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A COMPARISON OF RELIEF

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ABSTRACT

In order to take advantage of computer analysis of a large data set to ask questions about rock/relief relationships hitherto too awkward to handle, a simple digital database is being created for the British Isles. This has been extended to cover the areas around each of the FSC Field Study Centres. The considerable contrasts in relief and landform from one Centre area to another are confirmed and for the first time presented in a precise and quantitative manner. In addition, evidence is found of the effect of past lower sea levels on river slopes, whilst the major impact of glacial erosion on several localities is confirmed. The data permit the effects of rock resistance on relief to be allowed for, leaving evidence for relatively recent tectonic uplift in some areas. Fuller analysis requires baseline data from a larger area of the British Isles, since quite a high proportion of the geological strata outcropping around the Field Centres are not found in Northern England/Southern Scotland, the current extent of the main database.

INTRODUCTION TO THE DIGITAL MAP

There are many factors affecting the large-scale relief of Britain; rock type and geological structure, Tertiary (and perhaps contemporary) uplift, the impact of glaciation and other styles of past erosion, the overall drainage pattern and the distance to the sea (both present and past) must all be included. There may be others of great significance that we have not identified. It has seemed possible that a relatively simple database of some of these variables could be assembled and interrogated using a computer. This approach is being developed as part of a research contract for Nirex which is looking at ways of estimating the impact of future erosion (over a timescale of at least one million years) on any planned repository for radioactive waste. Because the site currently being considered is at Sellafield, the digital database so far constructed covers Northern England and Southern Scotland and will soon extend across the Irish Sea (including the geology and relief of the floor of the northern Irish Sea).

The database uses the one kilometre squares of the National Grid and the Northern England/Southern Scotland area covers fifteen 100 x 100 km grid squares and excluding Ireland has 61,120 km^2 of land. For every one of the 61,120 squares we have entered the highest and the lowest altitude to the nearest metre from the 1:25,000 maps. We have also recorded geology (both the age and the lithology) for the dominant outcrop of each square using the latest available maps, generally at 1:63,360 or 1:50,000, and the river distance in kilometres to tidal water from the 1:50,000 series. From this considerable (though still growing) database we have been able to establish a number of general relationships between river distance, geology and height above sea level. In particular, it has proved possible to classify the many different outcrops into five bands of varying resistance to erosion. This uses three indicators of resistance; 1) the ratio between the mean height and the mean river distance (expressed as a logarithm because of the skewed distribution); 2) a measure of the height of the upper 20% or so of the rock outcrop; and 3) slope, derived from the average height difference across all the kilometre squares of the outcrop. Where the areas of each rock type (both age and lithology) are reasonably large (over 100 km^2) and not restricted to a particular locality, the resistance classification is robust, but for smaller or unusually located areas the class may prove to be incorrect once a wider area is available for analysis. This has proved a problem in extending the classification to new rock types found only around the Field Study Centre areas and not already known from Northern England, especially as the southern skew to the distribution of FSC Centres means that only two fall within the area fully digitised.

THE FSC CENTRE AREAS

The aim has been to identify an area, within reach of each Field Centre, and, to allow easy comparison, these have been standardised at 2500 km^2, i.e. 50 km x 50 km, with the Centre as near the centre of the square as possible. The exception was the two Centres, Dale Fort and Orielton, where a single area was chosen around both of them whilst, in addition, for Centres near the coast (e.g. Slapton and Nettlecombe) the sea area was reduced by placing the Centre towards one edge of the square area covered.

For those who have worked from the Centres, the area will appear rather large, though, from some Centres, the limits will frequently be visited by geographers seeking a range of contrasting landscapes. Nevertheless, they are representative of the territory within reach. With nine areas and five variables for each kilometre square (high point, low point, river distance, and geology, both age and lithology) the total database comes to over 100,000 values. The main variables for each area are summarised in Table 1. The Centres are placed in sequence by maximum elevation and this order is retained for all subsequent tables. The pattern of these values is most quickly appreciated if we rank them and this is done in Table 2.

One way of characterising the distinctiveness of the various Field Study Centre areas is to note that six of the nine score at least one "1" or "9" in the rank table. Slapton scores a "2" and an "8", and Blencathra scores "2" for maximum height, leaving only Nettlecombe scoring middle ranks throughout. It is also possible to recognise groups of centres with rather similar characteristics: thus the "mountain" centres of Blencathra and Rhyd y creuau stand out in terms of various measures of altitude, with Malham close in terms of average height, though falling well short in terms of maximum height. The three predominantly lowland centres of Preston Montford, Juniper Hall and Flatford Mill are also quite distinctive, and the extreme characteristics of Flatford are well displayed by the dominance of the lowest rank for four of the seven columns.

