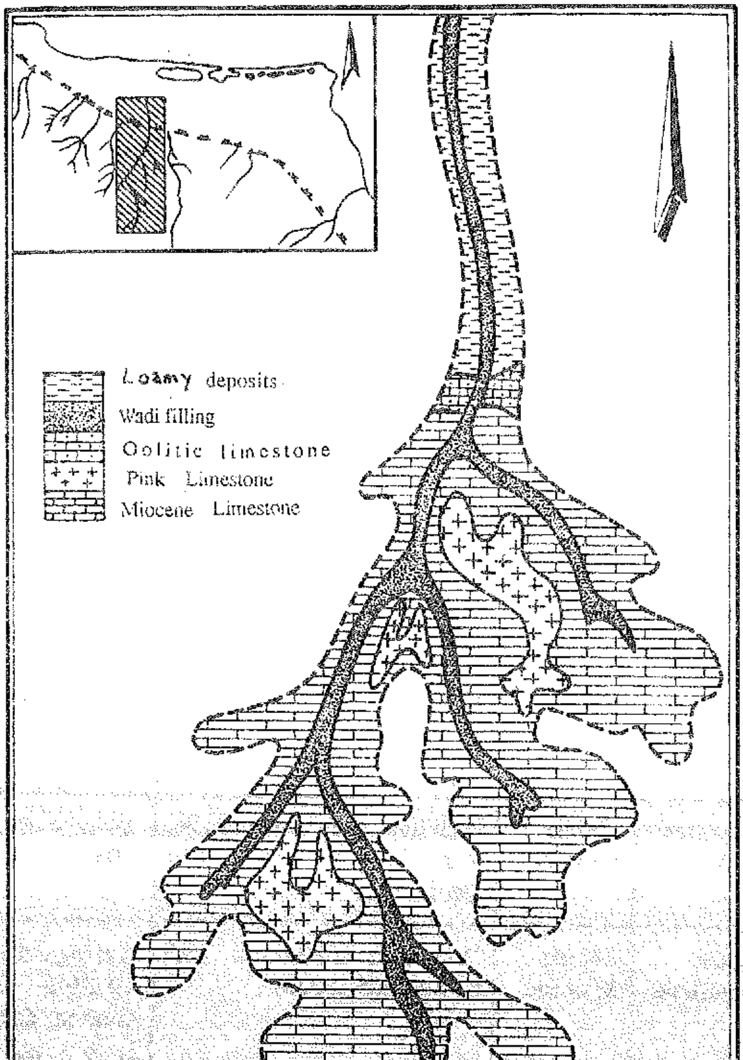


(Fig. 1) : Lacation of the study area.

Table 1. Stratigraphy of the study area

Formation	Age	Lithology	Structural Features
Quaternary	Recent	Limestone fragment and soil, alluvium with much boulders, wadi filling	
	Pleistocene	Oolitic limestone, well-cemented	False bedding
Pink Limestone	Pliocene?	Dominant white chalky and pink limoestone with conglomerate at base .	Average thickness 2.0-7.0m. moderate dips 20-30° N
Green & Yellow Shale	Middle Miocene	Dominant shale , marly (Silty in texture and highly weathered) .	Average thickness 7.0m.
Gastropod Limestone	Middle Miocene	Dominant limestone, marly with big echinoids .	Average thickness 5.0m. moderate dips 18-29 N Local monoclined folds .
Grey green Shale	Middle Miocene	Dominant grey green shale, marly (silty in texture) and arenaceous .	Average thickness 9.0m.
Pecten Limestone	Middle Miocene	Dominant limestone with Oysters and pectens .	Average thickness 10-20m. Joints cmmon, dominantly dip and strike joints.
Grey green shale	Middle Miocene	Dominant grey green shale, calcareous, salty gypsiferous .	variable thickness , exposed in lamination form.
Limestone	Middle Miocene	Dominant limestone , marly and sandy, medium hard with Polyzoa .	Average thickness 3m., gentle dips ranging from 8-10° NE.

(Source: Shata , 1957; El-Shazly, 1964; Taha , 1974) .



(Source: El-Shazly, 1964; Taha , 1974)

(Fig. 2) : Generalised geology in the study area

2.2 *Geomorphology*

The area under investigation has distinct geomorphological characteristics. A valley system represents one of the main consequent sculpture which dominante the surface of the " Shaquqa - Siqueifa Plateau" . It occupies the whole of the area (about 21.7 sq. kms.) , and has a dendritic drainage pattern. Within the limits of the mapped area , Wadi El Raml comprises three trunk lines with numerous valleys occupied by gullies which are actively extend headwards. The tributary valleys are deep narrowly confined and relatively youthful trenches . They are characterised by steep , V- shaped slopes (mean angles of valley - side slopes 50.8°) . The eastern side of this basin has a rather steep face , sloping at a rate of 58°± . The slope of the other sides is rather moderate with angles seldom 45° . On the eastern side , the outcrops are always , better exposed , while the other sides are covered with talus deposite . The steepness of the eastern side of Wadi El Raml basin and also the occurence of good exposures may be a direct response to nowadays wind action , blowing mainly from the north-west direction . Besides , the tributaries have several " water falls " , which may be described as " natural steps " , cutting down through thick beds of limestone and shale . Most of these steps are up to 5m. in height and at their base water commonly accumulates as ponds .

Valley devides are well-defined in the area and interfluves are not wide . However , because of the present entrenched and actively developing valley system with waterfalls in many tributaries, the morphology of the area is remarkably similar to youthfully dissected areas of high relief . It is possible that slight earth movements, principally in the middle portion of the Wadi where there is evidence of a local structural high , climatic changes which are well-decumented in comparable latitudes and relatively recent anthropogenic causal factors are possible factors for consideration in any explanation of the origin of the present morphology .

A variety of degradational and aggradational processes are active throughout the study area . Intensive rainfall storms (about 35% of total annual rainfall) on dry marly limestone surfaces which have relatively low infiltration rates give rise to vigorous denudational processes , such as rock collapse , rock flowage , sheetwash , rilling and gullying , on the valley-side slopes . some other degradational processes , e.g. debris slibe debris fall and rock fall are operating on the valley sides throughout the year . The rock fall process is common, particularly when there is an undercutting of dipping beds wherever there are incompetent layers in the sequence . Consequently , tributary channels are often choked with debris, pebbles , and boulder which have moved by sheetwash , and by slumping from the steep adjacent slopes . On the other hand, extensive colluvial deposits mantled many footslopes , reflect the effect of aggradation process in the study area (Abou El-Enin , 1975 ; Akl , 1985) .

3- THE CONCEPT

The geomorphic properties of a landform or a terrain type can be expressed in terms of its genetic relationships as follows :

$$G = f(\ell - s, c, b)$$

Where : G = any geomorphic properties , $\ell - s$ = lithology and structure ,

c = climatic condition , b = biotal factor .

