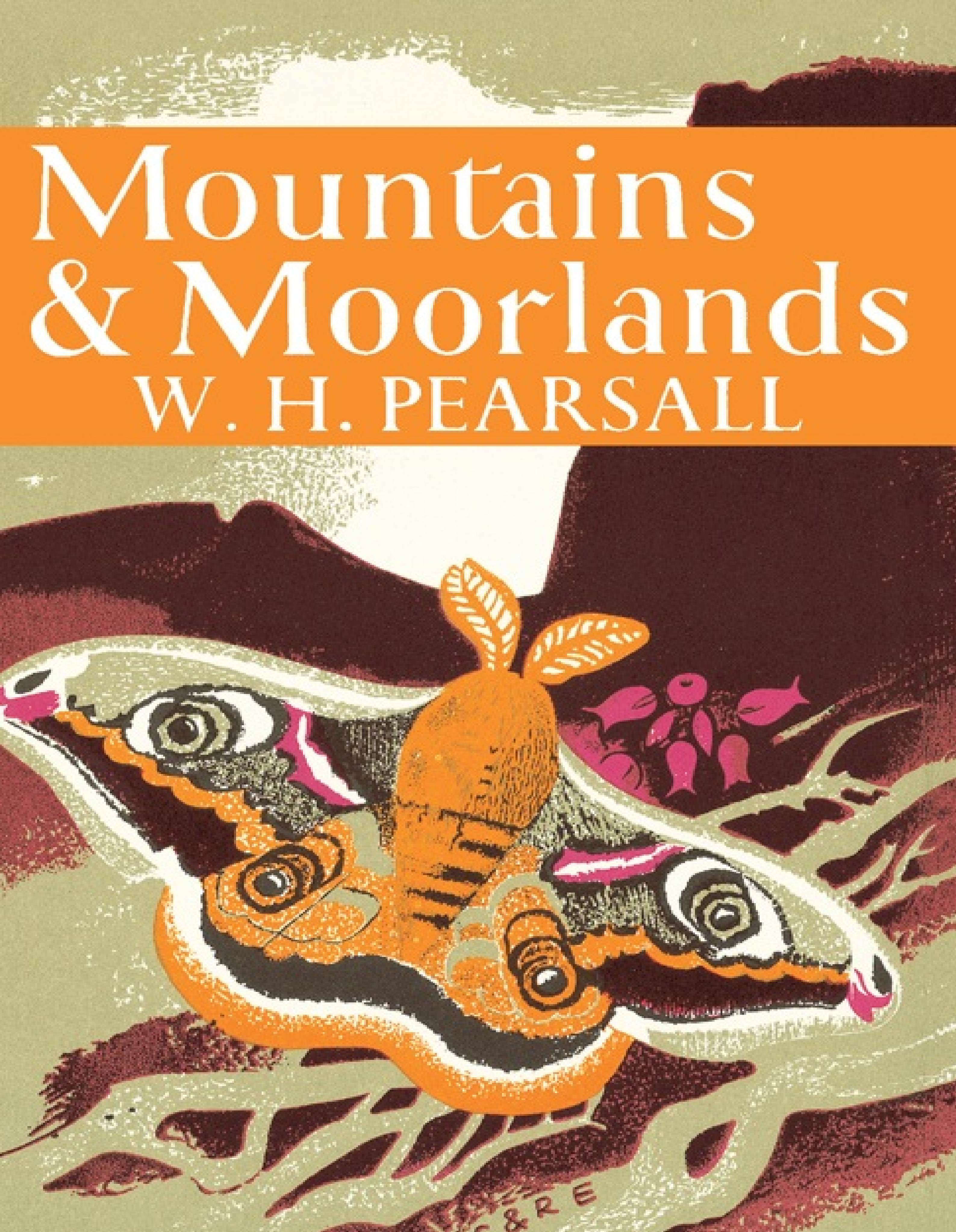
Mountains & Moorlands

W. H. PEARSALL



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W. H Pearsall

COLLINS
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EDITORS:

The aim of this series is to interest the general reader in the wild life of Britain by recapturing th inquiring spirit of the old naturalists. The Editors believe that the natural pride of the British public the native fauna and flora, to which must be added concern for their conservation, is best fostered b maintaining a high standard of accuracy combined with clarity of exposition in presenting the resul of modern scientific research.

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EDITORS' PREFACE

THERE are really two Britains—two different countries, their boundary a line that strikes diagonal across England from Yorkshire to Devon. To the north and west of this line is the region of mountain and old rocks; to its south and east the newer, fertile land of the plains. These regions differ vastly their climate, rocks, soils, scenery, plants, animals—and men.

It is of the mountains and moorlands that W. H. Pearsall writes. Moorland, mountain-top an upland grazing occupy over a third of the total living-space of the British Isles, and, of all kinds land, have suffered least interference by man. Mountains and moorlands provide the widest scope f studying natural wild life on land.

In the present volume Professor Pearsall has brought together the results of over thirty year work among the high hills, the lakes and the moorlands of northern and western Britain. He is botanist, but these pages show that animals have appealed to him almost as much as plants, a doub interest that is rarer than it should be among naturalists. It is doubtful whether any other author coul single-handed, have presented such a well-balanced picture of the wild life of an area as Profess Pearsall has done in this volume.

Although he is now banished to the gently undulating south (he is head of the Botany Departme at University College, London) the whole of Professor Pearsall's previous working life has been spe within call of the mountains and moorlands about which he writes—at Manchester, at Leeds, an finally as Professor of Botany at Sheffield University. During this period he has made man outstanding contributions to ecological research, especially in the Lake District, but it is obvious fro his book that the severely scientific discipline that these researches demand has by no mean extinguished his deep love of the countryside in which they were carried out. On the contrary, th aesthetic and the scientific approaches have reinforced each other, as they should—but frequently d not—in any fully developed naturalist.

For many people, perhaps the most arresting point in the book will be the idea that since the en of the Ice Age our mountains and moorlands have been subject to a process of inevitable change, or of the trends being towards the growth of bog and peat-moss at the expense of grassland an woodland, and towards a general impoverishment of soils; further, that during the last 3,000 years o so this and other changes have been progressively accentuated by man's interference, so that th difference between the natural history of our moorlands to-day and a bare two centuries ago is ve marked. Indeed, work such as Professor Pearsall's is putting the history of our country in a new ligh His chapter on the future possibilities of our uplands is equally striking.