These points will be obvious to anyone who knows the Centres; all we have done is to add a little precision to the perception. However, some of the relationships already listed in Table 1 throw a more detailed light on some features. For example, it is probably not immediately obvious to the visitor to Preston Montford, set in a fundamentally lowland terrain with the Severn on the edge of the property, that the average river distance to the sea is over twice that of the Malham area with its upland topography and its position on the main Pennine watershed.

RELIEF

We can also readily use the computer to assemble histograms for height/area

TABLE 1. *Values of some relief/geology variables*

	Average of high elevation (m)	Average of low elevation (m)	River distance (km)	Sea area (km^2)	Area Pre-Palaeozoic (km^2)	Area Post-Palaeozoic (km^2)	Average height (m)	Maximum altitude (m)
Rhyd y creuau	290	367	30	76	2392	32	212	1085
Blencathra	260	340	31	24	2066	410	180	978
Malham Tarn	298	353	62	0	2494	6	243	735
Slapton Ley	163	209	10	606	1667	227	116	599
Preston Montford	150	179	131	0	1560	940	120	550
Dale Fort and Orielton	87	118	7	840	1660	0	55	536
Nettlecombe Court	162	203	24	156	1129	1215	120	519
Juniper Hall	74	90	31	0	0	2500	57	295
Flatford Mill	36	45	11	350	0	2150	27	110

TABLE 2. *Rank values for main relief variables*

	Height	Average High	Average Low	River distance	Sea area	% New Rocks	Maximum height
Rhyd y creuau	2	1	2	5	5	7	1
Blencathra	3	3	3	5	6	5	2
Malham Tarn	1	2	1	2	7=	8=	3
Slapton Ley	4	4	6	8	2	6	4
Preston Montford	6	6	4=	1	7=	4	5
Dale Fort and Orielton	7	7	8	9	1	8=	6
Nettlecombe Court	5	5	4=	6	4	3	7
Juniper Hall	8	8	7	3	7=	1=	8
Flatford Mill	9	9	9	7	3	1=	9

relationship, plotted in Figure 1 on a cumulative basis. Such histograms are commonly used, whether at the global or a river basin scale, but are normally tedious to construct. The "standard" curve for the FSC areas is a gentle, concave upwards curve, with less and less land at each successive height above the mean height — in some cases with the concave portion limited to the upper third of the height range. Examples are Flatford Mill and Juniper Hall, with Malham Tarn, Slapton Ley and Dale Fort rather similar, although in each case with noticeable departures. Thus, Dale Fort has little land between 0 and 30 m OD, whilst Malham, without a coast, begins at 70 m and does not enter the straight-line stage until 130 m. Yet another area without a coastline, Preston Montford, begins with a straight line rise from its lowest altitude (60 m) followed by a simple inflexion at 140 m to another straight line which rises steadily to about 270m. Delay in reaching the point where equal areas lie at successive heights is seen for Rhyd y creuau where the lower limit of the straight line is at about 250 m.

We can immediately identify Slapton as anomalous since it rises smoothly (with declining areas with each height band) to 150 m, but then changes to a much more

FIG. 1. Line graphs for all nine FSC areas showing cumulative area below successive altitudes. The total area for each centre is 2500 km^2 except where the area includes sea which is excluded from these calculations. Points are plotted for every 20 m band.

TABLE 4. *Average slope in relation to average height*

	Average height (m)	Average HP–LP (m)	HP–LP/mean height	Mean slope (degrees)	Modal slope (degrees)
Rhyd y creuau	290	153	0.528	8.3	6.1
Blencathra	260	159	0.612	8.7	1.7
Malham Tarn	298	110	0.369	6.0	3.7
Slapton Ley	163	93	0.572	5.1	4.4
Preston Montford	150	59	0.395	3.2	0.8
Dale Fort and Orielton	87	64	0.740	3.5	2.9
Nettlecombe Court	162	82	0.508	4.5	3.7
Juniper Hall	74	33	0.449	1.8	1.4
Flatford Mill	36	17	0.472	0.9	0.7

and Juniper Hall in Figure 2b. Malham has the clearest set of subsidiary peaks in the frequency distribution, with maxima (of descending size) at 5.2, 6.8, 10.1, 11.6 and 14.3 degrees.