The merit of this expression lies only in its ready charaterisation of the controlling factors of any geomorphic property , but also in its flexibility to allow the study of each of these factors as an independent variable which would define the state of the geomorphic system . Thus we may isolate :

(1) Lithology and structure function $G = f(\ell - s)$

c, b constant

(2) Climo function $G = f(c)$

$\ell - s, b$ constant

(3) Bio - function $G = f(b)$

$\ell - s, c$ constant

All the three controlling functions , $\ell - s$, c , and b are multiple factors and produce sets of functions . Each individual landform has several properties , an assemblage of which defines the geomorphic complex . Thus ,

Geomorphic complex = $G = f(\ell - s, c, b)$

Variations in this ensemble give rise to the different levels in the characterisation of landforms (Abou-Raddy , 1989) .

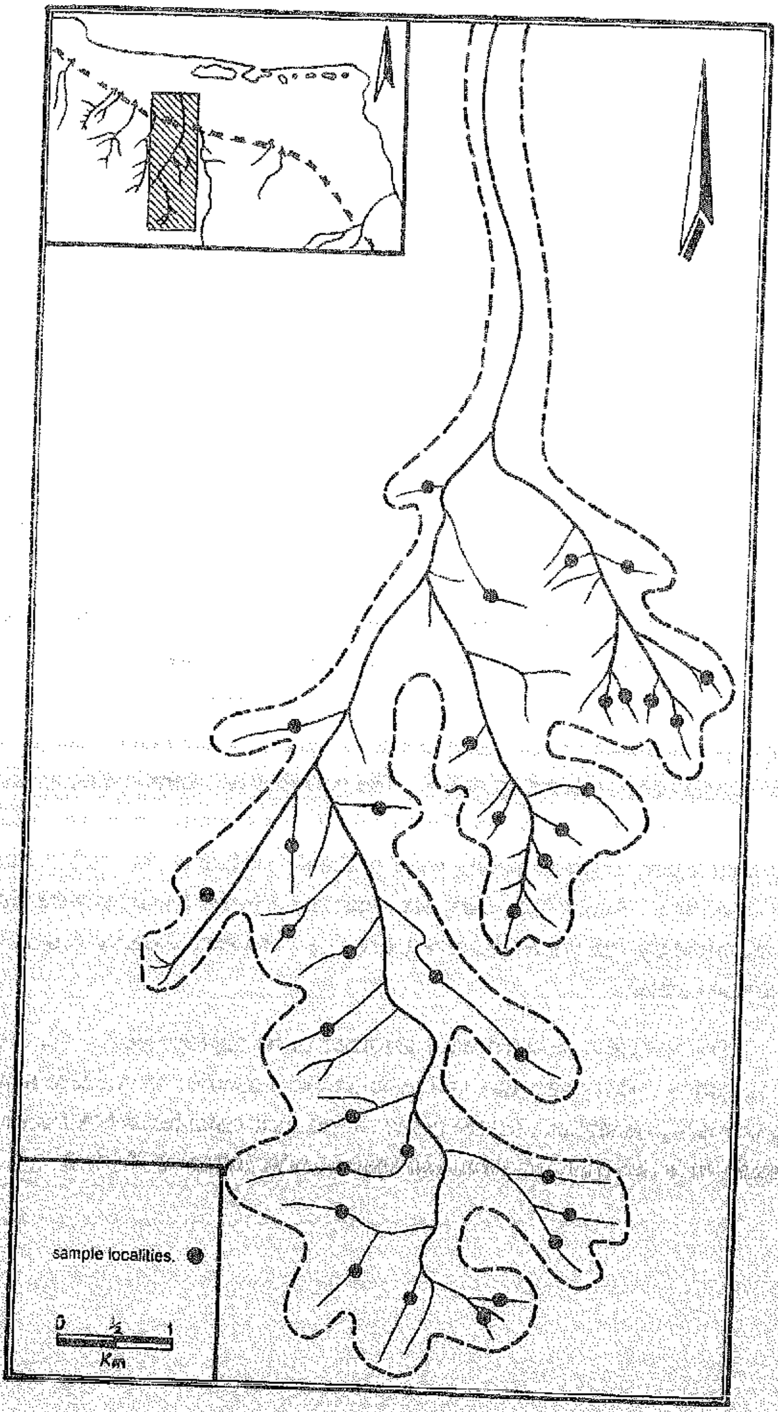
4- MATERIALS AND METHODS

The methods and techniques which have been employed to achieve the objective of the present investigation were mainly those of planning the sampling design , measurement procedures in the field and statistical procedures for data processing and analysis . The fieldwork lasted for a period of ten days during which all measurements were taken .

4.1 *Experimental Design*

For the purpose of this study tributary valleys were restricted to those at least 20m. long 2m. deep which formed part of an interconnected net of drainage lines . A special random method for obtaining representative data to reflect the properties of tributary valleys was designed and used . This method was point sampling where grids were drawn over an enlarged aerial photograph of the area, at scale 1 : 10000 , and the random points chosen were plotted on these grids . From each of these points a random orientation was drawn to contact the tributary valley channel in a point being used as a sample locality , whereas sample points which fell on valley heads as well as on the main drainage liens were rejected and replaced by others . The quantitative determination of sample size was not attempted before the field work . It was assumed , however , that not less than thirty . sample points were probably sufficient for such a limited fieldwork time . According , thirty six randomly selected locations were plotted on the tributary valleys of the area (Fig. 3) , and each locality was given a reference number .

The variables selected were assumed to be appropriate for the present investigation . Many structure and geomorphic properties of drainage network can be readily quantified , but the groups of selected variables and their attributes considered in this study are listed and operationally defined in Table 2 .



(Fig. 3) : Location of the sample localities.

Table 2 : Geologic attributes and geomorphic properties

Measured variables	symbol	Unit	Remarks
Structure variable			
1- Dip of bedrock	ϕ	degree	Measured with a clinometer accurate to ± 1° .
2- Bedding strike orientation	S_{10}	-	Measured with a prismatic compass to the nearest 1° . Always at 90° to true dip direction . Divided into 36 classes each with 10-degrees.
3- Total joints	T_{10}	-	T_{10} is maximum frequency of joints . Originally based on 20 joint orientation readings obtained from the lower valley-side slopes using a prismatic compass . Divided into 36 classes each with 10 - degrees .
Geomorphic variables			
4- Lower valley-side slopes	θ	degrees	Measured , above the concavity of the valley side to the major break of slope , with suunto clinometer calibrated to read to 1/2° . A maximum of ten random measurements , assumed to be sufficient to portray the range variation within the sample locality , were taken from both sides of the valley looking downvalley . Most of the valley-side slopes in the area become relatively steeper towards their base , hence the lower part of the valleyside is assumed to be representative of the overall slope . Therefore , the short oversteepened at the base of valleyside , basal concavity , and bluffs at the upper part of the slope are not included . These shorter slopes at the base are related to fluvial erosion processes in the channel rather than to those processes that have produced the main valleyside , and the basal concavity is due to local accumulation of slopwash . Likewise , the uppermost parts of the slope are not formed by processes that are mostly operative on the main valleyside but by fall process . The reason for selecting this parameter is because , firstly , it is easily measured , and secondly , measured values of valley side slope are commnly randomly distributed (Strahler , 1954 and hence they are appropriate for various statistical analysis.
5- Aspect	A_N	-	Measured with a prismatic compass at the randomly selected points where valley-side slope was also measured . Always at 90° to the trend of valley side . Divided

