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Variations within and between weathered granite and head on Dartmoor

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The evolution of Dartmoor slopes has been determined largely by the interaction between weathered granite (growan) and solifluction material (head). But little information exists concerning the relationships between and the variability within these materials. This paper attempts to provide some of this information by presenting the results of grain size analysis of 44 samples of growan and head from a variety of exposures plus a detailed examination of one exposure. If boulders are excluded, head is generally finer and less well sorted than growan but only the sorting values are statistically different. Growan is a relatively homogeneous material with little horizontal or vertical variation. The only clear way of differentiating growan from head is by using the Rosin and Rammler distribution. Materials which have been crushed or have originated from a process of random breakage plot as straight lines. The majority of growan samples plot as straight lines whereas few of the head samples do. The exposure examined in greater detail suggests that the head there was not created as a single deposit. Also the junction between head and growan is indistinct suggesting gradual incorporation of growan into head layers. The nature of these materials indicates that the evolution of Dartmoor slopes has been extremely complex with several phases of activity.

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Introduction

Dartmoor slopes possess abundant evidence of the action of past periglacial processes, being mantled by a variable thickness of frost-induced soil layers (head). There have been a number of general investigations into the nature of the head and its relationships with underlying weathered granite (growan) but not detailed study. Waters (1964) has argued that the gradual cryergic transfer of material from one part of the slope to another would lead to the inversion of a pre-existing weathering profile. Green and Eden (1973) have challenged this argument. They conclude that slope materials are not the result of the progressive stripping of a normal weathering profile but have been derived from many parts of the slope with a substantial amount of basal material being incorporated into the transported layer. Examination of the nature of head and growan may enable these ideas to be tested.

Grain size analysis

Twenty two samples of head and growan respectively have been analysed. The samples have been taken from a variety of exposures widely distributed over the main coarse-grained granite of Dartmoor.

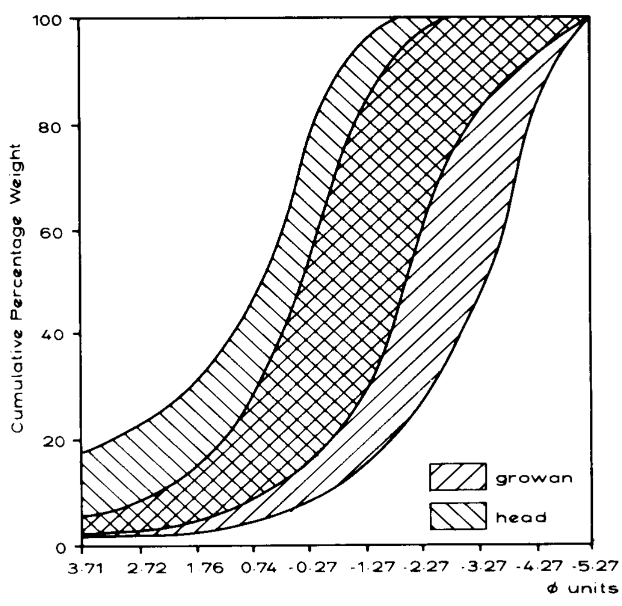

Figure 1. Envelope curves for grain size distribution or growan and head samples.

Envelope grain size distribution curves overlap to a considerable extent indicating a strong similarity between the two materials (Fig. 1). Differences and similarities become more apparent when statistical parameters are calculated (Table 1). These results show that head is finer and less well sorted than growan, although only the difference in sorting values is statistically significant. The standard deviation of the sample values indicates that both materials are relatively uniform although sorting values for head show greater variability. There is a remarkable similarity in mean skewness values for both materials. Negative skewness is to be expected since the materials represent either a weathering mantle or material which has suffered mass movement with perhaps little or no selection of particle size.

Plots of one descriptive parameter against another have often been used to suggest differences between materials. The plot of sorting values against median particle size shows a reasonably clear differentiation between growan and head although there is some overlap (Fig. 2a). Some differentiation occurs on a plot of skewness against sorting (Fig. 2b) and the relationship appears to be circular. These trends have been found for other materials where two distinctly separated populations are present. In the case of head, this implies two distinct grain size populations and at least two types of deposit.