RIVER DISTANCE

When we relate overall mean height (MH) to river distance (RD), for the whole of Northern England, we find a relationship which is close to linear, both for the area as a whole, and for each rock type. This relationship was not expected, but it applies separately to all the major geological outcrops and the confidence values on the regressions are very high. The slope is steeper for the more resistant rocks, and shallower for the weaker rocks. The relationship should not be confused with the curved long-profile of the main river, for the height area relationship is averaged across all the grid squares with the same river distance, so the dendritic pattern of the drainage comes fully into play. Table 5 uses the value for the ratio MH to RD for Northern England (5.58) and also the average value for the nine FSC areas (7.22). We find that the overall agreement is very poor, and about all we have done is to show that Malham (which lies within the Northern England/Southern Scotland area on which the ratio of 5.58 is based), Nettlecombe and perhaps also Flatford have mean altitudes which can be related to the effect of river distance, although it is true that these represent a wide range of values for river distance. Of the others, Preston Montford is very much lower and Juniper Hall considerably lower than we would predict. Rhyd y creuau, Blencathra, Slapton and Dale Fort and Orielton are higher than river distance alone would predict, even if the higher average value for the nine FSC areas is used. Returning to the variables listed in Table 1 we find that one further factor still to be taken into account is rock resistance, since some of these departures roughly match the proportions of older and younger rocks shown there.

THE EFFECT OF GEOLOGY ON ALTITUDE

We are all aware of the link between rock resistance and relief, though the relationship is by no means a simple one and has rarely been quantified. As any visitor to Juniper Hall will know, the Chalk rises steeply above the vale on the mudrock of the Gault clay, and the Lower Greensand (the Hythe Beds in particular) rises at least as high as the Chalk and in turn overlooks a wide vale on the mudrock of the