Measured variables	symbol	Unit	Remarks
			into 8 classes : N , NE , E , SE , S , SE , SW , W , NW .
6-Valley width	V_w	metres	Valley width is the horizontal distance from bank to bank , or between the bases of oversteepened slopes on opposite sides of the valley floor . It was measured using a 30-meter tape at 3 random points at each sample location and the mean of these measurements was taken to represent the required value to this parameter . Valley - floor width is related to discharge and its relationshp with valleyside slopes is important in that it could reveal the effectiveness of channel downcutting or the effectiveness of removal of waste at the base of valleyside slope . It is assumed that the relationship of these two variables is one of the most important factors controlling the morphology of valleys .
7- Valley depth	V_d	metres	Valley depth is the vertical distance between the valley floor and the highest interfluve crest . It was not directly measured in the field , but angular measurements were taken along a fixed distance and a claculation was carried out to obtain the valley depth as follows : a horizontal distance along the valley floor was delimited and at both ends of this distance two angle reading were taken , with reference to the highest spot of the interfluve at the sample locality . The following equation was used : $V_d = h + \frac{d (\tan O_1) (\tan O_2)}{(\tan O_2 - \tan O_1)}$ where : h = the height of the observer , d=a fixed horizontal distance , O_1 = first angle at one end of the distance , O_2 = second angle at the other end of the distance .
8- Orientation of valley segment	OV_s	-	Valley-floor segment is defined as a distance not less than one metre in length at the right angle to contour trend of basal portion of valleyside . 20 contiguous measured lengths form a longitudinal transect across a sample area . Orientation of each segment was measured using a prismatic compass and ranging poles, and represented by mode orientation (0-360°) of the most frequent valley segment .

4.2 *Data Processing and Statistical procedures*

Data on the geological attributes and geomorphic properties (measured) has been grouped into classes before being fed to the Olivetti 101 desk top computer , by which much of the computation necessary for the analysis of the data was carried out . In addition , the orientation of bedding strike (S_{10}) , and valley-floor segments (VO_s) corrected to true bearing (Magentic variation , for this , part of Egypt , is 0° 34 'W) .

The primary statistics for dip bedrocks (ϕ), valley-side slopes (θ) , Aspect (A_N) , valley width (V_w) and valley depth (V_d) is summarised in Table 3 .

Table 3 : Statistical data for measured geological and geomorphological properties

Variables*	Mean ($\bar{X}$)	Standard deviation	Best estimate of S.D.	Variance σ^2	n
ϕ	18.12	5.60	5.68	32.31	34
A_N	41.70	4.00	4.06	16.50	33
A_{NE}	43.82	3.67	3.72	13.86	35
A_E	45.65	3.80	3.88	15.04	25
A_{SE}	48.30	4.07	4.14	17.18	28
A_S	46.24	6.01	6.14	37.69	24
A_{SW}	40.91	5.03	5.10	26.02	36
A_W	50.48	4.00	4.08	16.61	27
A_{NW}	43.50	6.23	6.34	40.19	29
θ	50.83	4.36	4.42	19.55	36
V_w	6.84	6.50	6.59	43.46	36
V_d	15.07	7.16	7.26	52.73	36

Prior to the application of the adopted statistical techniques , the usual frequency distribution was only carried out for the measured variables : dip of bedrocks (ϕ) , valley-side slopes (θ) valley width (V_w) and valley depth (V_d) .

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* Definition of variable symbols same as in Table 2 .

The frequency histograms (Fig. 4) show that the distribution of the valley -floor width (V_w) , valley depth (V_d) and bedding dip angles (ϕ) has a positive skewness as indicated by a preferential right handed symmetry . They also show that angles of the valley-side slopes are quite well ditributed and approach normalcy . Therefore , the logtransformation method (Gregory , 1968) was used to normalize the data of the above variables (Fig. 5) so as to enable parametric tests to be carried out .

The statistical techniques employed are of four types : the poisson distribution function , analysis of variance , correlation coefficient and linear regression analysis . The following procedure was adopted for the analysis of the collected data : 1) the orientational relationship between the sets of variables , valley-floor segments (OV_s) , toatal joints (T_{10}) and bedding strike (S_{10}) ; 2) comparison of sample values for the variables of valleysside slopes (θ) according to four types of slopes - within eight (10 - degree) classes of dip of bedrocks , and valleyside slopes (θ) according to eight (45 - degree) classes of aspect ; and 3) correlation and regression for the set of geomorphic and geologic variables aimed at the description and prediction of the relationships between these variables . It is not proposed to enter into detailed consideration of mathematical and computational aspects of these methods as there are many texts have been produced on all aspects of those numerical methods used in this study (Doomkamp and King , 1971 ; Seber , 1977) .

5- RESULTS AND DISCUSSION

5.1 *Orientational relationships between geological variables and valley form properties*