Grain size analysis has shown that although there are differences between growan and head there is considerable variation within and overlap between the two materials. The only clear way of differentiating growan from head is by using the Rosin and Rammler distribution. This distribution has found wide application in engineering practice, especially in the study of materials which have been crushed or have originated from a process of random breakage. The frequency scale has been constructed so that such materials plot as straight lines. Based on the work of Krumbein and Tisdel (1940) and McEwen *et al.* (1959) it was expected that growan samples would show a distribution close to Rosin's Law. This expectation is borne out (Fig. 3a). Apart from a few samples the distributions produce nearly perfect straight lines. Head samples deviate quite considerably from the expected straight lines (Fig. 3b), which is a further indication of considerable mixing of the materials. The goodness of fit to Rosin's Law would appear to be a good means of differentiating growan from head. Materials producing a straight line are unlikely to have been distributed by surface processes.

Dunnabridge exposure

Examination of the exposure at Dunnabridge (NGR SX635748), near Princetown, presents an opportunity to examine the detailed relationships between growan and head as well as the smaller scale

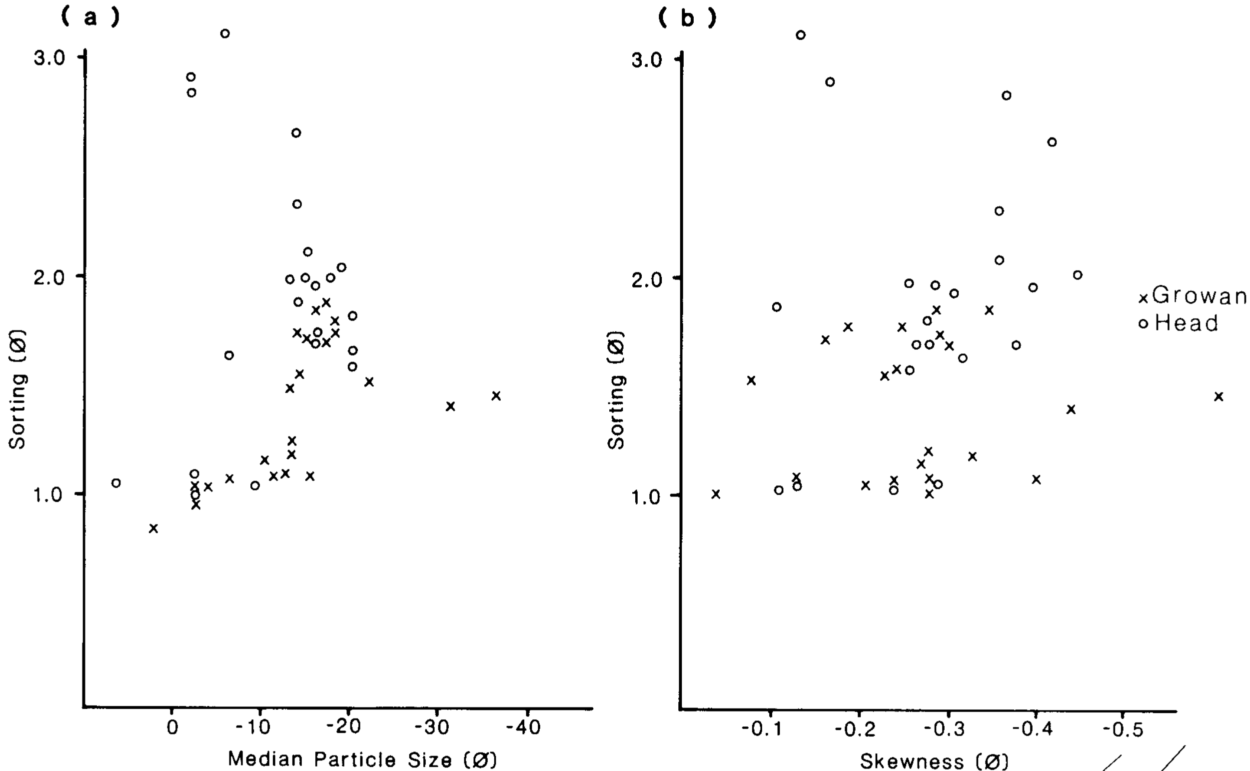

Figure 2. Relationships between (a) median particle size and sorting and (b) skewness and sorting for growan and head.

