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SOME SOURCES OF SYSTEMATIC VARIATION IN THE MAIN HEAD DEPOSITS OF SOUTHWEST ENGLAND

INTRODUCTION

The quantitative characteristics yielded by a study of head deposits in southwest England were summarised in a previous paper (MOTTERSHEAD, 1976). A major conclusion of that paper was that the sediment parameters investigated

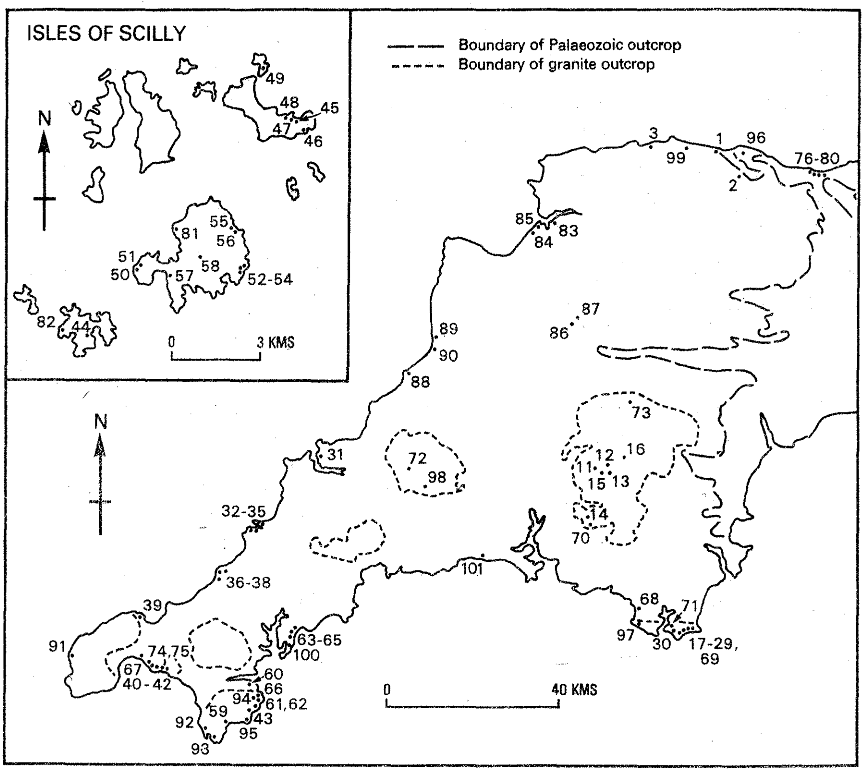

Fig. 1. Southwest England, location of sample sites

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exhibited considerable variability. The objective of the present paper is to examine some of the sources of this variability.

The lithology of the field area, the distribution of sample sites, and the mode of sampling were outlined in the previous paper. This paper is concerned with the Main Head alone, of which 84 samples were collected from 57 separate and widely distributed localities (Fig. 1). The Main Head sampled is derived from weathered bedrock, from the wide variety of indurated Palaeozoic rocks of the region. Sampling methods and analytical techniques were outlined in the previous paper. The data on which this paper is based are listed in appendices in the thesis of the author (MOTTERSHEAD, 1971).

Granulometric data are available for 84 samples of Main Head, and permit the calculation of the derived parameters of mean particle size, skewness, and sorting value. For the same sample set, data on matrix colour, assessed by hue value, are also available. A data set consisting of 52 samples exists for orientation strength, a measure of the degree of preferred orientation exhibited by clasts with a long axis in excess of 20 mm. Roundness values for clasts larger than 20 mm are available for 35 samples of Main Head.

SOURCES OF VARIABILITY

Sediment characteristics can be regarded as a function of transportation processes and source material. Variations in either of these two factors can therefore be expected to produce variations in resulting sediment characteristics. It is therefore reasonable to consider in what ways, and at what levels, variations in source material and process may occur. Table I offers some speculations on likely sources of variability.