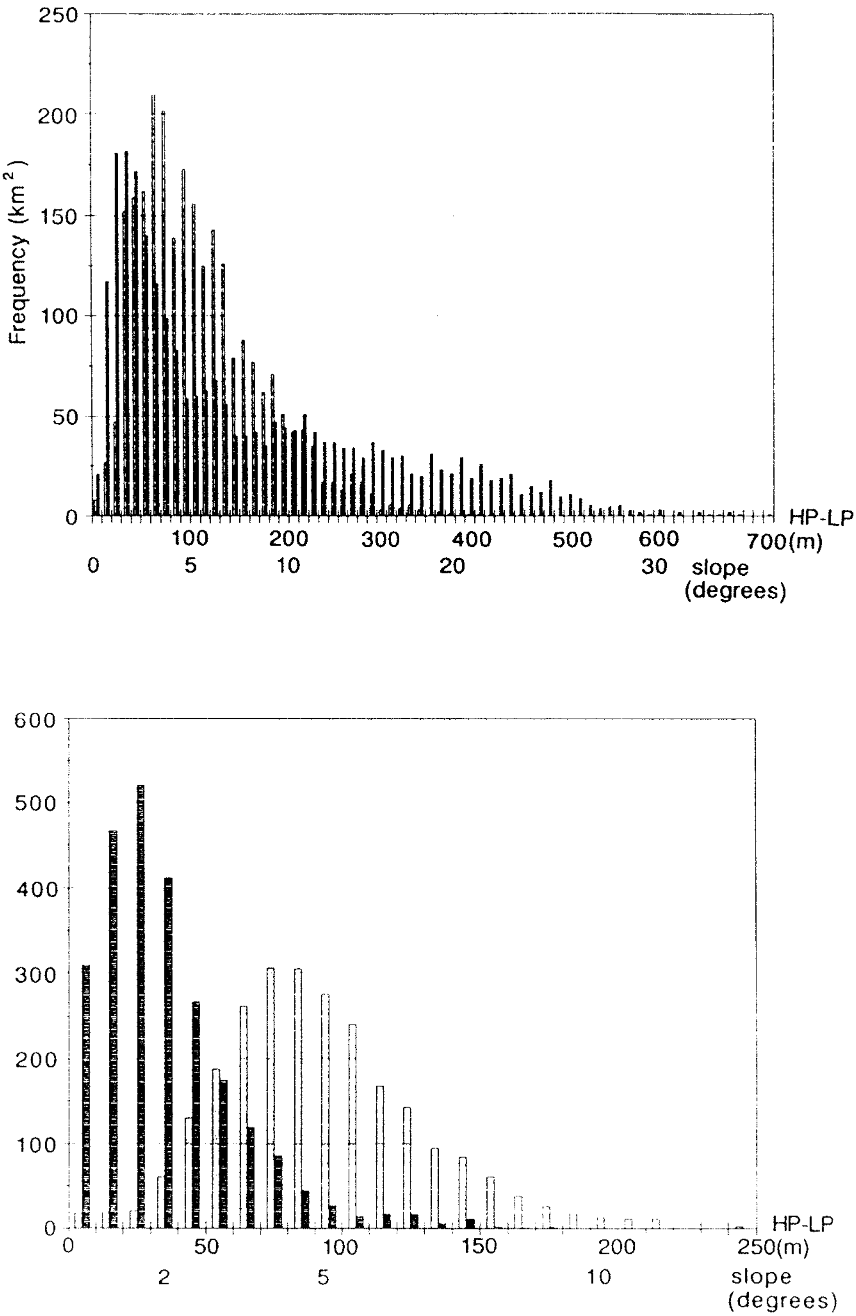

FIG 2. Histograms of slope angle based on the difference in height within each one kilometre square, for four areas. Approximate slope angles are shown as well as the HP–LP value in metres on the horizontal axis. Figure 2a shows Blencathra (dark bars) and Malham Tarn (lighter bars); Figure 2b shows Juniper Hall (dark bars) and Slapton Ley (lighter bars). Note that the scales are not the same.

TABLE 5. *Calculation of expected height from River Distance*

	Actual mean height (m)	Mean river distance (km)	Calculated mean height (Alt.=5.58RD)	(Alt.=7.22RD)
Rhyd y creuau	290	29.7	166	214
Blencathra	260	31.0	173	224
Malham Tarn	298	62.6	350	452
Slapton Ley	163	9.6	54	70
Preston Montford	150	130.6	729	943
Dale Fort and Orielton	87	6.9	38	50
Nettlecombe Court	162	23.8	133	172
Juniper Hall	74	31.0	173	224
Flatford Mill	36	11.0	61	79

Weald clay. Similar relationships are found in most areas of the British Isles, and given our complex geology they account for much of the diversity of relief. The digital database we have assembled allows, virtually for the first time, a more rigorous approach to this topic.

As noted briefly in the Introduction, we have identified three apparently independent measures of rock resistance; recording essentially the mean height in relation to mean river distance, the height of the highest 20% of the area of each rock outcrop, and the measure of mean slope provided by the average height difference within each kilometres square. The values are weighted equally for all the rocks forming the whole data set for Northern England/Southern Scotland to give a value of 1.00. The same arithmetic is then carried out for each geological outcrop to give values either side of 1.00. Five arbitrary resistance classes are then identified as set out in Table 6.

It is worth noting that there is a very strong effect of rock age on the division into

TABLE 6. *Five rock resistance classes based on N England/S Scotland data*

and	Resistance scores based on equal weighting of log(relief/RD), slope (HP–LP) highest relief (Mean HP + SD)				
	Very Resistant	Resistant	Average Resistance	Weak	Very Weak
Range	1.55–2.69	1.15–1.54	0.90–1.14	0.50–0.89	< 0.50
Average value	1.833	1.291	1.025	0.733	0.305
Area (km^2)	4,253	14,124	18,330	13,564	10,849
Geology types	8	28	27	18	12
Pre- Palaeozoic & Palaeozoic (km^2)	4,134	14,055	17,199	11,011	0
Post-Palaeozoic (km^2)	119	69	1,131	2,553	10,849

classes, with only one post-Palaeozoic rock (the Arran granite) in the Very Resistant class, and no Palaeozoic rocks in the Very Weak class. It is also apparent that the resistance of the Chalk and the Lower Greensand in southeastern England is relative only; in terms of the Northern England/Southern Scotland data the Chalk lies near the top end of the Very Weak class.

Some of the rocks characterised above occur in the seven FSC areas outside Northern England and thus can be assigned a rock resistance class. It is then possible to assign other rocks in these nine study areas to the same classes, based on local comparison of their rock resistance scores with those of the known rock types. Often the outcrops concerned are small, and several of the areas around FSC Centres have few rocks overlapping with the main data set. But for this first approximation, the resulting classes are acceptable and the values concerned are set out in Table 7. They are also shown in a set of computer-drawn maps in Fig. 3.

We can use values for those rocks which occur both in the FSC areas and in our main area of study to calculate the difference between each of the three elements of rock resistance between the FSC areas and the whole are of Northern England/Southern Scotland. The results are least reliable where the area of overlap is small, and obviously most reliable for the two areas lying within the main database, though even here some allowance should be made for those rocks which occur almost only in the FSC area—true for both the Borrowdale Volcanic Series and the Skiddaw Slates in the Blencathra area. The relevant values are set out in Table 8, expressed as percentages of the main database values for each rock with the results summed for each FSC area proportional to the area of each rock outcrop. Although the detailed calculations are not presented here, it is reassuring that there is broad agreement between the different geologies within each FSC area. This suggests some non-lithological effect on the rock/relief relationship is involved.