Before the growth of modern transport most people in the south of England had little chance knowing how those in the rest of Britain lived; there was little opportunity for studying an appreciating the lives of those who lived in the unspoilt countryside of the north and west. But to-da the mountains and moorlands of Highland Britain are within reach of every one, and we hope th Professor Pearsall's book will help to quicken—and guide—interest in those parts of this countr which now provide the main (almost the only remaining) opportunity for observing and investigatin wild life and human problems in Britain as it was before modern man's heavy hand was laid upon it.

THE EDITO

AUTHOR'S PREFACE

THIS book is an expression of many happy days in the field and is thus a tribute to the many naturali friends who have consciously or unconsciously helped towards it by sharing their interests ar enthusiasms. I should like to think that they may find some satisfaction in its dedication and that the would feel that they had in part contributed towards its creation.

When so much is owed to others, it may seem invidious to mention any by name. But the large part of the animal population is composed of insects and for these specialised knowledge unavoidable, even for a general review. I count myself extremely fortunate in having been able obtain the sort of information I wanted, and also pertinent criticisms, from Mr. C. A. Cheethar Professor J. W. Heslop Harrison and Mr. W. D. Hincks, the last of whom also verified the name according to the *Check List of British Insects*. Mr. W. H. R. Tams very kindly gave much help in th preparation of Plate 30. The Editors too have been generous in help and criticism; and, finally, tribute must be made to the photographic skill of Mr. John Markham.

In spite of this, I fear that this may be thought an odd book, remarkable more for its omissio than its scope. It tries to integrate certain aspects of upland biology of which it may safely be said th about ten years' intensive work would be required to do them reasonably well. The real integratio perhaps, is that it tells about some of the things that have interested its author.

W. H.

University College, London

PREFACE TO REVISED EDITION

Professor Pearsall died in October 1964. A lifetime of active work as a field ecologist, universi teacher and administrator, ecological advisor and one of those most concerned with the foundation the Nature Conservancy, had left him too little time to write. *Mountains and Moorlands* remains as h major work for the general reader; it is a classic, and must not be touched by a lesser hand. But in th twenty years since its publication, further research has inevitably modified certain concepts. When was asked by Collins to revise *Mountains and Moorlands* for this edition, it seemed to me th Chapter 10, on ecological history, should be largely rewritten in the light of new work and th emergence of the technique of radiocarbon dating since 1950. Chapter 10 was partly based on the wo of Dr. Verona Conway and myself, and the revised edition of this chapter has been approved by D Conway and by Mrs. Pearsall. I am grateful to Miss Clare Fell for advice on changes in th interpretation of the archaeological record in North-west England since R. G. Collingwood's accou of 1933, which formed the basis of Professor Pearsall's discussion of the ecological history of North west England. In other chapters I have changed only a few sentences, to conform with ne discoveries, and have provided additional bibliography to cover relevant work published since 195 Chapter 15, a brief account of the work of the Nature Conservancy in Highland Britain, has been add to the book because of Professor Pearsall's concern with the Nature Conservancy—he was for man years Chairman of its Scientific Policy Committee—and because of the relevancy of the work of th Conservancy to the matters discussed in Chapter 14 of *Mountains and Moorlands*, which was writte before that work had begun.

The nomenclature of plants has been revised to conform with current usage; on the advice various colleagues, the revised nomenclature, with two exceptions, conforms with that found Clapham, Tutin and Warburg's *Excursion Flora of the British Isles*, Second Edition; the Censu Catalogue of British Mosses, by E. F. Warburg, Third Edition, published by the British Bryologica Society in 1963; the Census Catalogue of British Hepatics, by J. A. Paton, Fourth Edition, publishe by the British Bryological Society in 1965; and A New Check-list of British Lichens, by P. W. James in The Lichenologist, Volume 3, 1965. The exceptions are that *Scirpus caespitosus* has been retaine instead of *Trichophorum caespitosum*, as in Clapham, Tutin and Warburg, and that *Cladonia sylvatic agg*. has been retained, as it includes the two species, *Cladonia arbuscula* and *C. impexa*, of th Check-list.

W.

University of Leicester and The Freshwater Biological Association

CHAPTER 1

INTRODUCTION

> “The grounde is baren for the moste part of wood and come, as forest grounde ful of lynge, mores and mosses with stony hilles.”
>
> (LELAND)

A VISITOR to the British Isles usually disembarks in lowland England. He is charmed by its orderl arrangement and by its open landscapes, tamed and formed by man and mellowed by a thousand yea of human history. There is another Britain, to many of us the better half, a land of mountains an moorlands and of sun and cloud, and it is with this upland Britain that these pages are concerned. It equal in area to lowland Britain but its population is less than that of a single large town. It lies no as always, beyond the margins of our industrial and urban civilisations, fading into the western mis and washed by northern seas, its needs forgotten and its possibilities almost unknown.

Nevertheless, to the biologist at least, highland Britain is of surpassing interest because in it the is shown the dependence of organism upon environment on a large scale. It includes a whole range habitats with restricted and often much specialised faunas and floras. At times, these habita approach the limits within which organic life is possible, and they are commonly so severe that ma has avoided them. Thus we can not only study the factors affecting the distribution of plants ar animals as a whole, but we can envisage something of the forces that have influenced huma distribution. Moreover, in these marginal habitats we most often see man as a part of a biologic system rather than as the lord of his surroundings.

This book, then, deals primarily with mountains and moorlands as habitats for living organism Many plants and animals are mentioned, usually without detailed descriptions, except where they ca be seen to be a characteristic part of the environmental system as a whole, or where they illustra typical relations between organisms and environment. For this reason also no attempt is made to giv full lists. It is also inevitable that the plant-soil relationship occupies in outline a large part of th story because this is the feature which links the animate with the inanimate.