In respect of the bedrock properties, it seems probable that increasing variability will exist at increasing spatial scales, as a successively greater variety of

Table I

Estimates of likely variability of factors influencing source material and process, at different spatial scales

	Individual site	Lithological group	Regional scale
(a) Source material variability			
Fracture intensity	L	M	G
Granular texture	L	M	G
Mineralogy	L	M	G
Degree of weathering	M	M	M
(b) Process variability			
Aspect	L	G	L
Slope angle	L	G	L
Distance of transport	M	G	L

L — low: M — moderate: G — great

lithological types is included. Thus fracture intensity, which will govern clast size, and granular texture and mineralogy, which will influence the granulometry of the regolith, can be expected to show increasing variability from the individual site, through the lithological group, to the regional level. The degree of weathering will vary with total depth of weathering and position within the weathering profile, and these can vary quite considerably over a distance of a few metres. It seems reasonable, therefore, to suggest that degree of weathering may not vary greatly beyond the site level.

The factors affecting solifluction processes have been evaluated by a number of workers in studies of contemporary periglacial environments (Washburn, 1967; Benedict, 1970; Harris, 1972). Table I (b) suggets the scales at which the major process factors are likely to vary. Aspect, which strongly influences frequency of freezing and depth of thawing, and slope angle, will vary little at an individaul site. At lithological group level, however, much greater variation will be encountered. Within the much larger sample on the regional scale, these factors may be regarded as homogeneous, since all possible variations may be encompassed, and variability will therefore be low at this scale. Distance of transport is a factor which may be moderately variable at an individual site, for two reasons. Firstly, the exposure sampled may vary along its length in distance from the bedrock slope from which the head deposit is derived, and secondly, it is not possible to estimate with precision the distance of transport of each individual particle within it. Within the sample, some particles will have been transported greater distances to the sampling site than others. Distance of transport may be more variable at the lithological group level, but the variability in this factor can reasonably be expected to decrease at the regional scale of sampling.

The effect of these potential sources of variability can be tested in a number of ways.

1. Both source material and process are considered to vary at different spatial scales. Accordingly variability in sediment characteristics at different spatial scales can be expected to reflect the operation of both these factors.

2. At the regional scale, process factors are assumed to be resonably homogeneous, therefore samples drawn from different lithological groups may be expected to demonstrate the effect of different source materials.

3. At the local scale, source material can be expected to show low variability, and variation in sediment characteristics can therefore be attributed largely to differences in process.

Accordingly the available data will now be analysed in these three ways.

VARIABILITY AT DIFFERENT SPATIAL SCALES

Data were available in sufficient quantity to permit investigation of five sediment characteristics — mean particle size, skewness, sorting value, matrix colour, and orientation strength at differing spatial scales. In respect of the granulometric characteristics and matrix colour, data were analysed at four spatial scales. At the smallest scale of variability, six contiguous samples were collected, using a one metre square quadrat (MOTTERSHEAD, 1976). Four further samples were collected from the same locality (site 1) to make a group of ten samples derived from a 600 m length of exposure — the site level. The third level of spatial grouping is the lithological group, in this case the sedimentary group containing 28 samples, from which the site samples were drawn. The fourth level of grouping is the regional sample population, comprising 84 samples. Orientation strength data were available for three levels of grouping. In this case six samples from one locality, equally spaced along an exposure 800 m in length, 15 at the lithological group level, and 52 from the regional sample population were employed.

These data are set out in Table II. The mean and standard deviation are calculated for each sediment characteristic at each level of grouping. Inspection

Table II

Sediment characteristics variability at different spatial scales

	Overall sample			Sedimentary group	Site	Total contiguous samples
Mean particle size *	n		84	28	10	6
	mean		3.79	3.19	1.50	1.56
	S.D.		1.93	2.07	0.54	0.54
	C.V.		51.39	64.89	36.00	34.61
	C.V.	ratio	1.00	1.27	0.70	0.68
Skewness *	n		84	28	10	6
	mean		5.34	5.96	6.71	5.97
	S.D.		2.21	1.20	0.66	0.98
	C.V.		41.38	20.13	9.84	16.41
	C.V.	ratio	1.00	0.54	0.25	0.22
Sorting value	n		84	28	10	6
	mean		4.18	3.96	3.20	3.55
	S.D.		0.88	0.87	0.36	0.34
	C.V.		21.05	21.97	11.25	10.14
	C.V.	ratio	1.00	0.83	0.53	0.47
Colour *	n		84	28	10	6
	mean		17.70	16.67	12.73	12.50
	S.D.		4.04	3.59	0.83	0.00
	C.V.		22.82	21.41	6.51	0.00
	C.V.	ratio	1.00	0.94	0.28	0.00
Orientation strength	n		52	15	6	—
	mean		52.35	51.29	48.05	—
	S.D.		13.16	12.61	5.50	—
	C.V.		24.91	24.58	11.45	—
	C.V.	ratio	1.00	0.95	0.46	—

* Indicates transformed data.

of the means alone shows that in most of the characteristics presented, the subsamples at each level differ from total the sample population means. From this it can be inferred that the subsamples are drawn from statistically different populations, and that there are factors operating between the levels of sampling to produce these differences.