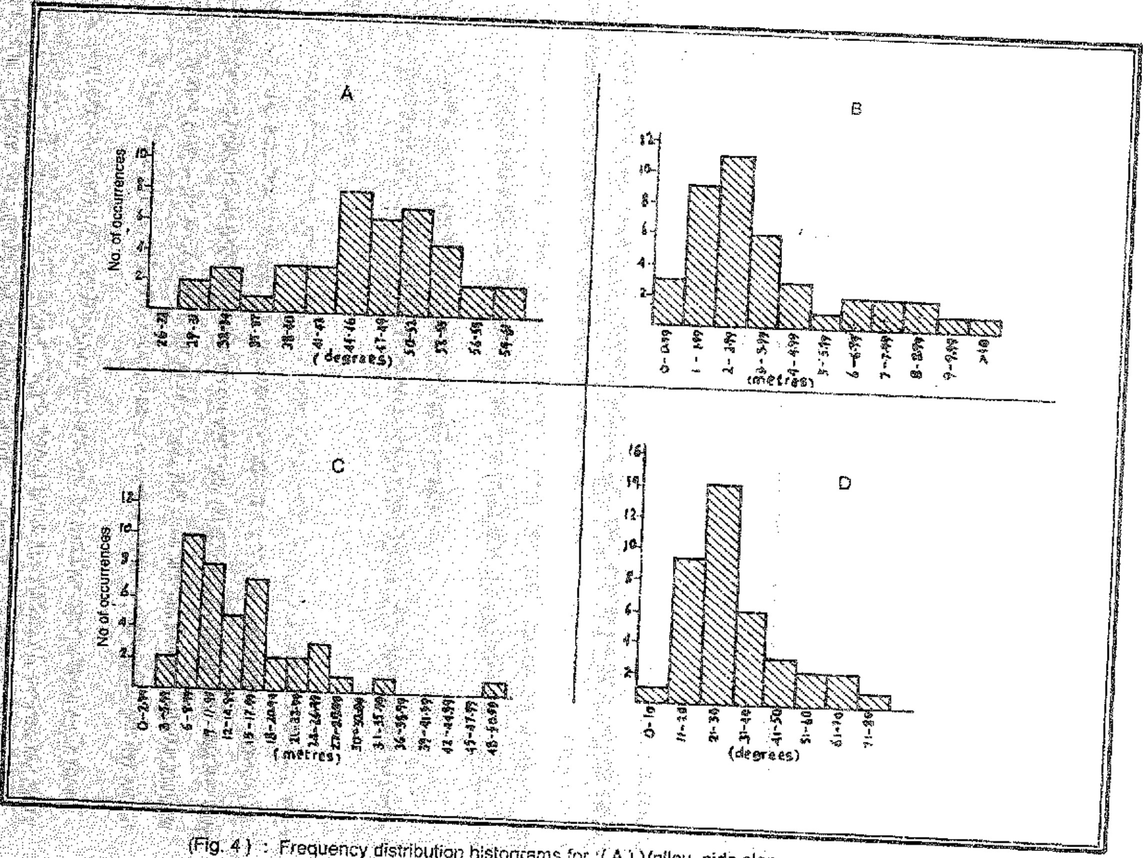
An attempt is made to assess the degree to which valley-floor segment and valleyside slopes orintations are related to geologic structure orientations , mainly total joints and bedding strike . Two main methods have been usually used to examine the relationship between the orientation of geological variables and orientation of valley form properties , and these are mainly based on comparing the orientational distribution of the two variables . The first method relies upon visual comparison and inspection of hemispherical frequency diagrams in order to point out the marked peaks and troughs in joints as a geologic parameter , and valley orientations . The second method is to test statistically whether the relationship between joint and valley orientations is significant or not using the Chi-squared test, or to determine the extent to which the joint and valley orientation frequencies are statistically correlated using the Spearman Rank Correlation method and Product Moment Correlation Coefficient method (Brown, 1969). The procedure in applying either method depends upon the overall joint pattern and not upon the detailed types of joints.

In the present study the quantitative technique adopted is based on a statistical method which depends on analysing the overall frequency distributions of angular differences between the orientations of two variables, as measured from various sample localities in the area studied. Just as important, however, is the semi-circular distribution (not direction) of the variables for this particular method.

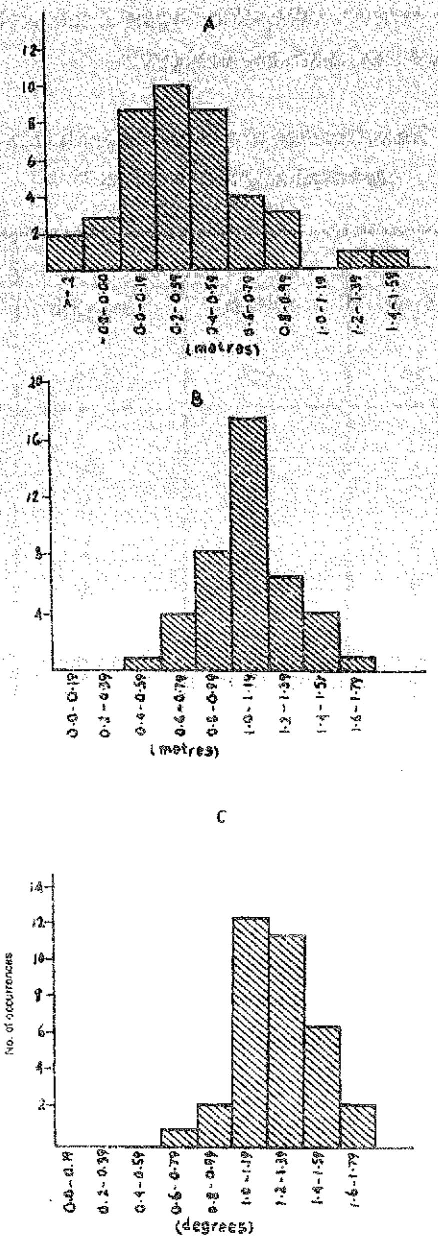
5.1.1 *Relationship between orientations of valley-floor segments and structure variables (total joints and bedding strike)*

For the purpose of demonstrating this relationship the angular differences between the modal class of total joints, and bedding strike as well as the maximum orientation of valley floor were calculated. Such angular differences between each two variables cannot exceed 90° and could be as small as zero. The frequency of the differences of each pair of variables were allocatd between nine (10-degree) angular differences classes from 0 - 90°. In so doing, and assumption was made that if there is no orientational relationship between any one structure attribute and valley floor the angular differences of orientation will have a random distribution.

Therefore it is important to test statistically whether the observed pattern of the angular differences in orientation between each pair of variables departs significantly from the expected pattern of randomness. In order to achieves this test, the Poisson distribution function, which is an approximation to binomial distribution when the number of observations is large and the probability is low (Cole and King, 1970), has been adopted to calculate the minimum limit, or permissible limit, whithin which all observations should fall with a 95% probability level. From the table of the Poisson distribution (Lindley and Miller, 1953) the value 8 was taken as the minimum frequency required for a significant peak at 95% level. This was based on the mean of sample areas for each two variables. In our case, the total number of sample localities was 35 (36-1 = 35), and the mean used was 35 ÷ 9 = 3.9. The resulting frequency of angular



(Fig. 4) : Frequency distribution histograms for :(A) Valley- side slopes,
(B) Valley width, (C) Valley depth, and (D) Angle of dip of beds.



(Fig. 5) : Log-frequency distribution histograms for :
(A) Valley width, (B) Valley depth, and
(C) Angle of dip of beds.