It would hardly be possible to frequent upland Britain without becoming an admirer of its beaut Its scenery is due to the interplay of its geological structure, of its climate and vegetation, and human influences. It thus becomes important to the biologist as an *integration* of the interplay of the habitat factors and often his first interest will be to look keenly at the scenery for clues in the analys of the environmental factors. As Professor Dudley Stamp has pointed out in his volume *Britain Structure and Scenery*, the scenery of the British Isles is remarkable in its diversity, and th conclusion applies with special force to the British Highlands. Diversity of aspect means diversity habitat and of biological pattern. It offers a fruitful and as yet hardly explored field for the naturalist work and one which is particularly attractive because very valuable results can be obtained witho highly specialised knowledge or apparatus.

While the study of the relations between organism and environment is no new aspect biological inquiry, it is nowadays dignified by a special name and is called the science of ecology. Th ecological study of mountains and moorlands may be in its infancy but their fauna and flora have lon been objects of interest to naturalists. It is evident from the routes they followed and the lists of plan they collected from 1660 onwards, that John Ray and his associates were no strangers to the hig northern hills, but the first record of an ascent of a British mountain we owe to another botanist—sto Thomas Johnson—whose account of the ascent of Snowdon in 1639 all naturalists will enjo especially perhaps the concluding sentence: “Leaving our horses and outer garments, we began climb the mountain. The ascent at first is difficult, but after a bit a broad open space is found, b equally sloping, great precipices on the left, and a difficult climb on the right. Having climbed thre miles, we at last gained the highest ridge of the mountain, which was shrouded in thick cloud. Here th way was very narrow, and climbers are horror-stricken by the rough, rocky precipices on either han and the Stygian marshes, both on this side and that. We sat down in the midst of the clouds, and fir of all we arranged in order the plants we had, at our peril, collected among the rocks and precipice and then we ate the food we had brought with us.”

Johnson lived in troubled times and he was later to die of his wounds as a Cavalier soldier. interest in the Alps may be said to have started as a result of de Saussure’s scientific expedition Mont Blanc in 1787, we may perhaps fairly regard Johnson as a British de Saussure at a far earli date, though on a more modest and unassuming scale.

FIG. 1.—Map of areas discussed, showing some of the Nature Reserves in Highland Britain.

CHAPTER 2

STRUCTURE

THE British Highlands are composed of blocks of hard and old rocks that occupy the north ar west of these islands. While the biologist is not primarily concerned with the manner in which the rocks originated and attained their present condition, the geological structure of the uplands is matter of some importance to him because it determines the character of the soil and the nature of th habitats available for living organisms. Consequently, a slight acquaintance with geological structu and processes forms part of the necessary background of the present subject and one, moreover, whic is of interest in helping us to understand the great scenic and biological diversity of different parts Highland Britain.

Almost every mountain observer has been struck by the evidence of decay which centres arour the larger peaks. There is shattered rock round their summits (see Pl. III) while below every crag w find scree and from every gully there runs a stone-shoot (see Pl. 2b) formed from débris coming dow from above. In the mornings the ceaseless downward trickle of stones or the occasional rock-fa proclaims the constant attrition to which the steeper hills are subject. Thus to the distant observer th mountains may seem to be permanent, "the immortal hills," but to those who know and move amon them a different impression is formed, in which breakdown and change play by far the most promine part.

The causes of this constant weathering of the rock surfaces are primarily the uneven contractio and expansions of the rocks caused by fluctuations of temperature, the action of rain and frost and th force of gravity. Any cracks that develop become filled with water and are expanded when the wate freezes and widened when it thaws. The actions of rain and of gravity tend to remove the smaller roc fragments so that nothing accumulates to protect the constantly exposed surface. Thus the surfac continues to be weathered away until the slope approaches an angle of rest (usually between 30° an 40°). Rainwash, soil-creep and the gradual downward movement of larger stones continue, long aft this angle is reached, to move the materials towards the valley.

Still more important in the long run are the effects of running water, for this not only tends t move materials downwards, but it may also remove them from the area altogether. In the course o time, therefore, every mountain torrent erodes a gully of its own construction, and the coars materials eroded are deposited below the gully on a gravel fan or delta (see Pl. 2a) while the fin materials are carried ultimately to the plains beyond the mountain area. It follows that the land-form in the uplands tend to be those which have survived the processes of weathering and erosion. In term of these ideas, the uplands, whether moorland or mountain, have survived because the rocks of whic they are formed are harder or have resisted removal rather than because they are being or have bee lifted up. At the same time there must have been some original mountain-building process.

Many facts can be used to illustrate this argument. Almost every visitor to the English Lak District becomes familiar with a type of scenery in which there is a foreground of lower and rounde hills, backed by a skyline of larger and steeper mountains. This is well shown in the photograph

Esthwaite Water in Pl. 3b and this type of scenery has a simple explanation. The rounded hills in th foreground are composed of rocks less resistant to weathering and the high mountains of harder more resistant rocks, in this case the hard volcanic “tuffs” or ashy beds of the Borrowdale Volcani series which make up much of the mountain core of the Lake District. Both to the north and the sou of these hard rocks lie softer slates and grits. Although to the uninitiated these rocks present generally similar appearance, they exhibit considerable difference in hardness. As the hard Borrowdale rocks have weathered much more slowly, they now generally form much higher groun than do the adjacent softer rocks. The actual junction of the harder and softer rocks is shown in Pl. where it will be seen that the harder rocks are mountain slopes, the softer being soil-covered ar cultivated.

There are many equally good examples elsewhere of the influence of the hardness or softness rocks upon land forms. A second illustration may be taken from Scotland, where, north of th Highland line, there are to be found long stretches of steeply inclined and metamorphosed grits, ha and resistant rocks which give the line of the summits, Ben Lomond, Ben Ledi, and Ben Vorlich. Th valleys intersecting this area lie on beds of softer rocks, shales, limestones and phyllites, which hav suffered correspondingly greater erosion and so have been cut down below the general upland level.

The general concept of mountain structure thus illustrated can be applied on a larger scale, for has been pointed out already that the distribution of mountains and moorlands in Britain is essential that of the older and harder rocks. These lie, as we have seen, to the northwest of the British Isles, ar their range covers all the main mountain areas. The causes of this distribution lie in the far-dista past when large-scale earth movements were taking place, and there seems to have remained since tendency for the north and west of the British Isles to stand as a raised system. While any attempt trace these mountain building movements lies outside the scope of the present discussion, it may b interesting to indicate something of their effects on upland structure.