Some of the similarities we have recognised in terms of measures of relief are no longer apparent. Instead we have some new alliances. That Slapton and Nettlecombe are similar is no great surprise, though it is remarkable that for those rocks where comparison is possible they are far higher and steeper than is true of the baseline area of N England/S Scotland. In contrast, the Dale Fort and Orielton area, just across the Bristol Channel, is low overall and particularly low in terms of the highest altitudes. Juniper allies itself with Malham in being only a little above the overall averages, though Juniper Hall is highest on Height/RD, whilst Malham Tarn is highest on slope. Preston Montford and Flatford Mill are both well below average values, especially on Height/RD where Preston Montford is remarkably low (the RD distances are of course very high) but with no values more than a few percent above average. Finally, Rhyd y creuau and Blencathra are linked, not only in relief, as will be obvious to anyone who knows both well, but also in a very similar pattern of departure from the database values, with very similar exceedances on both Height/RD and Slope, and lower departures for the Highest altitudes. We examine possible reasons for these departures in the final section.

An Explanatory Approach to the Relief of The Nine FSC Areas

We can guess at least three further factors which may be invoked to account for the anomalies unexplained by the preceding analysis. The first is the complication that although the general relationship between Mean Height and River Distance is linear, the regression lines show positive values where the river distance is zero. In other words, there is usually some high ground within a kilometre or two of the coast. The second is the effect of glaciation on relief; the third the possibility that the height of some of these

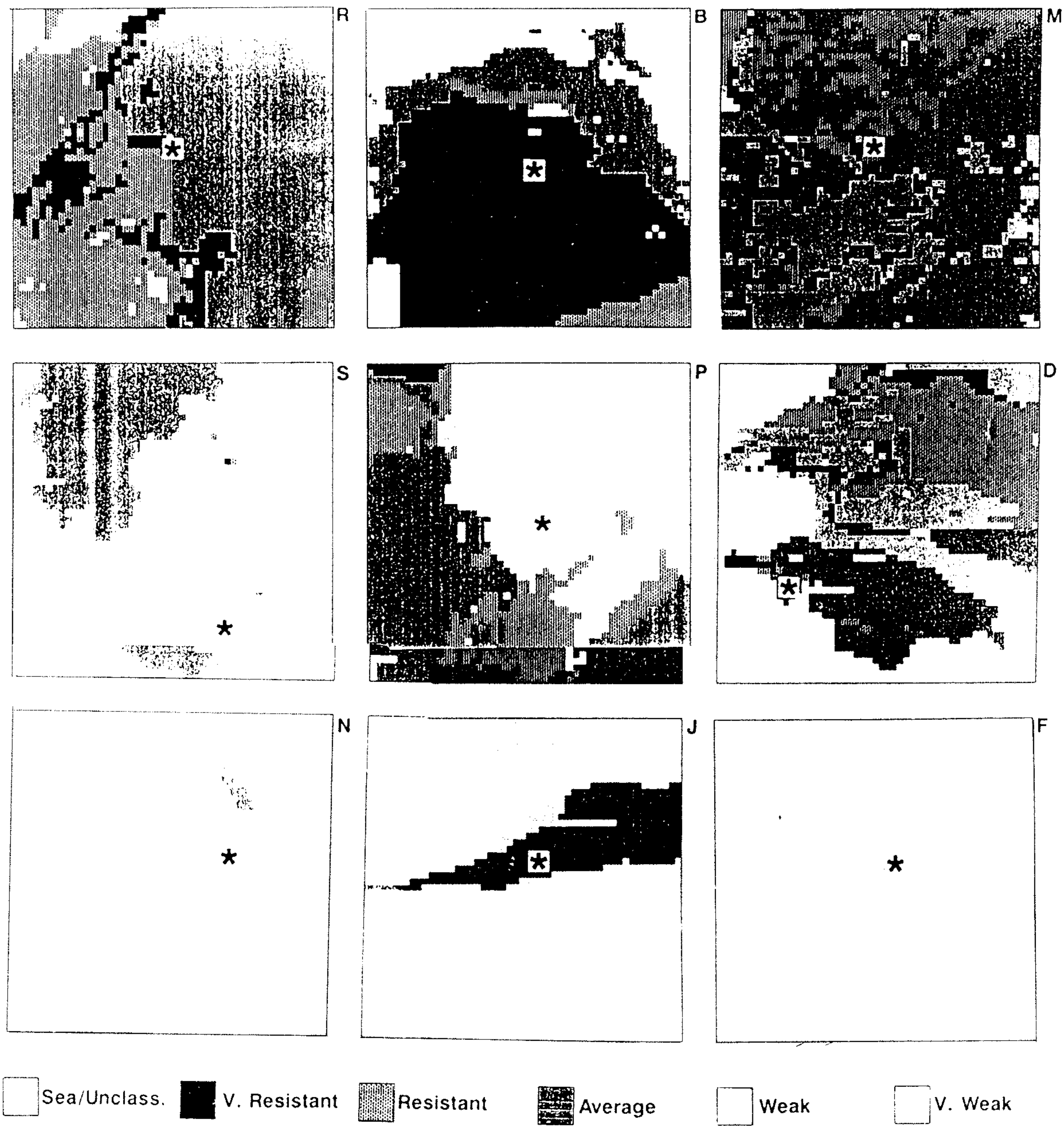

FIG. 3. Computer-drawn maps of relative rock residence (for basis of calculation see text) for all nine FSC areas. Sea is shown in white. The Centre(s) are shown by asterisks.