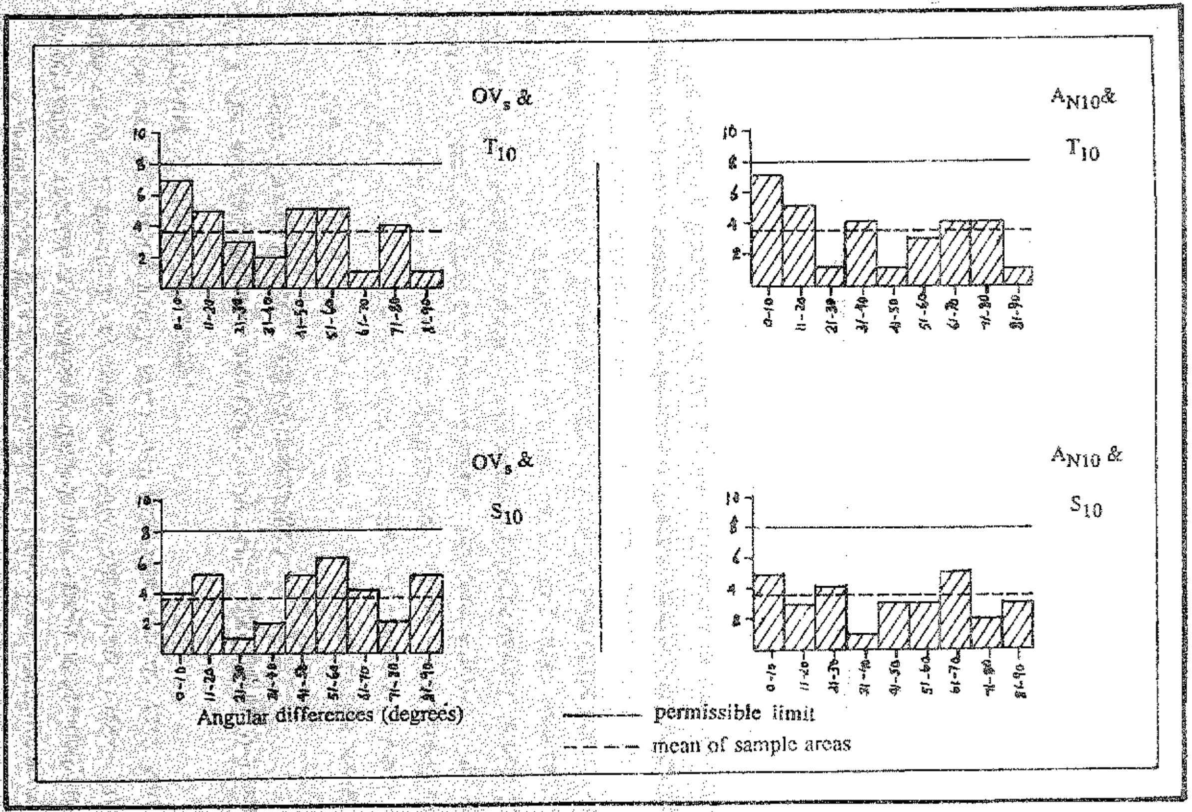
differences in orientation between valley-floor segment and geologic structure variables is given in Table 4 , and illustrated in Figure 6 .

Table 4 : Statistical data for measured geological and geomorphological variables *

Angular differences classes (degrees)	OV_s & T_{10}	OV_s & S_{10}	A_{N10}& T_{10}	A_{N10} & S_{10}
0 - 10	7	4	7	5
11 - 20	5	5	5	3
21 - 30	3	1	1	4
31 - 40	2	2	4	1
41 - 50	5	5	1	3
51 - 60	5	6	3	3
61 - 70	1	4	4	5
71 - 80	4	2	4	2
81 - 90	1	5	1	3

** Definition of variable symbols same as in Table 2.*

A preliminary study of the data in the above Table reveals the following outcomes . The similarity in orientation between the valley floor and other variables is not significant between valley floor and total joints (T_{10}) and bedding strike (S_{10}) . However , the peak class in the distribution of the total joints (T_{10}) approaches the permissible limit of " 8-values " and since this peak class is in the class 0-10° , its is the best indication of relatively significant similarities in orientation as it represents the minimum angular difference between these two variables . The valley floor orientation and and bedding strike (S_{10}) , do not behave sympathetically with one another , and show no similarity i.e., the peaks were absent indicating that the pattern of orientation of valley floor may change randomly with the change in orientation of the this geologic structure variable .



(Fig. 6) : Orientational relationship ebtween drainage networks (valley- floor segments, valley-side slopes) and geologic structure variables (total joints and bedding strike).

It would appear from the above that the joints have exercised a relatively stong control over the orientation of the tributary valleys in the study area . In other words , as the joints represent the weaker alignments in rocks , they are planar structure along which water may penetrate into the rock mass thus facilitating the creation of valleys .

5.1.2 *Relationship between orientations of valley-side slopes and structure variables (total joints and bedding strike)*

The orientation of valley-side slopes (A_{N10}) used in this analysis was defined by adding 90° to the slope aspect readings , as corrected to true bearing . The same method procedure , as applied above to the orientational analysis between valley floor and structure variables , has been adopted . The angular differences between the maximum orientation of slopes in each sample locality and the modal class of orientation of joints and bedding strike were calculated . As in the previous test , the mean of sample areas for each of the two variables is 3.9 and the permissible limit within which all observations should fall with 95% probability level , as taken from the table of Poisson distribution , is the value of 8 . The resulting frequency of the angular differences in the orientation of valley-side slopes and structure variable in nine (10-degree) classes is given in Table 4 , and illustrated in Figure 6 .

The results in the above Table show that the angular differences between the orientations of valley-side slopes and geologic structure variables (total joints and bedding strike) is, again , not significant . In other words , the orientation of valley side slopes did not exhibit such a similarity with orientations of other joints and bedding strike i.e. the absence of peaks in the frequency idicates that the pattern of orientation of valley-side slopes changes randomly with the change in orientation of the other geologic structure variables .

5.2 *Comparisons of sample values (Slope angle, True dip, Slope aspects)*

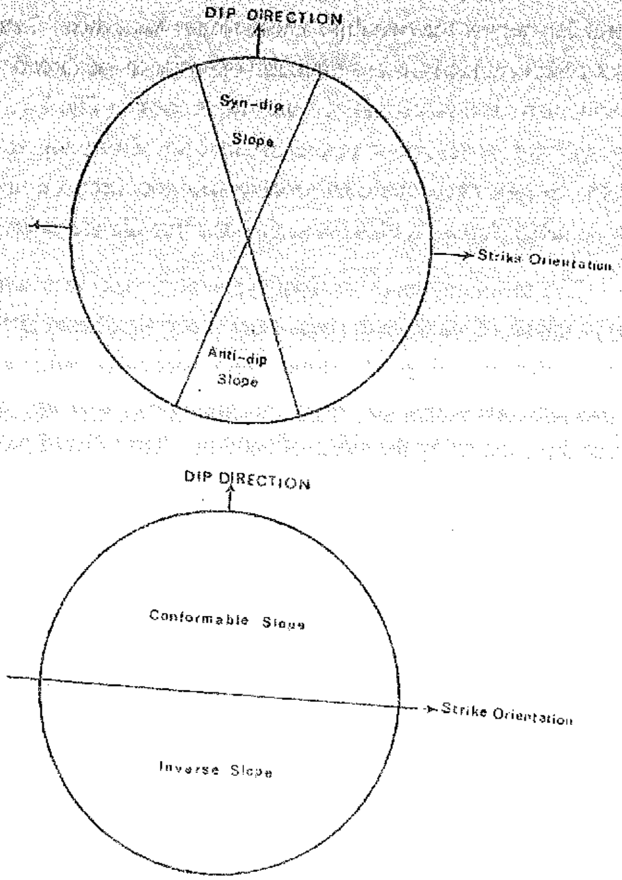
In this section the analysis of variance , which is the testing of three or more sample means simultaneously in order to test the hypothesis that all come from the same population , is applied to various groups of sample values of : valleyside slopes ; true dip of bedrocks , and slope aspects .