In the simplest cases, of which the Pennine range in Northern England is a good example, th upland area represents essentially a fold in the earth’s crust. In the Pennines, this fold ru approximately north and south and a transverse section through it would show the gener arrangement represented in Fig. 2, with the newer rocks (including the Coal Measures) represented o either side of the fold, that is in Lancashire and Yorkshire, but absent from the top of the Pennine themselves. There is evidence of various types which points strongly to the probability that new rocks, from the Coal Measures upwards, have in fact been removed by erosion from along the crest.

Thus the Craven Uplands, including Ingleborough at their southern end, are separated from th main block of the Southern Pennines by the great Craven Fault system. Just south of this fault, Ingleton, coal was formerly mined from strata lying *above* those which correspond to the rocks on th top of Ingleborough. The assumption seems clear, therefore, that these Coal Measures have bee removed by erosion from the area north of the Craven Fault.

The Craven Uplands are also interesting in another respect.

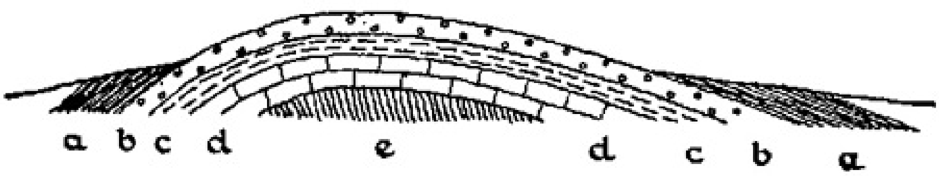

FIG. 1.—General character of Pennine anticline. (Diagrammatic.) *a*, Coal Measures; *b*, Millstone Grit; *c*, Yoredale Shales, etc.; *d*, Carboniferous limestone; *e*, Ordovician and Silurian.

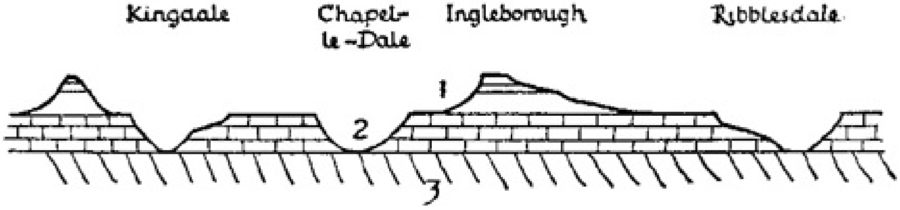

FIG. 2.—Dissection of Craven Pennines by river valleys: 1, Yoredale rocks; 2, Carboniferous limestone; 3, Ordovician and Silurian. (Diagrammatic.)

The three parallel summits of the mid-Pennines, from east to west—Great Whernside (2310 ft Penyghent (2273 ft.) and Ingleborough (2373 ft.), but also, to the north-west, Whernside (2414 ft.) ar Grey Gareth (2250 ft.), reproduce almost identical characteristics in structure and altitude. They a separated by a series of river valleys, Wharfdale, Littondale and Ribblesdale, then also by Chapel-l Dale and King-dale, which have very obviously been cut down through the original rock formation here almost horizontal (see Fig. 2). A reconstruction of the mid-Pennines on an east-to-west sectio thus shows these mountains as the surviving elements of the Pennine fold, resting on a mass of th still older Silurian rocks, upon which also the rivers now run. North and south of these Crave Uplands, the Pennines have commonly the character of a high moorland plateau (see Fig. 28). It only when these plateaux have been greatly dissected by erosion and by river action, that distinctiv mountain peaks are frequent. This has happened not only in Craven but also at the southern extremi of the Pennine range where dissection has also split up the plateau into peaks such as Kinder Scout ar Bleaklow.

Now whatever their origin may otherwise be, it is extremely common to find that mounta masses have the character of dissected plateaux. There is perhaps no better example of this in Brita than the Cairngorms as a whole. The observer standing at any considerable distance from the mountains (so as to be able to see most of the major summits) will inevitably be struck by the fact th the group as a whole presents a nearly level or gently domed-shaped profile. This may be see particularly well from near Aviemore (see Fig. 3), and it is suggested by the skyline in Pl. 5. In oth words, these peaks, so impressive at close quarters, are due to the cutting up of the high plateau b deep and steep valleys. Even on isolated peaks like Lochnagar, the vast summit plateau clear indicates the remains of one still more extensive.

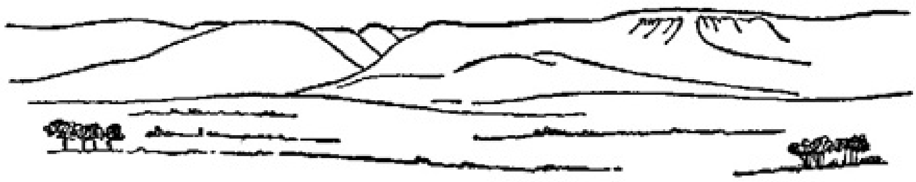

FIG. 3.—Silhouette of the northern face of the Cairngorms—a dissected plateau.

Imagine the processes of erosion and dissection proceeding over many square miles of near horizontal strata, until much more has been removed than is left, and it will be possible to understan the origin of the extreme examples of mountain or plateau dissection to be seen in Western Ross an Sutherland. Here, formerly, nearly horizontal layers of Torridonian sandstone covered an ancien surface of hard and resistant crystalline rocks. To-day, such mountains as Suilven and Canis represent the last remains of these sandstone masses, most of which have long since vanished. In th category also must no doubt be placed Lugnaquilla (3039 ft.) in south-eastern Ireland—the la remnant of rocks overlying a large boss of granite.