The *spread* of values within subsamples at different levels can be assessed using the standard deviation. This measure, however, is in part dependent on the value of the mean. Accordingly the coefficient of variability (C.V.), defined as

$$\text{C.V.} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

is employed to assess variability within the various subsamples. For each sediment characteristic the C.V. at each level of grouping is expressed as a ratio of the regional sample population C.V. The results are set out graphically in figure 2.

Four main observations can be made from this analysis.

1. Variability consistently increases at higher levels of grouping, with the sole exception of mean particle size.

2. In general the greatest increases in variability take place between the site level and the group level.

3. Between lithological group level and regional sample level there is generally only a limited increase in variability, and in the case of mean particle size, a decrease between these two levels.

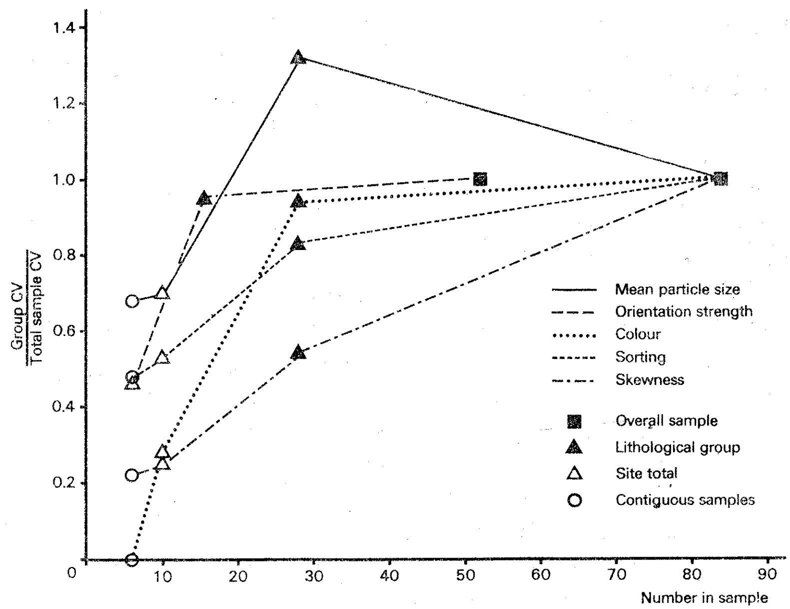

Fig. 2. Variability in sediment characteristics at different levels of grouping

4. In respect of matrix colour, zero variability exists between contiguous samples, and most of the total variability exists at the lithological group level.

It is concluded from this analysis that most of the observed variability is accounted for by factors operating between the site level and the lithological group level. Above the latter there is only a limited increase in variability between the lithological group sampled and the regional sample population. The assumption was made earlier that the factors which induce variability at different spatial scales are factors concerned with both differences in process, and differences in source material. Reference to Table I shows that most of the source material characteristics increase in expected variability at this same level, whilst all of the process factors increase in expected variability at this level. Above the lithological group level process factors may be expected to show a decrease in variability. Thus it is between the levels of the individual site and the lithological group that increases in expected variability in both source material and process factors coincide.

The results presented here appear to substantiate these assertions, since observation confirms that this is also the level at which the greatest increase in variability takes place in the resulting deposits of Main Head. Thus much of the variability in Main Head deposits can be attributed to differences in both source material and process factors between individual sites.

VARIATION BETWEEN LITHOLOGICAL GROUPS

Several authors make reference to the fact that the character of solifluction deposits varies according to source material (Tricart, Cailleux, 1964; Jahn, 1967; Dutkiewicz, 1967). Accordingly, the samples were divided into lithological groups in order to determine whether such differences are apparent in the quantitative sediment characteristics.

Sample sites were classified into five groups, according to bedrock lithology. These were as follows:

Group I: Granite — these are generally coarse grained and massive rocks, distributed in several major outcrops along the spine of the peninsula of southwest England. A further granite outcrop is represented by the Scilly Isles, some 40 km offshore from the tip of the peninsula.