TABLE 7. *Geological areas by rock resistance class*

a) by total area

	Area of most resistant rocks (km^2)	Area of more resistant rocks (km^2)	Area of average resistant rocks (km^2)	Area of less resistant rocks (km^2)	Area of least resistant rocks (km^2)
Rhyd y creuau	278	857	1190	63	0
Blencathra	1294	136	442	326	240
Malham Tarn	2	357	1559	573	0
Slapton Ley	1	2	556	1273	33
Preston Montford	27	389	817	672	569
Dale Fort andOrielton	70	492	557	510	0
Nettlecombe Court	0	0	30	1561	741
Juniper Hall	0	0	0	342	2136
Flatford Mill	0	0	0	0	2150

b) As percentage of land area

Rhyd y creuau	11.6	35.9	49.8	2.6	0
Blencathra	53.1	5.6	18.1	13.4	9.8
Malham Tarn	0.1	14.3	62.6	23.0	0
Slapton Ley	0.1	0.1	29.8	68.3	1.8
Preston Montford	1.1	15.7	33.0	27.2	23.0
Dale Fort and Orielton	4.3	30.2	34.2	31.3	0
Nettlecombe Court	0	0	1.3	66.9	31.8
Juniper Hall	0	0	0	13.8	86.2
Flatford Mill	0	0	0	0	100.0

TABLE 8. *Calculated departures from the main database values for the three elements of rock resistance for those rocks found in an FSC area which also occur in the main Northern England/ Southern Scotland area. Data plotted as a percentage of the Northern England/Southern Scotland averages*

	Percentage of area with rocks in common	All three resistance attributes	Mean height/ river distance	Slope (HP–LP)	Highest altitudes (HP + SD)
Rhyd y creuau	16	129	133	131	124
Blencathra	75	128	137	138	108
Malham Tarn	97	113	98	129	113
Slapton Ley	16	179	196	224	117
Preston Montford	43	68	18	78	107
Dale Fort and Orielton	40	86	156	62	39
Nettlecombe Court	12	185	154	244	158
Juniper Hall	38	115	131	105	110
Flatford Mill	10	77	58	102	72

areas has been affected by tectonic uplift (or down warping) sufficiently recently for the effects to persist in the landscape.

Adjusting River Distance

We are so used to the appearance of the British Isles on maps and so familiar with the abrupt break along our coastline as land gives way to sea, that it is easy to forget how recently the postglacial Flandrian transgression brought the sea to its present high level. Indeed, the average sea level over the last one million years has been between -40 and –60 m and the last few glacial maxima have seen low sea levels in the range -100 to –140 m. Data are better for the last million years than for the rest of the Quaternary (roughly the last two million years), but an average level around 40–50 m below present sea level seems likely. The interglacial periods of high sea level have been relatively brief (perhaps 10% of total time) so the British Isles are really the unsubmerged higher ground of a greater Britain extending some way across the continental shelf. The long-term evolution of the landscape has been affected by, and probably adjusted to, the greater river distances which result, and some allowance must be made for this. However, although this reduces some of the differences in Table 8, it increases others, so it is unlikely to be the main story. The effects of increasing river distance by three arbitrary amounts (10, 30 and 50 km) are shown in Table 9

Table 9 shows that, if we allow for sign, the calculation using RD + 30 km is the closest approximation to the baseline value for the average of the nine FSC areas. However, since river distance is not the sole factor, it should also be noted that the extreme addition of 90 km comes closest to the true value for Slapton and Nettlecombe —and also inevitably has the greatest effect on the Preston Montford difference. The pattern of change with increasing adjustment is controlled by the mean river distance for the base area used in all these calculations—Northern England/Southern Scotland—which has a mean river distance of 30.8 km. Thus Rhyd y creuau, Blencathra and Juniper Hall are virtually unaffected by this adjustment, Slapton and Flatford will show the greatest proportional increase in predicted relief, Malham and Preston Montford in particular are the only two which will decline. The best fit value for all nine FSC areas of 30 km obviously reflects the particular mix of river distance values here and leads to the limited though useful conclusion that the landscape appears to be adjusted to a longer river distance than today, though whether the "best fit" figure of 30 m is valid will require a larger data set to determine. The issue has to be left in the air, but it is a concept we should not forget.