There is one other point about the effects of erosion which is worthy of brief mention. If mountain mass or ridge were composed of uniform materials and if it were equally eroded on a sides, the shape of the mountain would tend to approach more and more closely, as time went on, t that of a perfect cone. This generalised type of mountain is not perhaps very common in Britain- though isolated hills like Muckish and Errigal in Donegal are of this general type as well as many the rather lumpy mountains in the Scottish Highlands, especially perhaps Schiehallion. The Paps Jura, illustrated in Pl. 3a, show the disintegration of a quartzite ridge in this way. A common Britis variant of this simple type is one in which the summit is distinctly flat-topped or tabular. This particularly to be seen in some of the examples already mentioned. The three most prominent Pennin summits, Cross Fell, Ingleborough (see Pl. 17) and Kinder Scout all have this form as do th Sutherland mountains Suilven and Canisp, and MacLeod’s Tables, west of Dunvegan in Skye. It is du to the presence at the summit level of a horizontal stratum of hard and resistant rock, usual Millstone Grit in the Pennines and Torridonian Sandstone, capped by Cambrian quartzite Sutherland, the latter containing so much white quartz that the rock may be mistaken for a snow-ca when seen from a distance (see Pl. III).

The Craven Uplands show in a particularly striking manner the dependence of mountain scene and vegetation on the geological structure. The rocks are horizontally stratified and they consist of a upper zone, mainly of Yoredale sandstones and shales, below which lies a great thickness o Carboniferous Limestone, once called the Mountain Limestone from its association with upland are in Britain. Where the overlying rocks have been removed by erosion, the hard limestone may for extensive plateaux, and because it is almost pure calcium carbonate, it yields practically no soil o weathering. It is traversed in all directions by deep vertical fissures and is consequently dry (see P XXII). The surface, aptly called “limestone pavement,” is usually devoid of vegetation except whe traces of glacial drift occur, but a luxuriant flora lives in the shelter of the fissures. The limestor plateaux are often bounded by almost vertical “scars” (see Pl. XVIII). A very striking type of scener is thus produced, a feature not only of the Craven Uplands and mid-Pennines in general, but also large areas in Western Ireland (Clare and Mayo).

In contrast, the Carboniferous Sandstones (including Millstone Grit) and shales are no calcareous and are almost always covered by the moorland vegetation which is so characteristic feature of the high plateaux of the northern and southern Pennines. In Craven, where these rocks a exposed along with the limestones, the contrast between the two sorts of rock is often very strikin and is well illustrated in Pl. 4. Thus both the physical and chemical qualities of the rocks may affe the scenery and vegetation.

The simple conical form that is to be expected where rocks of approximately uniform texture a equally eroded on all sides, is lost not only when the harder rock strata occur, but also wherever th mountain is composed of strata that are not horizontal. Thus both Blencathra and Dow Crags in th

Lake District show one gently sloping aspect (see Fig. 4) which is that of the “dip” or slope of the roc strata, while on their steep faces the rock weathers into blocks, more or less at right angles to the d of the strata, so that a

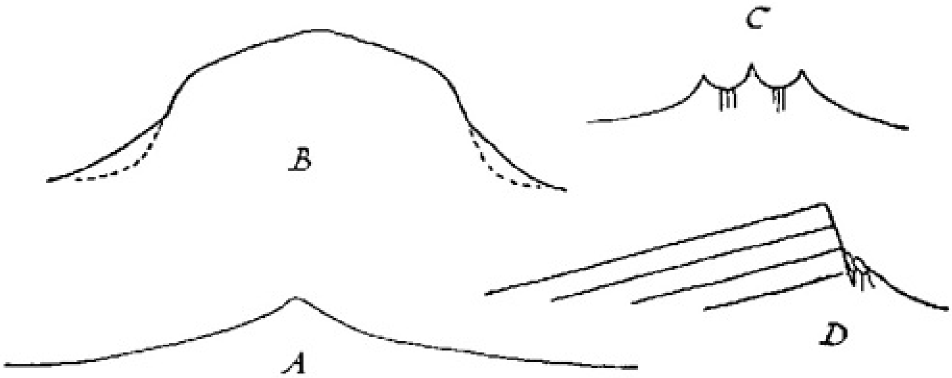

FIG. 4.—Some types of mountain form. A, Symmetrical weathering of uniform rock; B, Recent oversteepening below ancient upper form; C, Ridge with softer interbedded rock; D, Dip and scarp slopes.

steep angle tends to persist. In Wales, Tryfan also shows this type of structure in a still mor spectacular manner (see Pl. II) and it is very generally to be seen in the different mountain areas, ofte recurring, again and again, wherever the rock strata act as guiding planes for the inevitable erosion.

Sometimes hard rocks arranged in this manner overlie much softer ones. Such is the essenti structure of Mam Tor, the “Shivering Mountain” in Derbyshire, and also of Alport Castles not fa away. In both cases, hard sandstones and grits in the upper part of the escarpment have below the soft shales which are constantly washing and weathering away. Thus, on Mam Tor, the upper parts o the escarpment is constantly being undermined and so are constantly falling. Alport Castles, contrast, represent an immense wedge of the mountain detaching itself from the face behind ar falling outwards with infinite slowness, pushing before it into the valley a great wave of earth, as well shown in Pl. 6. There are no better examples in Britain of the instability of mountain structur than these two Derbyshire hills.

In other British mountain areas, the comparatively simple arrangements of rocks seen in th examples already discussed are obscured and other considerations become important. An upfold lik that met with in the Pennines is called an *anticline* (see Fig. 1) and a corresponding valley-shaped fo (or depression) would be called a *syncline*. Now it is a striking fact that the mountain summits ve often represent the remains of a syncline. Naturally this is only in areas where great erosion has take place. The reason for the persistence of the synclinal folds as mountains is that when folding tak place as a result of lateral pressure, the synclinal folds will be compressed and so will tend to becon harder. Anticlinal folds, on the other hand, will come under tension and so will tend to crack.

Thus when weathering and erosion takes place, the anticline, being shattered, is more easi attacked and suffers more, while the syncline, being compressed and hardest, therefore tends to b more slowly affected. It is thus logical, if somewhat unexpected, to find that great peaks or perhap particularly ridges often represent the remains of a syncline, though the synclinal structure may n always be evident because the main ridge of the mountain often represents the long axis of th synclinal fold.

The classical example of synclinal mountain structure, of which a fine picture exists in Lo Avebury’s *Scenery of England*, is that of Y-Wyddfa, the main peak of Snowdon, as seen from betwee the Crib Goch and Crib y Ddysgl under suitable conditions—with a powdering of recent snow. Th face is usually in shade and not easily photographed to bring out the rock structure, but the essenti features are shown in Fig. 5.