5.2.1 *Angle of valleyside slope (θ) and angle of dip of beds (ϕ)*

For the purpose of comparing various groups of sample mean values of true dip of bedding and valley-side slopes , the Analysis of Variance Test , has been adopted . Manipulating data of angle of dip and angle of slopes for this test involved the segragation of slope angles , as related to different amounts of dip , according to their position in relation to the direction of true dip within a narrow zone of 20° around the true dip . These slopes are called " Syn-dip slopes " , and slopes which are inclined in a direction opposite to the direction of the true dip in the same narrow zone are called " anti-dip slopes " (Fig. 7) . In addition , slopes were split up by reference to the orientation of bedding strike into two main groups . Slopes which are conformable with the direction of true dip are called "conformable slopes " and those against the true dip are called " inverse slopes" .

The mean angles of the four types ot slopes were subjected to the (one way) analysis of variance to see if there was a significant difference between the mean angles of valley-side slopes with particular reference to their relative position and orientation i.e., along the direction of true dip , against the direction of true dip , and along the strike of bedding . The Olivetti programa 101 , p. 203 desk top computer was programmed to carry out the test by programme No. ST 1003 . The resulting statistics for individual dip class is summarised in Tables 5 and 6 for ready comparison .

Inspection of the output of the analysis of variance in Tables 5 & 6 indicates existance of significant differences in the mean angles of the four types of slopes only in " 11 - 20° and 41 - 50° " , and " 21 - 30° " , 41 - 50° " and 51 - 60° dip of bedding classes for " syn-dip and antidip " , and " confoemable " and " inverse slopes " respectively at 5% significance level . The immediate conclusion is that the samples do not come from the same population , hence that there is a significant difference in mean angles of valley-side slopes . On the other hand , the F-value calculated for the analysis of variance of the same types of slopes in most dip of bedding classes is less than the tabulated at 5% level of variance ratio , which is definitely not significant . It is concluded , then , that there is no significant difference in mean angles of syn-dip and anti-dip slopes , and conformable and inverse slopes which cannot be attributed to change in dip of bedding . However , this in contrast to the known measurements of the relations between the dip of underlying bedding and angle of slopes i.e., slopes



(Fig. 7) : Types of slopes in relation to the dip direction and strike orientation.

dipping in the reverse direction of bedding are different from those paralleling the bedding (Leopold and et. al., 1964) .

It seems that some other factoer (s) other than dip of bedding has a controlling influence on slope-angle variations in the area under study .

Table 5 : Analysis of Variance
syn-dip slopes and anti-dip slopes

Dip Classes	0-10°	11-20°	21-30°	31-40°	41-50°	51-60°	61-70°	71-80°
Sum of squares among sets	-	251.82	276.42	61.93	317.24	457.67	43.83	-
Sum of squares within sets	-	1396.33	3457.19	467.41	98.56	318.72	229.58	-
d.f. among sets	-	1	1	1	1	1	1	-
Mean squares among sets	-	251.81	276.42	61.93	317.24	457.67	43.83	-
d.f. within sets	-	24	26	9	5	3	6	-
Mean squares within sets	-	58.18	132.97	51.93	19.71	106.24	38.26	-
F-ratio	-	4.33	2.07	1.19	16.09	4.31	1.14	-
F-table 5% value	- -	4.26	4.22	5.12	6.61	10.13	5.99	- -
Significant or not		Sig.	not	not	Sig.	not	not	

d.f. = *Degree of freedom*

Table 6 : Analysis of Variance
(Conformable Slopes & Inverse Slopes)

Dip Classes	0-10°	11-20°	21-30°	31-40°	41-50°	51-60°	61-70°	71-80°
Sum of squares among sets	6.60	22.71	638.63	221.31	206.20	1234.05	17.01	56.47
Sum of squares within sets	631.42	3302.52	1874.25	1234.40	936.54	2625.80	417.72	151.55
d.f. among sets	1	1	1	1	1	1	1	1
Mean squares among sets	6.60	22.71	638.63	221.31	206.20	1234.05	17.01	56.47
d.f. within sets	6	29	17	10	22	20	12	5
Mean squares within sets	105.23	113.88	110.25	123.44	42.57	131.29	34.81	30.31
F-ratio	0.06	0.20	5.79	1.79	4.84	9.39	0.49	1.86
F-table 5% value	234	250	4.45	4.96	4.30	4.35	241	6.61
Significant or not	not	not	Sig.	not	Sig.	Sig.	not	not

d.f. = *Degree of freedom*

5.2.2. *Angles of Valleyside slopes and aspect*

The literature contains much discussion of the interpretation of the relationship between slope angle and aspect . This section deals with the analysis of valleyside slopes and aspect in order to examine the relationship between them statistically . In this regard , valleyside slopes were divided into eight classes according to aspect , so as to bring out the greatest variability . These classes are as follows : North (338° - 22.5°) , South (158° - 202.5°) , North-east (23° - 67.5°) , South-west (203° - 247.5°) , East (68° - 112.5°) , West (248° - 292.5°) , South-east (113° - 157.5°) , and North-west (293° - 337.5°) . Here , the Snedecor's F-test was used to test whether there were significant differences in slope in different aspect . This statistical test was selected as a comparison to be made between more than two sets of data .

The following are the net computations of this test as applied to the valleyside slopes and aspect in the study area .