Glaciation

Glaciation has obviously been a factor in the evolution of the relief of the Rhyd y creuau and Blencathra areas, indeed Snowdonia was used by W. M. Davis around the turn of the century to explain the impact of alpine glaciation on a fluvial landscape. The considerable dissection of both upland areas can, in part, be attributed to erosion by valley glaciers and both areas contain lakes within rock hollows. Of course, the whole of Northern England/Southern Scotland, from which our relationships come, has been glaciated, but not as intensively as these wet and mountainous (and thus, in the past, heavy snowfall) areas along the eastern side of the Irish Sea. We would expect intense valley glaciation to reduce the mean height by reducing the low (trough floor) values and to increase the slope factor. In fact, the values in Table 8 show higher values for slope, but relatively high values for average relief/river distance. This suggests some further factor is at work and it may be uplift induced by the unloading resulting from both glacial erosion and the removal of the load of the ice dome within the last 15,000 years (see next section).

Less obviously, glaciation is probably the most important factor in the lowering of the Preston Montford area. There may also have been a contribution from tectonic movement (in this case subsidence of the Triassic Cheshire Basin) and this will be discussed below. So far as glaciation goes, the immediate evidence is the impact of the Last (Devensian) glaciation which has left behind an average thickness (prior to the most recent period of river incision) of about 30 m of till and associated meltwater deposits. This is almost all derived from local outcrops with a small contribution (e.g. flint) from the floor of the Irish Sea. The full argument cannot be elaborated here, but it seems that successive glaciations have eroded older drifts as they advanced (pushing them forward and flushing them down the valleys to the sea) and left a new till (and related fluvioglacial gravels) as they retreated. Thus the total impact of several successive glaciations can amount to more than 100 m of erosion. The major ice streams pushing out from the Irish Sea basin into the Cheshire lowland seem to have had such an impact. I suspect that such a concept has not been used in field teaching in the area, but it deserves serious consideration.

Thus we may use glacial erosion to account for part of the lowering of the Cheshire Basin and for the above-average dissection and thus steep slopes of the upland areas of Snowdonia and the Lake District. However, the fact remains that both the upland areas are higher than predicted, whilst the Preston Montford area seems even lower than the impact of glaciation alone. We also need to consider the Slapton and Nettlecombe areas where there has been no glaciation and where the mean altitude is higher and the slopes far steeper than the average for our baseline area. We were able to explain part of the

TABLE 9. *Effect of increasing RD values on the value of mean altitude/RD for each area*

	Mean ht/RD	% of base urea	with RD +10 km	% of base area	with RD +30 km	% of base area	calc. RD +50 km	% of base area
Rhyd y creuau	12.25	177	9.16	176	6.09	174	4.56	173
Blencathra	10.97	159	8.29	159	5.57	159	4.19	159
Malham Tarn	5.64	82	4.86	93	3.81	109	3.14	119
Slapton Ley	21.82	316	10.70	205	5.30	152	3.52	134
Preston Montford	1.35	20	1.26	24	1.10	31	0.98	37
Dale Fort and Orielton	17.34	251	7.07	136	3.24	93	2.10	80
Nettlecombe Court	8.55	124	6.02	115	3.78	108	2.75	105
Juniper Hall	2.87	42	2.17	42	1.46	42	1.10	42
Flatford Mill	4.05	59	2.12	41	1.09	31	0.73	28
Average FSC	9.43	137	5.74	110	3.49	100	2.56	97
Base Area values	6.91	100	5.21	100	3.50	100	2.63	100

unexpected height by the effect of rivers draining to a coastline well offshore, but it would require a very large displacement were that the sole reason.

Neotectonics

One possible reason for some of the remaining disparities, especially for Slapton and Nettlecombe (positive) and Preston Montford and Flatford (negative), is that they are the result of relatively recent tectonic movement. The movement is not necessarily continuing today, but was recent enough to have had a considerable effect on the elevation of the whole land surface. That Slapton, with the buoyant Dartmoor granite, should rise is highly probable; that Preston Montford would sink (at least that large part of the area east of the margin of the Welsh upland) is also highly likely. There is some evidence that the Red Rock Fault has moved in Quaternary times, with upward displacement of the Pennines and relative subsidence of the Triassic Basin. The very preservation of the Trias within the Cheshire Basin suggests subsidence.