Another fine and well-known section illustrating synclinal structure is exposed on the Clogwy du’r Arddu, to the north-west of the main

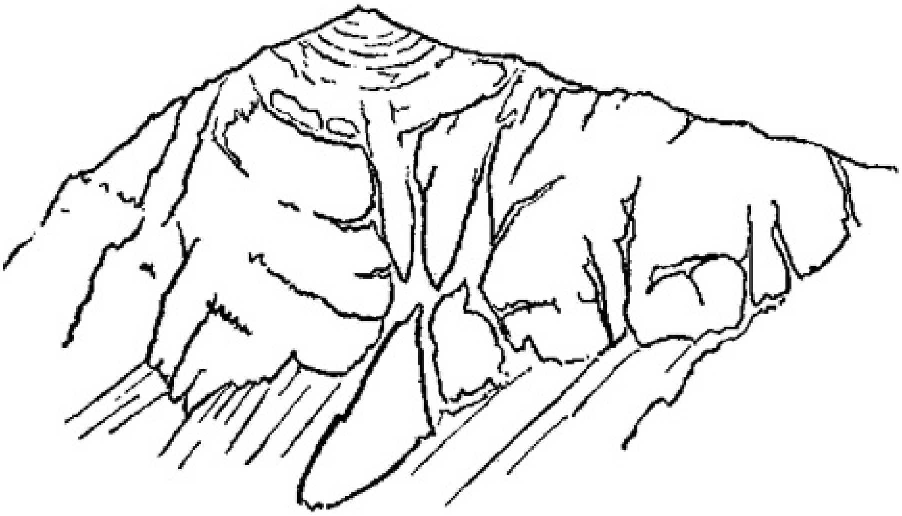

FIG. 5.—Rock structure showing syncline on Y-Wyddfa—the Snowdon summit.

summit, where a great synclinal fold makes up the whole of the precipice. These rather simp illustrations serve to illustrate a very important fact that where great earth-movements have take place the contortions of the rock strata may greatly affect their hardness and resistance to erosion.

Snowdon itself represents the bottom of a great fold whose crest lay somewhere to the south-eas In that locality some 20,000 ft. of rock must have been removed by erosion. The human mind ca hardly appreciate the length of time, not less than hundreds of millions of years, which erosion on th scale must have taken. The rocks now exposed belong to two ancient systems which we have alread encountered in discussing an earlier illustration (see Pl. 3b). They are in geological terminology Ordovician and Silurian age (see *Britain's Structure and Scenery* by L. Dudley Stamp). The centr core of Wales, as of the Lake District, consists of Ordovician rocks which are solidified volcanic ash and stones (*tuffs*) and lava flows, with interbedded marine strata indicating a submarine origin. The make up some of our boldest mountain scenery, though there is nothing to suggest that the individu mountains such as Snowdon, Cader Idris or Scafell have ever been volcanoes. Associated with th Ordovician tuffs and lavas are extensive sedimentary rocks of later Silurian age which are mainly fi grits or shales, and these, though generally softer, are as a rule rather poorer in bases like lime. The form somewhat more rounded hills (sometimes described as *moels*, their Welsh name), to-day almo always grass-covered like the lower slopes of the Ordovician crags. The general appearance is we shown in Pl. XXIII. Together, the Ordovician and Silurian rocks make up some of the most extensiv areas of British upland country, characteristic not only of Wales and the Lake District, but also of th Southern Uplands of Scotland and Southern Ireland.

The mention of volcanic action should not necessarily suggest an identification of parts of particular mountain with the cone and crater of an extinct volcano. The correct interpretation of sig of volcanic action among British mountains is usually possible only if one keeps clearly in mind th fact that most mountains are likely to be the remnants of larger structures. Usually then it will be va to look for anything so obvious as the cone and crater of a Vesuvius or a Stromboli. The neare approach to this sort of structure that we are likely to find in Britain is seen in some of the Laws Southern Scotland.

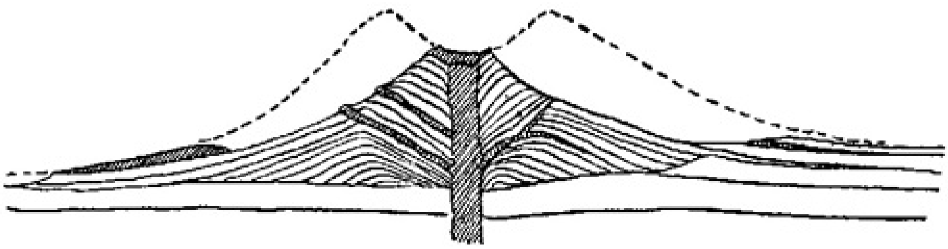

FIG. 6.—A Scottish "Law"—eroded remains of ancient volcanic vent. The shaded areas are basalt (lava flows)—the laminated areas are volcanic tuffs (ashes).

These usually represent the vents of small volcanoes which have become plugged with solidified lav whilst the surrounding cone has been more or less completely removed by erosion. A simplifie section is given in Fig. 6. One of the most complete examples, Largo Law in Fife, is essential similar but has two main vents. The figure shows the position of the vents and the lava flows whic are marked by “basaltic” rocks. Around these are the remains of the cones formed by tuffs o solidified volcanic ashes and stones. The mineral composition of these volcanic tuffs is characteristi so that they can be recognised where no volcanic cone is evident. It is this type of identification that used in the case of the Ordovician tuffs already mentioned, where the scale of output w immeasurably larger and no certain vent can be found.

Igneous rocks apart from volcanic lavas more usually fall into one of two main morphologic types. The largest areas are occupied by *plutonic* rocks, representing enormous masses of molten roc which has solidified without reaching the surface. There are secondly “dykes” and “sills,” bo representing intrusions of molten rock among other pre-existing strata. In the case of *dykes* th intruded material runs through cracks or planes at right angles to the general stratification—in th case of *sills* the molten rock follows between the bedding planes and therefore runs parallel to th general “dip” of the rock. Sills are often more resistant than the rocks into which they have bee intruded, and when this is the case they may form striking cliffs. Especially well-known examples a some of the sills in the Edinburgh district, of which perhaps Salisbury Crags are the most impressiv In Northern England the Whin Sill not only forms natural escarpments on which part of the Roma Wall stands, but it is associated both with a remarkable flora and with a series of majestic cascades i and near Upper Teesdale. Far away on the western side of the Pcnnines, it outcrops again on the gre western escarpment, particularly at Roman Fell and in the spectacular amphitheatre of High Cup Nic where it is eighty feet thick.