Group II: Sedimentary rocks — a wide variety of rocks is represented in this group, mainly of Devonian and Carboniferous age. Lithologically this group encompasses a range from indurated grits, through phyllites to fissile shales, exhibiting in all a wide variety in mineralogy and fracture pattern.

Group III: Basic igneous — two main rock types fall into this group. These are gabbro, similar in texture and fracture pattern to the massive granite, and the highly fractured and fissile peridotite.

Group IV: Schist — these highly distinctive rocks were sampled in a restricted area of outcrop at the southernmost part of the county of Devon (sites 17—30). Two mineralogically distinct groups of rock are present, quartz-mica schists and hornblende-chlorite schists. Both groups are fissile and exhibit very marked schistosity, fracturing to form blade-like clasts.

Group V: Metamorphic — two main lithological types are encountered in this group, which incorporates slates and greenstones, the latter metamorphosed being basic intrusive rocks.

The classification adopted is considered to be the most éffective in relation to the samples available, and the distribution of rock outcrops in the region, although considerable lithological variety exists within some of the groups. The number of samples within each group is approximately in proportion to the area of outcrop, with the exception of the schists which are strongly represented, since the head developed on that outcrop afforded exceptional opportunity for study. This classification had the further advantage that for the major sediment characteristics examined, no one subsample contained less than ten percent of the overall sample total.

The sediment characteristics of these five groups are laid out in Table III. Certain transformations of the data were carried out, in order to facilitate computation, as follows:

Mean particle size: $x \rightarrow (x + 5)$ in order to produce positive values throughout the data set.

Table III

Sediment characteristics by lithological group

Group Lithology		I Granite	II Sedimentary	III Basic igneous	IV Schist	V Metamorphic	Overall sample total
Mean particle size * (∅ units)	mean	4.44	3.19	3.17	4.05	3.66	3.96
	S.D.	1.87	2.07	1.84	2.40	1.53	2.19
	n	18	28	9	20	9	84
Skewness *	mean	4.69	5,96	5.65	5.06	5.96	5.34
	S.D.	1.43	1.20	1.22	1.63	1.63	2.21
	n	18	28	9	20	9	84
Sorting value (∅ units)	mean	3.81	3.96	4.67	4.93	4.28	4.18
	S.D.	0.99	0.87	0.83	0.79	0.46	0.88
	n	18	28	9	20	9	84
Colour *	mean	18.09	16.67	19.17	17.87	20.00	17.7
	S.D.	8.22	3.59	3.95	2.29	1.32	4.04
	n	18	28	9	20	9	84
Orientation strength (%)	mean	54.03	51.29	48.43	54.50	49.53	52.35
	S.D.	15.36	12.61	11.88	15.32	15.73	13.16
	n	13	15	7	14	3	52
Roundness value	mean	0.184	0.241	0.211	0.225	0.205	0.225
	S.D.	0.0135	0.0436	0.0177	0.0164	0.000	0.037
	n	4	17	7	6	1	35

* Indicates transformed data.

Skewness: $x \rightarrow (x + 2)^2$ in order to produce positive values, and to normalise the positively skewed distribution,

Colour: hue values converted to a numerical scale as described in the Munsell Soil Colour Chart (1954).

The range of mean and standard deviation values, for each sediment characteristic across the lithological groups can be compared by inspection. The statistical significance of the differences can be tested by analysis of variance with one-way classification, treating the data sets for all five sediment characteristics as normal distributions.

The results of analysis of variance are tabulated in Table IV. It is shown that between-group differences in values of mean particle size, sorting, and roundness are significant at the 0.01 level. Differences in skewness and clour are significant at the 0.05 level. Of the sediment characteristics examined, only orien-

Table IV

Summary of analysis of variance of sediment characteristics by lithological groups

		Degrees of freedom	Variance estimate	F ratio	Significance level (%)
Mean particle size *					
Between group variance	53.81	4	13.45		
Within group variance	260.57	79	3.30	4.08	1
Total variance	314.38	83			
Skewness *					
Between group variance	23.03	4	5.75		
Within group variance	154.75	79	1.95	2.94	5
Total variance	177.78	83			
Sorting					
Between group variance	11.25	4	2.80		
Within group variance	52.97	79	0.67	4.20	1
Total variance	64.22	83			
Colour *					
Between group variance	95.81	4	23.95		
Within group variance	672.64	77	8.73	2.74	5
Total variance	768.45	81			
Orientation strength					
Between group variance	200.85	4	50.12		
Within group variance	7948.77	47	169.12	3.37	N.S.
Total variance	8149.62	51			
Roundness					
Between group variance	0.0773	4	0.0193		
Within group variance	0.0644	30	0.0021	9.20	1
Total variance	0.1417	34			

* Indicates transformed data.

tation strength is consistently similar across the groups, showing no statistically significant variation.