variability that exists within them. The exposure, which is in a gentle mid-slope position, is approximately 8m wide and 3m high. It shows a mass of growan between two stacks of granite (Fig. 4). Above the growan and stacks is a variable thickness of head surmounted by a medium brown, loam soil. The junction between head and growan is vague and growan seems to have been incorporated into the immediately adjacent head layers. Indeed there is some slight indication that growan has been dragged out in a downslope direction. There are few large blocks in the head and those that do occur are to be found near the surface or adjacent to the stacks. The growan still retains the essential granite structure but is incoherent and easily excavated by hand.

In order to examine spatial variability and possible interaction between the materials, 24 samples were taken (4 vertical columns of 6, see Fig. 4), 12 each from head and growan respectively. A systematic sampling scheme was adopted so as not to pre-judge any evidence of spatial variation. Average grain size parameters are shown in Table 2. Both head and growan are coarse-grained with head being slightly finer. Head is less well sorted than growan and the difference is statistically significant. All samples exhibit negative skewness, and kurtosis values are relatively similar.

Plots of descriptive parameters with depth enable possible variations to be discerned (Fig. 5). The inferred junction between head and growan occurs between sampling levels three and four. Most of the columns illustrate similar trends. Growan is noticeably coarser adjacent to the lefthand rock stack (column 1) and there is some indication of a gradual fining from the bottom of the profile upwards. In the head, level 2 stands out as a reverse of this general trend. It is the coarsest and best sorted head sample and may represent a reasonably sorted solifluction deposit, later buried by a mixture of materials, including a substantial windblown component. The greater differences in sorting values for sampling levels in the head imply that the head was not created as a single deposit. The junction between head and growan is not well marked.

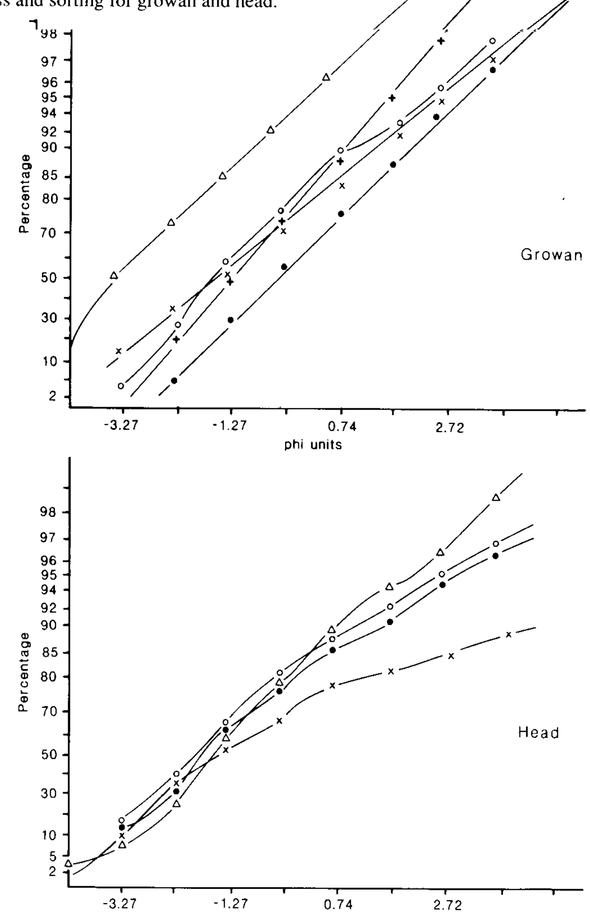

Figure 3. Some grain size distribution curves for growan and head plotted according to the Rosin and Rammler distribution.