Dykes are often on a much smaller scale, but when found among resistant rocks they often giv rise to striking gullies and cols. Perhaps the best-known mountain structure of this type is Mickledor the great gap separating Scafell from Scafell Pike.

The larger intrusions of igneous rock are very often great bosses of granite which may be man miles across. Classical examples are those in Galloway, which give the mountains of Criffel and o Cairnsmore of Fleet. To this type of structure belong the summit of Crib Goch and also Penmae Mawr in Wales, the latter familiar to every one who drives along the coastal road. Generally similar i the huge granite mass of Dartmoor. In all these cases the granite boss is harder than the surroundin country rock and so has been left more elevated than the areas around. Where the surrounding rock are hard, however, granite bosses may contribute no noteworthy structure to a mountain region, an this is the case in the Lake District, for example, where the Shap, Eskdale or Ennerdale granites are a relatively inconspicuous among the hard slates into which they were intruded.

Along the western seaboard of Scotland granite intrusions occur among other traces of volcan or plutonic activity. The Western Isles and many of their mountains include the remains of vast flow of basaltic lavas which formerly stretched from Antrim, through Staffa, Mull and Arran to Skye, an indeed, as far north as the Faeroe Islands and Iceland. Geologically, these lava beds are of Tertiar Age and very much more recent than the tuffs of the Lake District and Wales. Even to-day the beds l nearly horizontal, and though they form the well-known columns of Staffa and the Giant’s Causewa and are often exposed in sea-cliffs (those of Eigg and of Portree Harbour, for example), they do not a a whole contribute much to our mountain scenery. Nevertheless, the familiar view of the mountains o Mull, Sgurr Dearg and its neighbours seen from Oban, consists almost wholly of rocks of this typ forced upward by later volcanic action in Central Mull. Still farther north, in Skye, the Storr Roc (see Pl. IV) ~~and the Quirang are, moreover, both composed of these Tertiary lavas overlying~~ soft Jurassic shales, and the whole of the coastal scenery is dominated by them.

Much more important scenically were the great subsequent upwellings of molten igneous matt in this area, which are associated with the noble mountain scenery of Skye, Rhum and Arran. In Sky the principal contrast is between the Black Coolin and the Red Hills. The crags of the former a composed mainly of a hard and basic rock called *gabbro*, with a coarsely crystalline structure th delights the climber's heart. The Red Hills, in contrast, are granite and this has weathered far mo rapidly and uniformly to give mountains of smooth and rounded aspect. The contrast, known to eve visitor to Skye, is extremely well shown in the fine photograph (Pl. 1) of Blaven and Ruadh Stac, t former of gabbro and the latter of granite. The gabbro is intersected by igneous "dykes" whic running mainly north-west and south-east, serve to accentuate the differences, for these are mo easily eroded than gabbro and so tend to form the gullies in the great gabbro ridges. Pl. VII gives a excellent impression of the distant aspects of the rock and the ridges.

Somewhat similar contrasts are to be seen in Rhum, where the outstanding peaks of Hallival a Askival are composed of ultra-basic and coarsely crystalline rocks of an unusual type. Their cragg outlines contrast noticeably with the grassy and rounded appearance of the hills farther west, such Fionchre and Bloodstone Hill, both mainly built of more easily weathered basalt. A similar contrast seen between the peaks of igneous rock and the gentle moorland contours of the Torridonia sandstones in the northern part of the island, which form a foreground as seen from Skye. In northe Arran, too, there were great intrusions of igneous rocks. The granite of Goatfell stands out boldly, seen from Brodick Bay, against a foreground of softer sandstones.

The igneous geology of these western mountains is extremely complex and cannot adequately discussed here except where it plays a part in determining the characteristic features of a mounta mass. But a few words may perhaps be spared for Ben Nevis (4406 ft.) which, as the highest mounta in Britain, deserves at least a passing mention. Ben Nevis represents a central plug of rock, surround by two cylinders of intrusive granite, that is presumably by two cylindrical faults, filled up fro below by molten rock. The cap of the mountain core consists of ancient lavas (Old Red Sandsto Period) overlying Dalradian schists, and it is supposed that this central core of rock must have su considerably into the molten rock now represented by the granite cylinders. Going east from B Nevis, Carn Mor Dearg lies on the inner cylinder of granite and Aonach Mor (3,999 ft.) on the out cylinder. From the north-west, both types of granite can be distinguished on the route from Fo William to the summit of Ben Nevis.

A similar complex system centres round Glen Etive, with the Buchailles of Etive representing cap of rhyolites and tuffs on a core surrounded by cylinders of granite. Ben Cruachan lies wholly one of the granite intrusions and so too does the greater part of the Moor of Rannoch.

From the point of view of their influence on the animal and plant life, a highly importa property of the volcanic and igneous rocks is whether or not they are rich in basic substances li lime, potash and magnesia.

The geological classification expresses these features inversely in terms of the amount of t non-basic material, silica, which is present, as shown in the following table:

Table 1 SILICA CONTENT OF IGNEOUS ROCKS

Silica content (per cent)	75-65 *Acid*	65-55 *Intermediate*	55-45 *Basic*	45-35 *Ultra-basic*
PLUTONIC ROCKS	Granite	Syenite Diorite	Gabbro	Peridotite Serpentine
VOLCANIC ROCKS	Pumice Rhyolite Obsidian	Andesite	Basalt	

Biologically, the basic and ultra-basic rocks provide habitats which are generally mo interesting largely because they yield richer soil. The favourable feature of a high base content is, it true, often partly counteracted by the hardness of the rocks and an accompanying resistance weathering and erosion, as in the examples already given from Skye and Rhum. But many Britis basalts are not only basic but they also weather especially easily to yield a comparatively rich so The Ordovician tufls are often intermediate in character and may include much andesitic material. contrast, most British granites contain on an average over 70 per cent of silica and they yield soi which may consist of little but sand and which, as a result, are correspondingly infertile. The biologi thus soon learns to regard granite areas as a distinctive upland type, just as they are geologically a scenically. On the other hand, he has learnt to approach areas dominated by basic or ultra-basic roc with a certain amount of optimism. Their more varied vegetation and fauna runs parallel with t higher base-status of the soils and rocks, and the latter, indeed, often contain large amounts of bas such as potash, magnesia and iron oxides instead of the lime that prevails in many sedimentary rock By analogy with other parts of the world, it is probable that the presence of certain plants and anima on the basic and ultra-basic rocks is associated with these peculiarities of chemical composition of t latter.