It is therefore concluded that bedrock lithology is a significant determinant of the quantitative sediment characteristics of the Main Head deposits investigated. Differences in fracture pattern, grain size and mineralogy of the parent rock can be expected to produce significant variations in texture and colour of the regolith derived from the different bedrock types. These differences in regolith are in turn reflected in the sediment characteristics of the Main Head derived from such regoliths.

VARIATIONS AT THE LOCAL SCALE

Within the confines of a restricted locality, as opposed to an individual sample site, differences in source material will be minimised. Consequently it may be expected that variations in the sediment characteristics of the head will reflect process factors. Two examples will be used to illustrate this proposition.

First, a set of 18 samples of Main Head was drawn from 11 sites along an 8 km length of coastline cut in the schists of South Devon (sites 17—30). The head has accumulated at the foot of a bedrock slope rising often to an elevation of 130 m. Recent marine erosion has trimmed to a varied extent the coastal cliff cut in the head. Thus the exposures of head lie at varying distances from the bedrock slope from which the head is derived. This provides the opportunity for testing the effects of distance of transportation on the sediment properties of the head.

Distance of transportation estimated as the distance from the sampled exposure to the 100 foot (30 m) contour, which was interpreted as representing the line of the bedrock slope.

Significant correlations were obtained for mean particle size, stone content (defined as particles with an intermediate axis greater than 4 mm) and skewness. These are illustrated graphically in figure 3. Mean particle size decreases (increasing ø units) with distance, a relationship supported by the decrease in stone content with increasing distance of transport. Both correlations are significant at the 0.02 level. They can be interpreted in two ways. Either sorting selectively removes the finer material, which is therefore transported further, leaving the coarser particles behind, or material is further comminuted during transport. It seems likely that both of these processes operate simultaneously.

With increasing distance of transport, skewness values show a trend from positive to negative, again at the 0.02 level significance. KRUMBEIN & TISDEL (1940) suggest that weathered bedrock posseses a positive skewness, and during transport of sediment, sorting processes impart a negative skewness. This is borne out by the present results.

These results point to the conclusion that distance of transport has a significant effect on the sediment characteristics of Main Head. There is, however, a considerable scatter in the data. This is probably due to the unquantifiable

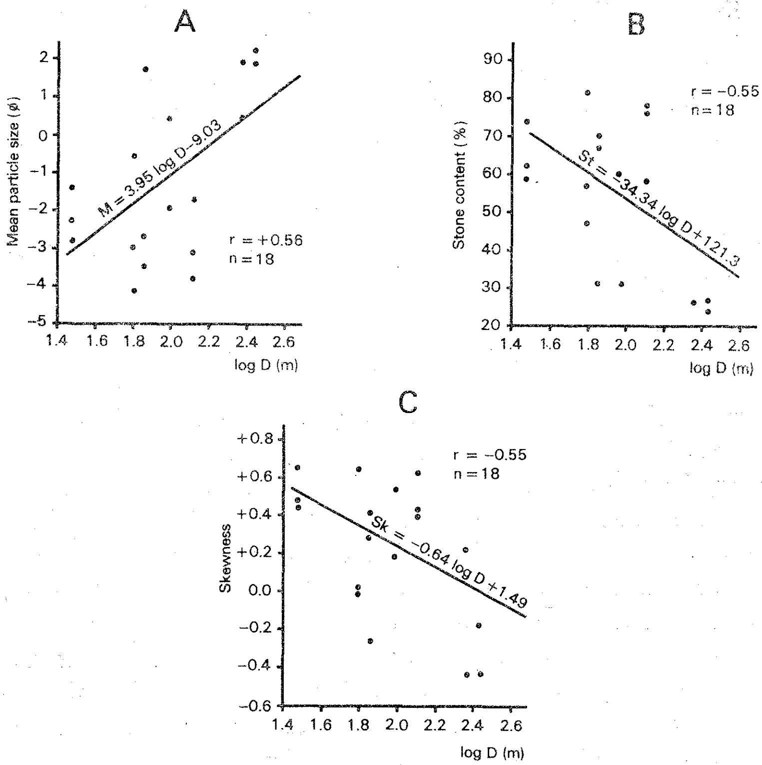

Fig. 3. Effects of distance of transport on sediment characteristics

effects of the variability of the initial source material and the estimate of distance. Although the samples selected were derived from a limited area, and from a rock type of limited variability, there are no means of knowing the state of the regolith in terms of degree of breakdown and granulometry, from which the individual samples were derived. In spite of this reservation, however, statistically significant relationships do emerge, and it is concluded that these represent real effects.