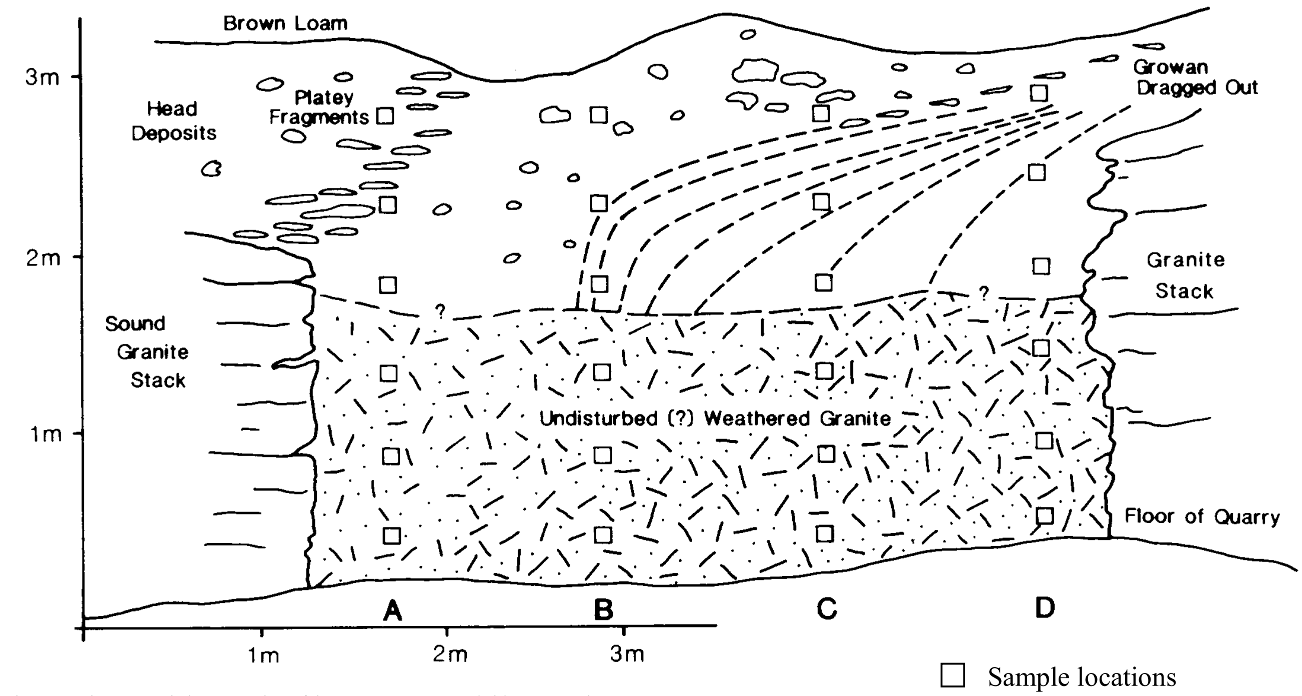

Figure 4. Diagrammatic interpretation of the exposure at Dunnabridge, near Princetown.

Growan appears to be a more uniform material than head. This can be analysed by determining the percentage overlap of the grain size distribution histograms for each sample. If the overlap between samples and every other sample is calculated, a matrix can be constructed which allows samples with similar grain size distributions to be ascertained at a glance. Values are generally high indicating that all the materials are relatively homogeneous, but the mean overlap value of head samples is 85.4% and that for growan is 91.9% showing that growan is a more uniform material.

Lateral trends can be portrayed graphically by taking each horizontal sampling level for head and growan in turn and plotting the four vertical values (A-D) separately (Fig. 6). Apart from the three very coarse growan samples and the high sorting value for one of the surface head samples, there is very little variation laterally except for a slight tendency for the growan to become finer away from the rock stacks.