The great variety of rock type and of rock arrangement which runs through the Western Islands less apparent on the Scottish mainland. There the mountain masses of the Grampians are main composed of hard and ancient rocks, so greatly contorted by subsequent earth movement that the arrangement is often obscure and it is consequently less easy to describe in broad general terms the relation to mountain structure. They are geologically, for the most part, schists or gneisses (which a respectively, metamorphosed and distorted shales or sandstones and grits) or finely crystalli igneous rocks. But the simple principles which have been stressed above are generally applicab when the structure of any individual mountain or upland area is considered. Without considering the in detail, it may be noted that the Grampians include three main areas of differing structural typ which have biological interest. Towards the south and west there is an area in which mica-schis predominate. This is a rock which weathers easily, yielding an open and uniform soil. It is marked a group of characteristic and somewhat lumpy, grass-covered mountains lying roughly along a curv line between Ben Lawers, Ben Doireann and Ben Alder, which possess a well-recognised biologic type.

The chief contrast in the Grampians is, however, between the eastern and western halves of t country. The former, exemplified particularly by the Cairngorms, is mainly a high though deep dissected plateau, which constitutes the greatest continuous area of high ground in the British Isle The Cairngorms are evidently in the early stages of a new erosion cycle, and their typical outline already discussed in connection with Pl. 5, contrast remarkably with those of Dartmoor, for exampl also a granite mass, but one characterised by land-forms indicating far advanced weathering a erosion (see Pl. XXXI).

In the western part of the Highlands, erosion and dissection have proceeded far more effectivel so that more often the mountains are partly isolated peaks or broken ridges. The change h undoubtedly been hastened not only by greater precipitation and glacial erosion in these areas, but al by the presence of numerous faults, running roughly from north-east to south-west, which hav offered full play to eroding influences and have given us a series of loch-filled valleys. The mo notable of these fault-lines is that of the Great Glen. Nevertheless, in spite of the much greater amou of erosion, the general level of the summits among the western mountains is very uniform and indicative of that of the original plateau from which they must have been derived.

The Scottish Highlands illustrate very well a point that was emphasised a long time ago by th late Professor J. E. Marr. In general, as upland surfaces recover from disturbances, they will tend develop systems of gentle slopes and to approach, as Dartmoor is doing, characteristic forms "subdued relief." Among the upper levels of our British mountain regions it is possible to see a larg proportion of land forms which are predominantly those of subdued relief. This implies that the forms must be of great age, for on account of the great hardness of the rocks, it must have taken a enormous time for the outlines to have "softened" in such an extreme manner. From arguments suc as these, it may be assumed that the general form of our mountain regions is often ancient, and th usually applies particularly to the positions of the main summits and the river valleys. Superimpose on these ancient features we have also features which are the result of comparatively recent agencie Foremost among these are the effects of ice and of glaciation.

Much British mountain scenery is that characteristic of a glaciated and ice-eroded country. Th there is a marked contrast with other regions will be at once apparent if one compares a typical Britis upland scene with one, for example, from the Grand Canyon of Colorado.

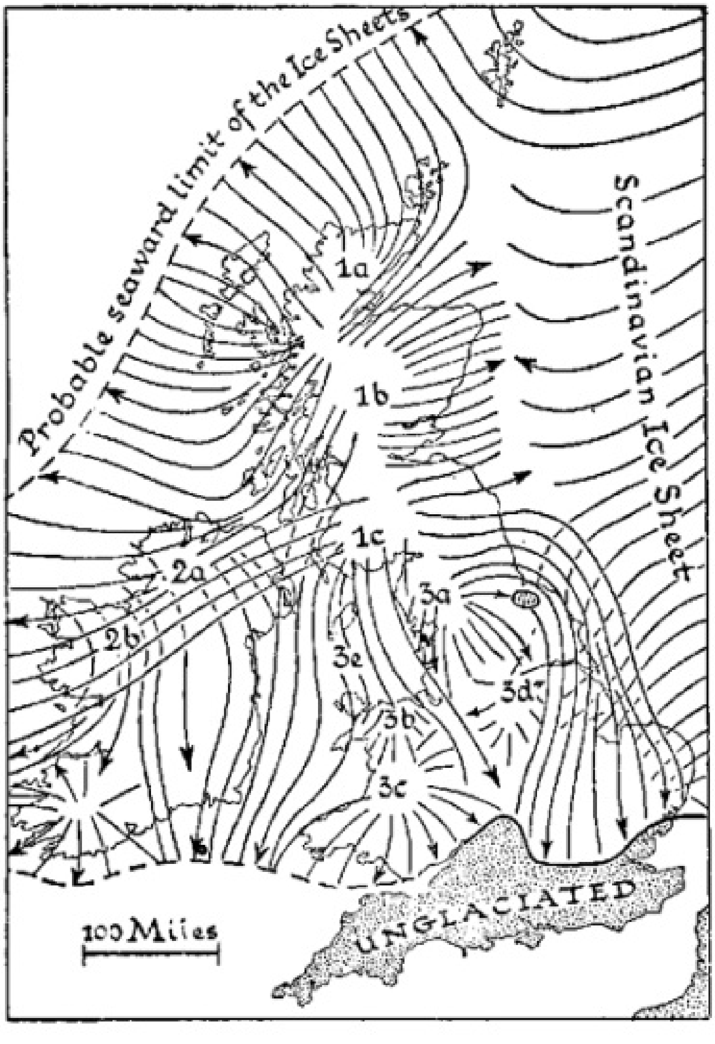

FIG. 7.—Ice movements in the British Isles. GLACIATION