Secondly, the local influence of aspect on preferred orientation within the Main Head is simply demonstrated. Figure 4 shows a small gravel pit cut into a solifluction fill comprised of Main Head of granitic origin (site 52). The exposure truncates the valley axis and the lower part of the opposed valley slopes. Preferred orientation data are shown for five locations around the exposure. A close relationship is demonstrated between preferred orientation within the head and slope azimuth, both of the valleyside slopes along the flanks of the exposure and of the valley axis in the centre of the exposure. Thus at the local scale, slope azimuth is shown to be an important factor causing variability in preferred orientation within the Main Head.

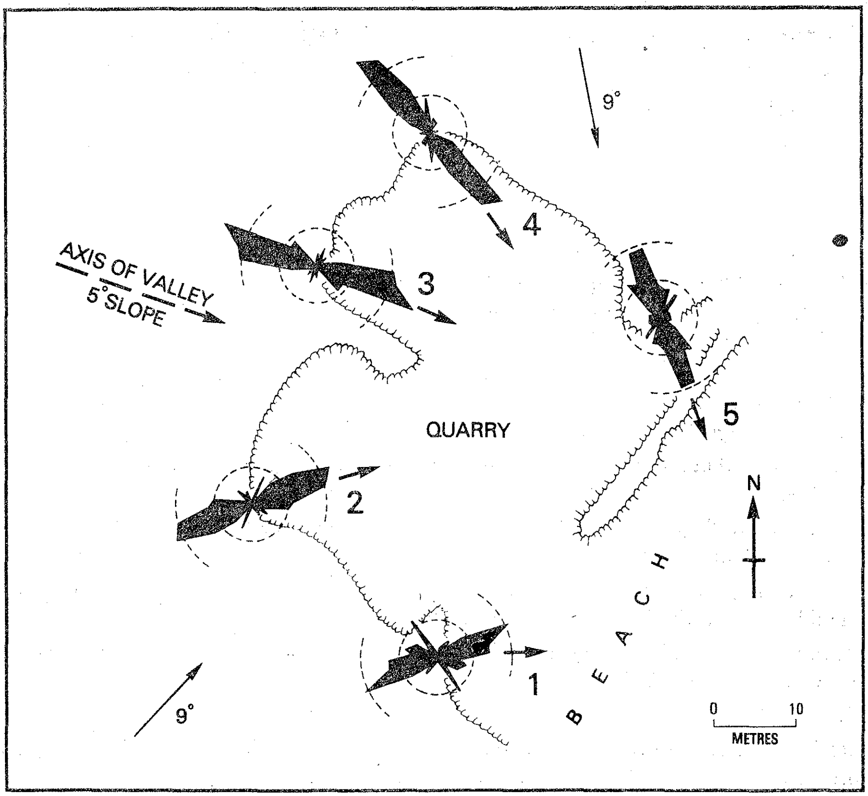

Fig. 4. Local variability in preferred orientation at site 52

CONCLUSION

Much of the variability in the sediment characteristics of the Main Head of southwest Englad can be considered to be randomly derived, in the sense that its origin can be neither identified nor quantified. By analysing the available data in different ways, however, certain systematic sources of variation can be identified.

It is shown that variability in sediment characteristics of the Main Head increases with sample size, at different levels of grouping from the individual site up to the regional sample. This is considered to reflect increasing diversity in process and source material at higher levels of grouping. The increase in variability is generally greatest up to the lithological group level.

The influnce of source material, as represented by bedrock lithology, is demonstrated by analysis of variance between lithological groups. Lithology is shown to exert a significant control on all sediment characteristics investigated with the exception of orientation strenght.

At the local scale, variations in the Main Head are considered to reflect primarily differences in process, since at this scale lithological variations are minimised. Significant variations are demonstrated in respect of distance of transport and slope azimuth.

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