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TYPES OF BRITISH VEGETATION

*BY MEMBERS OF THE CENTRAL COMMITTEE
FOR THE SURVEY AND STUDY OF
BRITISH VEGETATION*

EDITED BY

A. G. TANSLEY, M.A., F.L.S.

UNIVERSITY LECTURER ON BOTANY IN THE UNIVERSITY OF CAMBRIDGE

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TO
PROFESSOR EUGENIUS WARMING
THE FATHER OF MODERN PLANT ECOLOGY
AND TO
PROFESSOR CHARLES FLAHAULT
WHO THROUGH HIS PUPIL
ROBERT SMITH
INSPIRED THE BOTANICAL SURVEY OF THIS COUNTRY
THIS FIRST ATTEMPT
AT A SCIENTIFIC
DESCRIPTION OF BRITISH VEGETATION
IS DEDICATED
IN ALL GRATITUDE AND ADMIRATION
BY THE AUTHORS

St. Petersburg 1885-1886
C^a Oct. 1, 1923.

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PREFACE

THIS book offers an account of British vegetation from a standpoint which has not hitherto been adopted in any general treatment of the plant-life of this country. An endeavour is made to recognise and describe the different types of plant-community existing in the natural vegetation of these islands, and to trace their relations, so far as these have been elucidated, to climate and soil, and to one another—in other words to present a scientific classification and a balanced picture of British vegetation as it exists to-day.

The work of systematically surveying vegetation and recording the results on vegetation maps was begun in Scotland by the late Robert Smith in the closing years of last century, and continued by his brother, W. G. Smith, and various other workers. In 1904 these workers formed a committee, with the somewhat ponderous title of "The Central Committee for the Survey and Study of British Vegetation," to organise and facilitate work on these lines.

The memoirs and vegetation maps published by these workers, of which the titles will be found in the Bibliography on p. 367, have formed the nucleus of the material dealt with in the present book, which is thus a direct outcome of the work of the Central Committee. Its composition would have been impossible but for the

close co-operation secured by the existence of such an organisation. Since it was clearly out of the question for a committee as a whole actually to write a book, it was necessary for someone to undertake the task of correlating the contributions of various authors and securing uniformity of treatment. The editor undertook this task on the understanding that he should be allowed a free hand in editing the work of the authors, and this was in nearly every case most willingly accorded. The result of this loyal co-operation has been, it is hoped, to secure a consistent treatment of the whole subject. It is not to be expected that all the members of a large committee should agree in every detail, and each author is of course responsible only for his own contributions. The parts of the book to which authors' names are not attached have been written by the editor.

To the following gentlemen, not members of the committee, who have most kindly contributed sections or helped in other ways, the editor expresses his cordial thanks: to Professor Grenville Cole, F.R.S., of the Royal College of Science, Dublin, who contributed the section on the Soils of Ireland; to Professor G. S. West, of the University of Birmingham, who contributed the section on the British Freshwater Phyto-plankton; to Dr Horne, F.R.S., and Mr Crampton (the latter a member of the committee), of the Scottish Geological Survey, who revised the section on the Soils of Scotland; to Dr J. E. Marr, F.R.S., of the University of Cambridge, who read the proofs of the section on the Soils of England and Wales and contributed a paragraph on the East Anglian Heaths as representing a survival of steppe-conditions; to Dr Reginald Scully, of Dublin, who contributed the information on the vegetation of the Killarney woods; and to Mr J. A. Wheldon, of Liverpool, who kindly contributed

information on the bryophytic flora of the Lancashire sand dunes.

The following gentlemen, other than members of the committee, have very kindly contributed photographs: Messrs W. Ball, F. F. Blackman, C. J. P. Cave, R. H. Compton, F. H. Graveley, F. F. Laidlaw, S. Mangham, R. Welch, and A. Wilson.

The information on the distribution of crops is mainly taken from the official "Returns of the Board of Agriculture and Fisheries" and from the Agricultural Statistics of the Irish Department of Agriculture and Technical Education; to the officials of the Board the editor is indebted for most courteously given supplementary information, involving considerable trouble, with regard to changes in the area of wheat land.

The editor also desires to express his special indebtedness to his colleague, Dr C. E. Moss, who, besides contributing important sections of the book, has given constant help and advice throughout¹; and to Dr W. G. Smith, the Secretary of the Committee, who has read a considerable part of the proofs and contributed many valuable suggestions. The editor is indebted to his wife for undertaking the laborious task of constructing the general index.