Source of Variance	Sum of Squares	Degree of frredom	Variance Estmate
Between sample	1992.42	7	284.63
Within sample	15988.75	229	69.82

$$F = \frac{284.63}{69.82} = 4.08$$

Percentage points of F distribution

1% level = between 2.73 and 2.69

5% level = between 2/06 and 2.03

The above analysis of variance indicates that significant differences exist between the means valleyside slopes of the eight classes of aspect at 99% probability level . An alternative explanation based upon field inspection is as follows . Most to the valleyside slopes in the study area are aligned north - west - south - east . Of the 237 samples recorded , 33% face north - west - south - east . The contrasting steepness of north - west - facing and south - east - facing slopes is presumably independent of geologic structure (for this area the predominant dip of the rocks is to the northwest) , appears to be explicable in terms of differences in micro - climatic conditions due to contrasting exposure . The micro - climatic variations are probably great enough to induce denudational differences leading to significant variations in slope angle . South - east - facing slopes are more sheltered than north - west - facing slopes from the drying effect of the sun rays or by wind , and , as a consequence , they retain more moisture . Thus , the south - east - facing slopes are relatively less steep than the north - west - facing - slopes because they undergo intense erosion by surface processes which in turn leads to a decrease in the average steepness of valleyside slope . This is in accordence with the findings of Emery (1947) and Hack and Goodlet (1960) , who concluded that micro-climatic differences via moisture content differences , were responsible for gradient contrasts between opposite slopes .

However , as the study area was deliberately selected to maximise the effects of geologic structure and fluvial erosional activity , it is difficult to separate these latter effects from those of micro-climate in searching for a cause of the observed contrasts in gradient of opposite valleysides . In fact , in most of the area , the structural effect is noticeable and fairly obvious for the bedrocks have fairly consistent directional trends of north , and north west . The valleyside slopes , consequently , are relatively steeper of the sides that face north , and north - west than they are in the other directions , indeed , slope angle reaches a maximum on north - west facing situation .

5.3. *Relationships amongst valley form properties*

In order to assess the relationships between the following measured morphological and geological properties of the valley network . The lower valleyside slopes (mean angle θ) , the valley floor width (V_w) ; the valley depth (V_d) ; and the angle of bedrock (ϕ) by using the statistical techniques of correlation analysis and linear regression analysis . As the data pertaining to the former variables were normal or normalized using log-values (see section 4.2) the parametric test , the Product Moment Correlaton Coefficient (r) was used . The Olivetti programma 101 P203 desk top computer was programmed to perform the computations (Programme No. 234) . It gave the correlation coefficient (r) , regression Coefficient (b) , and the value of base constant - intercept (a) as shown in Table 7 . The significance of the "r" value is dependent on the number of observations upon which it is based . Thus , it was tested by means of the t-test , which determines whether or not the observed correlation coefficient is significantly greater than zero (Gregory , 1968) .

The following is an interpretation of results of the correlation analysis of morphologica and geological variables of valley form as shown in Table 7.

Table 7. Pair-wise Relationships between Morphological and Geological Variables

Variable	Correlation Coefficient (r)	Regression Coefficient (b)	Constant of Regression (a)	Significance Level
i. Log V_w & $\bar{\theta}$	-0.4937	-9.7538	51.1341	0.001
ii. Log V_d & $\widehat{\theta}$	+0.0745	+2.2956	48.5333	> 0.1
iii. Log ϕ & $\bar{\theta}$	+0.1682	+5.1210	40.6482	> 0.1
iv. Log V_w & Log V_d	-0.2519	-0.1089	1.1975	> 0.1
v. Log V_w & Log ϕ	-0.2370	-0.3898	0.9995	> 0.05

i) Log V_w & $\bar{\theta}$

The correlation table (Table 7) shows that there is a fairly good negative correlation between log. valley-floor-width and mean angle of valleyside slopes . It would appear that the wider a valley-floor is the gentler valleyside slopes will be . A general explanation of this relationship may be that the more confined a valley-floor is the more likely it is that active undercut will oversteepen the valleyside slope . In order words , in situations where active basal undercut is removed from the base of a slope then slope angle will gradually diminish . In the light of field observations such a result is surprising for valleyside slope angles often appeared to be of a similar inclination , whatever the valley-floor width . One reason for the contrast between the result of this statistical test and field observations may be that the sample size involved is not sufficiently large as to be adequately represent the population .

ii) Log V_d & $\bar{\theta}$

There is no significant correlation between log valley depth and mean angle of valleyside slopes . (It would appear that the mean angle of valleyside slopes remains approximately constant throught the valley network) . However , their is a slight suggestion that as a valley becomes deeper its slopes may become slightly less steep . Therefore it tentatively suggested that valleyside slope evolution in this area approximates to the parallel retreat model .

It is important, however, to note that there was some difficulty in obtaining accurate measurements of the depth of the narrow valleys. Thus the data is probably not very reliable.

iii) Log ϕ & $\bar{\theta}$

There is no significant correlation between the log. angle of dip of bedding and the mean angle of valleyside slopes. On deductive grounds, one might have expected that a slope angle would be inversely related to slope length, that slope length would be directly related to bedding dip, and therefore that gentler valleyside slopes would be associated with a low dip of bedding. In this particular case, the last assumption might not be valid and it seems possible, therefore, to suggest that as valleyside slopes become steeper they do not necessarily do so at the expense of the bedding dip. Furthermore, one difficulty in assuming the nature of this relationship is that there is relatively little variation in the dip of bedrock in this area and in addition other variables may partly affect the angle of valleyside slopes, for example aspect.