Conclusions

A variable thickness of both head and growan exists on most Dartmoor slopes and analysis of head suggests that considerable modification of surface form must have taken place during the Quaternary. Grain size analysis indicates that only relatively subtle differences exist between growan and immediately adjacent head. Of the two `models' of slope material development examined earlier, that of Waters (1964) appears the least applicable. The ideas of Green and Eden (1973) appear to be more realistic with evidence for mixing of materials as well as incorporation of debris into the head at various points. Both head and growan are coarse-grained and therefore slope evolution should be concerned with the properties of cohesionless materials. If the threshold slope concept of Carson (1971) applies then one would expect to find many slopes exhibiting clearly defined rectilinear sections. The nature of the growan suggests that the intense chemical weathering advocated by Linton (1955) is an overstatement and the material is more akin to the sandy weathering type found in temperate Europe. Estimates of temperature values at the time of maximum extension of the Devensian ice mass imply that Dartmoor was in a zone of discontinuous permafrost. Such permafrost must have penetrated some distance into growan as well as affecting head and it is difficult to imagine undisturbed growan occurring anywhere on Dartmoor. Thus it may be necessary to reassess the simple dichotomy of Tertiary weathering followed by Pleistocene periglacial movement of surface material.

Table 1. Summary of grain size parameters for growan and head samples from various sites on Dartmoor (phi units).

	Growan		Head	
	Mean	Standard Deviation	Mean	Standard Deviation
Median	-1.54	0.813	-1.22	0.793
Mean	-1.33	0.766	-0.89	0.78
Sorting	1.41	0.318	1.91	0.601
Skewness	-0.27	0.122	-0.28	0.1
Kurtosis	1.13	0.086	1.15	0.149

Table 2. Average values for grain size parameters grouped according to horizontal sampling levels at Dunnabridge (SX635748) (phi units).

	Horizontal levels	Mean	Sorting	Skewness	Kurtosis
	1	-0.79	2.52	-0.3	1.05
Head	2	-1.73	1.76	-0.33	1.14
	3	-1.37	2.02	-0.35	1.22
	4	-1.56	1.68	-0.24	1.12
Growan	5	-1.83	1.66	-0.33	1.13
	6	-1.89	1.66	-0.3	1.15

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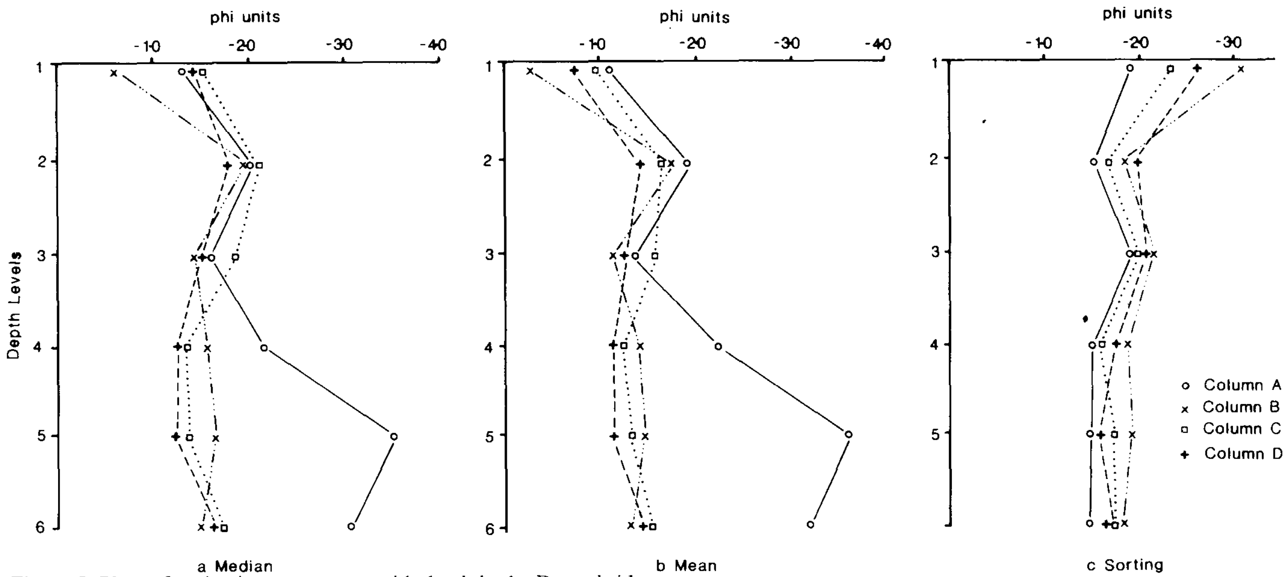

Figure 5. Plots of grain size parameters with depth in the Dunnabridge exposure.