Can we discover any further evidence for the reality of this tectonic movement from this data set? One line of evidence concerns the low point data for each area; only if the uplift is very recent and perhaps continuing would we expect to see the low point/river distance ratio abnormally high, and for slower or older uplift the river valleys will have adjusted, even if the interfluves retain the effect of older and/or slower uplift. On this criterion, only Slapton and to a lesser extent Dale Fort and Orielton may be regarded as anomalously high. Malham, and in particular Preston Montford, are anomalously low (i.e., the valleys are more deeply incised and have a lower longitudinal slope than average). For Malham, this records the effect of glacial erosion of the main valleys, for Preston Montford it is consistent with the overall impacts of glacial erosion and subsidence already suggested. Juniper Hall and Flatford Mill are also low, but they are low on height overall.

Another line of evidence is the depth of incision of the river valleys below the local interfluves. This has been established by using the height range data for a moving "window" of twenty-five kilometre squares by taking the highest value for each 25 km^2 and subtracting from it the lowest value for the same nine squares; the difference is then entered in the central square. Moving differences calculated this way provide us with information on the overall relative relief (i.e., the difference between ridges and adjacent valley floors). The relative relief or depth of dissection values obtained in this way are set out in Table 10

The very high values for Rhyd y creuau and Blencathra, and indeed the high value for Malham (note especially here the range for the modal values), reflect the deep glacial troughs which occur in those areas, rather than those valleys predominantly fashioned by fluvial dissection. The next highest values are those for Nettlecombe and Slapton, and these must reflect deep incision by streams (since they are both south of the glacial limit) in response to uplift, though this need not be continuing today for these deep valleys to persist.

A third criterion is the range of high point values at the coast. Relatively recent uplift might well show a plateau-like margin to the sea. This is certainly the case for most of the Slapton area and can be established quantitatively by considering the average high point values for river distances 0 kilometre (Table 11), i. e., those squares which include the coast.

TABLE 10. *Relative relief (depth of dissection) average over 5 x 5 km areas for the nine study areas*

	Mean	Mode	Maximum
Rhyd y creuau	426	280–300	1040
Blencathra	429	180–200	913
Malham Tarn	312	320–340	595
SlaptonLey	183	160–180	424
Preston Montford	168	40–60	423
Dale Fort and Orielton	116	80–100	454
Nettlecombe Court	198	180–200	482
Juniper Hall	96	50–80	250
Flatford Mill	41	40–60	85

TABLE 11. *Mean altitudes for squares with River Distance 0 and 1 kilometre*

	Mean (m)	Max (m)	No. (km^2)
Rhyd y creuau	76.3	380	120
Blencathra	15.4	31	7
Slapton Ley	83.6	169	227
Dale Fort and Orielton	60.8	213	318
Nettlecombe Court	66.9	383	80
Flatford Mill	14.8	75	290

I would conclude from these lines of evidence that the chances of relatively recent and very probably continuing uplift influencing the relief of the Slapton area (and also Rhyd y creuau, though there the postglacial isostatic recovery can hardly be in doubt) is very real. I can claim to have used this concept in field teaching at Slapton, but suspect the number who have is low, since the idea is relatively novel. The table suggests that both Nettlecombe and Dale have also been affected by uplift, and it will be recalled that Table 9 supported this for Nettlecombe, if less certainly for Dale Fort and Orielton, and that Dale Fort and Orielton has a relatively high value on the LP/RD figure.

If this concept of uplift (almost certainly of Quaternary age and perhaps even continuing today) is correct, how can we reconcile this with the drowned valleys or rias of the southwest? Here we need to recall first that the relief seems to have developed in relation to a shoreline some tens of kilometres out from the present coast and with a mean sea level of around −50 m. Thus, this uprising area has been dissected by valleys graded to a sea level lower than today. This is of course true elsewhere, but where there is no uplift, the resulting estuaries are less deeply incised and are more quickly modified by infilling with alluvium. In addition, the long peninsula of the southwest is surrounded by relatively deep sea, so that as sea level rose following the low stand of the Last glaciation at about −140 m, the additional load of water was imposed relatively near the present coast, forcing the crust down and drowning the valleys more deeply than would otherwise have been the case. This has occurred within the last 15,000 years, and has forced down the crust more rapidly than the longer-term uplift which is reflected in the relief values we have been considering; thus short-term and rapid water loading has been able to offset the long-term trend of uplift.

CONCLUSION

The timing of this paper for this anniversary part of *Field Studies*, means that this is the first published article using the new approach made possible by this simple and still developing digital map of the UK. In time, a broader database will allow more sophisticated analyses, but it is nevertheless hoped that the data presented here have encouraged some new thinking about the landforms of the areas around the FSC centres and some new concepts about the development of their relief. The absence of any references perhaps reinforces the point that this is an innovative attempt and not the final word on this topic.