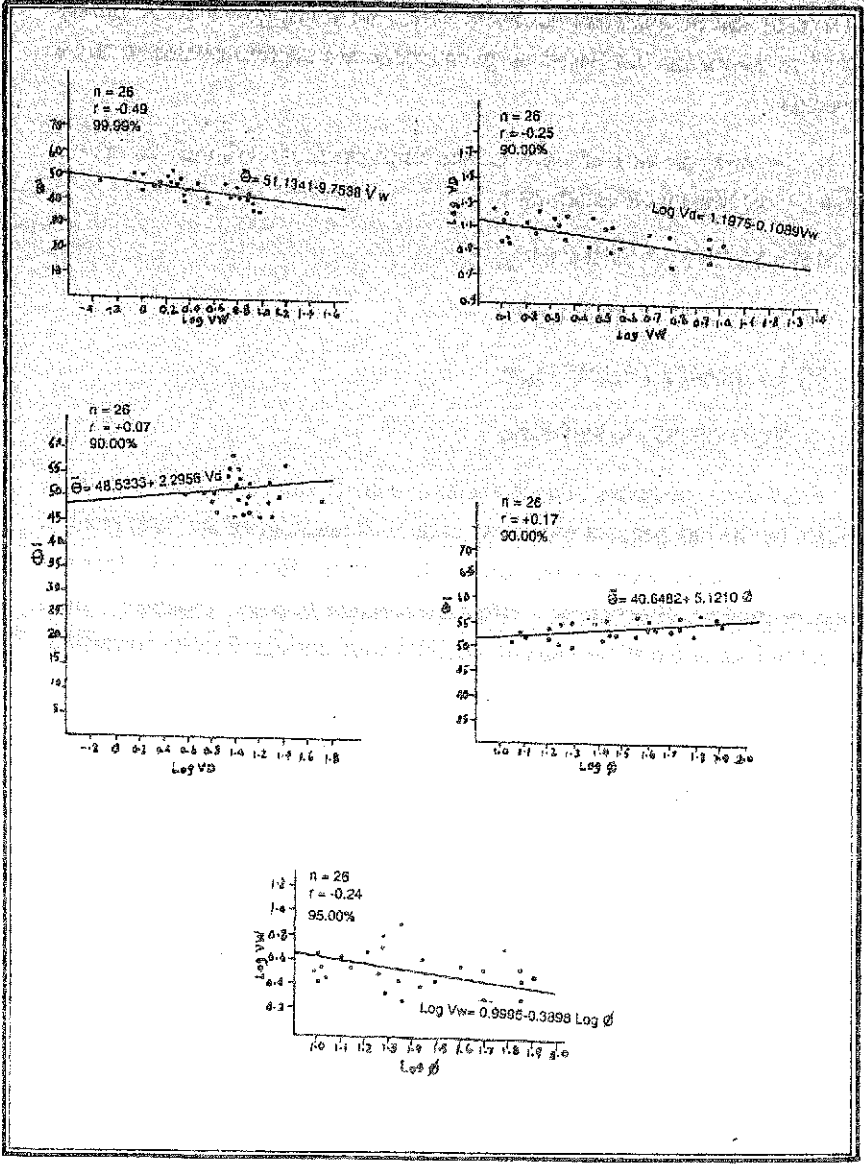
iv) Log V_w & Log V_d

There is no significant relationship between the log. valley - floor width and log-valley depth. In this particular case, however, reference to the geological characteristics, and mainly the lithology, of the study area will indicate that the thick Upper Miocene marls occupy extensive areas of the interfluves between the valleys. These soft rocks are easily eroded and therefore lowering of interfluves is likely to be rapid. Thus, it would appear that the channel widening is not accompanied by valley deepening because it is matched by a comparable lowering rate of the interfluves.

v) Log V_w & Log ϕ

There is moderate negative but still insignificant correlation between angle of beds and valley width. Here again, it may be attributed to the activity of the accumulation of slopewash on, and / or the erosion by gully channels at the base of slopes is a more significant factor in widening the valley floors.

The linear relationship between the above pairs of measured variables was established by plotting one variable against the other on a scatter graph (Fig. 8). This gives an idication of the type and degree of correlation between the two



(Fig. 8) : Scatter graph of the relationship between : (A) Mean valley-side slopes "Θ̄", and valley width"log VW", (B) Valley width" log VW" and valley depth "logVD" ,(C) Mean valley-side slopes"Θ̄" and valley depth"logVD", and (D) Mean Valley- side slopes"Θ̄" and angle of dip of deds"Ø", (E) Valley width" log VW" and Angle of dipØ" variables . As important , however , is the decision of considering dependent and independent variables for the regression analysis . In this analysis , V_w and ϕ were taken as the independent variables which were not governed by purely statistical relationships but based on geomorphic assumption related to these relationships .

In the comparisons of each of the four pairs of variables the linear regression lines has the the equations :

i) $\bar{\theta} = 51.1341 - 9.7538 \log V_w$

ii) $V_d = 1.1975 - 0.1089 \log V_w$

iii) $\bar{\theta} = 40.6482 + 5.1210 \log \phi$

iv) $V_w = 0.9995 - 0.3898 \log \phi$

From these equations , the dependent variables can be said to be partially explained by the independent variables , in that a knowledge of the latter enables one to make a fairly accurate estimate of the former . However , this does not necessarly imply a direct cause - effect explanation between variables . Since three out of four of the above pairs of variables were not significantly correlated , the scatter of points , along the regression line , gives only a visual impression of the relationship between those two variables .

6- CONCLUSIONS

The main feature of the present study is the application of some numerical techniques of analysis to morphometric variables obtained by field data collection. The purpose of the statistical analysis is to analysis relationships between these variables . In some cases numerical analysis has confirmed field observations . The explanation of the relationships observed is based mainly on published work and field observation .

The use of the selected numerical techniques required that the data be gathered using objective procedures . Moreover , the techniques used commonly necessitated that the data be normally distributed or be transformed to normality . However , a sample size of 36 has not proved to be adequate in spite of Strahler's (1950) findings . Therefore , a test for whether the sample would be adequately represent the population should have been made . Since some of the measured variables showed a positive skewness in their frequency distributions , log-transformations were used to normalize these data , and hence the correlation between them was based on a parametric test ; the Product-Moment Correlation Coefficient .

The Wadi El Raml basin area offers an opportunity to examine the relationship between selected geological and morphological properties of a deeply incised valley system . The area was chosen because of the favourable lithological and structural and morphological situations . Moreover , the data strongly indicated that the area is characterised by a distinct pattern of landform in which lithology and structure are relatively dominant feature influencing this pattern .

With reference to the main objectives of this study , the following conclusions may be made . In the analysis of orientational similarities between joints and valley-floor segments and between joints and valleyside-slopes , the "Poisson Distribution " function was used . This is an objective and comprehensive method of analysis as opposed to the visual inspection method or the Chi-squared both of which are conventional methods which have been commonly used in this regard . The orientation of valley-floor segments and the alignment of valleyside slopes showed a relatively distinct response to joint control , as it was found that these valley-form elements had significant similarities to the orientation of total joints . Thus , it seems possible to conclude that joint patterns control the form of valley network in the Wadi El Raml area .

It was also considered desirable to ascertain if valleyside slopes varied significantly in relation to the dip of strata and to aspect differences . Therefore , a comparison between the quantitative data of these variables was undertaken using the analysis of variance parametric test . In comparing the angle of valleyside slopes with dip of bedding , it was found that there were no significant differences in the mean angle of the four types of slopes , syn-dip ; anti-dip ; conformable ; and inverse slopes . On the contrary , the data analysis of the valleyside slopes and aspect revealed that there were significant differences in the mean angle of slopes for different aspect . It would appear therefore that any aspect - related micro - climatic differences on valleysides were , to some extent , influencing denudational differences which in turn has resulted in significant variations in valleyside slope angles .

In the study of relationships between morphological and geological properties of valley network, the Product-Moment Correlation Coefficient was employed . Data analysis revealed that valleyside slopes had a significant negative correlation with valley-floor width . The other .properties showed a non-significant correlation , but the relationship between them is governed by rock type and by the effectiveness of the geomorphic processes operating . In this regard , the correlation between valley-floor width and valley depth , between the dip of strata and valleyside slopes , and between valley depth and valleyside slopes needs to be fully examined . As a general conclusion , however , field data and statistical analysis suggest that the mean of valleyside slopes tend to remain rather constant throughout the valley network of the area , thus suggestting a parallel mode of slope retreat .

Finally , the present study rises an addition problem : the study of valley form relationship would be meaningless without considering the causal factors . An essential component of any such study is therefore a consideration of the geomorphological processes which are acting to create the valley form under study .

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