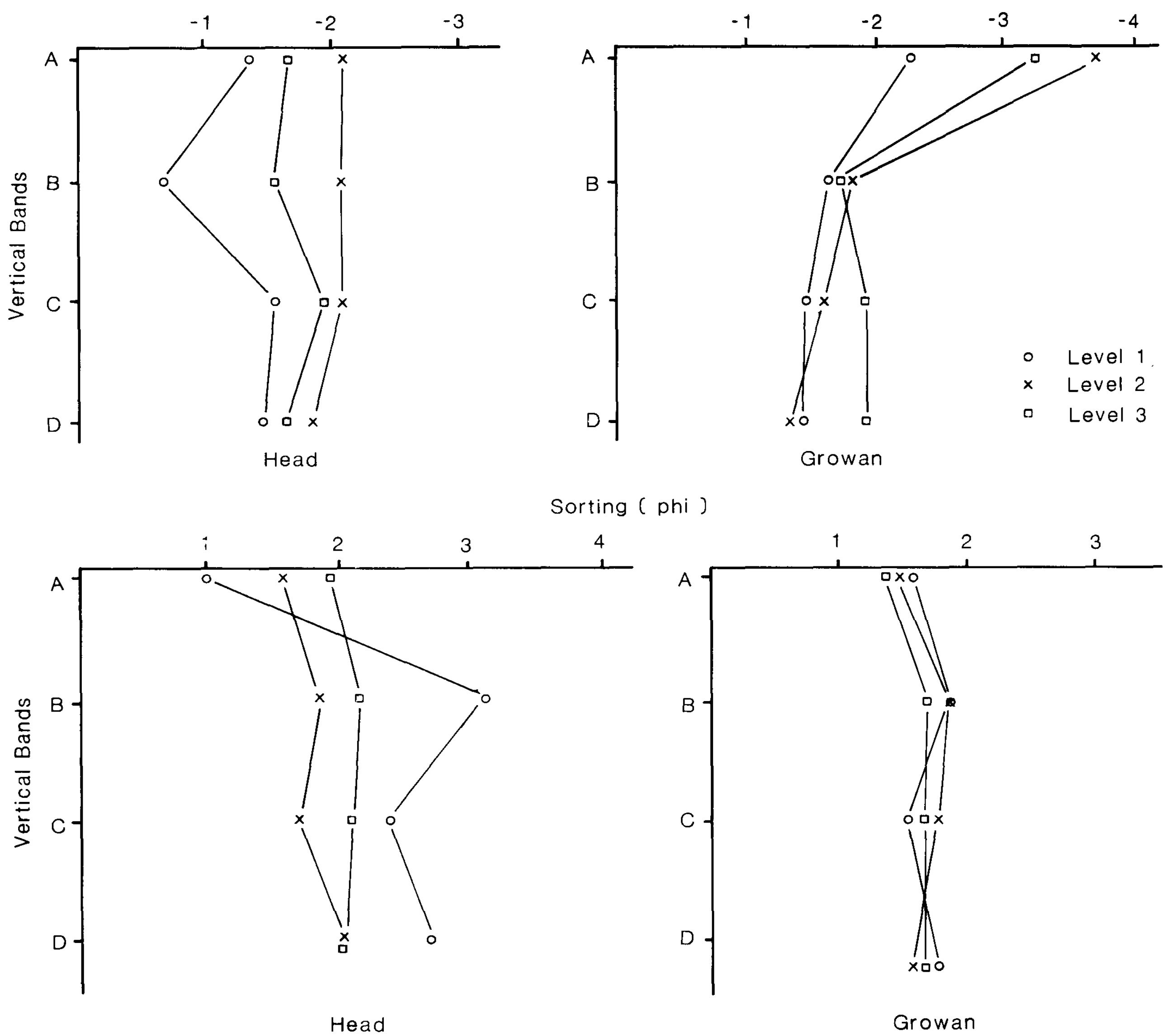

Figure 6. Lateral variation in median grain size and sorting coefficients for the Dunnabridge exposure.