The treatment adopted in Part II is first to give a general account of the various formations and associations recognised, with lists of species occurring in them. The plant-communities are then, in some cases, illustrated by descriptions of special instances.

¹ It is right also to mention that the concept of the plant-formation and of its relation to the association, which forms the logical basis on which the scheme of classification embodied in the book is constructed, owes its present form to Dr Moss. Cf. "The Fundamental Units of Vegetation," *New Phytologist*, Vol. ix. p. 18, 1910.

The imperfections of the book will be sufficiently obvious to the reader. Some are at present unavoidable owing to the unequal development of our knowledge of the vegetation of different parts of the British Isles. While some regions have been carefully explored and their vegetation analysed, others have been only "reconnoitred," and of others again, such as Wales and considerable parts of Ireland, the plant-communities, as distinct from the flora, are almost unknown.

Most of the continental work on plant-communities similar to or identical with British ones has been deliberately neglected. A serious attempt, which will eventually have to be made, to correlate British with continental plant-communities would have involved a task extending far beyond the immediate object in view.

The Bryophyta, and the lower plants generally, are, for the most part, mainly through want of knowledge, very inadequately treated, and in the case of many plant communities, ignored altogether. This is greatly to be regretted, since these plants are frequently of the first importance in differentiating plant-communities. The algal associations of the freshwater aquatic formation are scarcely touched upon.

In a book of this nature, involving the correlation of a great mass of unequally developed material from many sources, it is inevitable that there will be numerous errors and omissions. Great improvements will be possible in a second edition, especially having regard to the fact that the subject is advancing very rapidly; and the editor will be grateful for all criticisms and suggestions.

The treatment of the ecological effect of the different soils almost wholly lacks the basis which can only be afforded by careful quantitative analysis and comparison. Data of this kind are now being accumulated, but are not,

as yet, sufficiently extensive to be of use. It is believed, nevertheless, that the statements made about the relation of soils to the different types of vegetation, which are partly based on analysis and partly inferred, are essentially accurate, and afford a sound basis of classification. It is believed, in fact, that the classification of vegetation and the treatment of the genetic relations of plant-communities are in advance of anything hitherto attempted, though modifications are of course to be expected as knowledge advances.

The field of analytical and experimental ecology lies widely open to workers able and willing to devote themselves to the laborious tasks involved in the attack on the various problems underlying the phenomena of vegetation.

The chief obstacle to the rapid development of ecology on fundamental lines is the laborious and time-consuming nature of the work and the chemical and physical training required for its prosecution. It is hoped that this book will serve to call attention to many of the more immediate problems.

Nomenclature of specific names. The nomenclature of species and the order in which they are placed in the general lists for the most part follow the 10th edition of the London Catalogue (1908). To continental readers the adherence to the system of Bentham and Hooker will seem an anachronism, but the convenience of following a recognised standard list of British plants dictated this course.

Symbols denoting frequency. The symbols denoting the frequency of species in the general lists of the

composition of associations are as follows: d = dominant, ld = locally dominant, lsd = locally subdominant, a = abundant, la = locally abundant, f = frequent, o = occasional, r = rare, vr = very rare. It is to be understood of course that these symbols refer to frequency within each association as a whole, and have no reference to frequency in the country at large.

A. G. T.

GRANTCHESTER, CAMBRIDGE,
July, 1911.

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INTRODUCTION

THE UNITS OF VEGETATION—THEIR RELATIONSHIPS AND CLASSIFICATION

It has been well said by the distinguished plant-geographer Professor Drude of Dresden that plants may be studied in pure science from three points of view, and from three only:—the physiological, the phylogenetic and the geographical. Geographical Botany or Plant-geography may be defined as the study of the facts and causes of the distribution of plant-life over the surface of the earth.

When we consider the distribution of the plant-life of any given region or country, whether large or small, we find that it may be regarded from two distinct points of view. In the first place we may study the distribution of the species, and, in the case of the larger areas of the earth, the distribution of the genera and families of plants. The list of species, arranged taxonomically, is called the *flora* of the region or country, and the study of their distribution is *floristic* plant-geography.

But there is another way of regarding the distribution of plant-life. If we consider the general plant-covering or vegetation of any geographical region we find that it is naturally divided into units, each of which has a characteristic appearance or physiognomy and consists of characteristic species. These *vegetation-units* have been recognised from the earliest times, since not only do they form outstanding features of all landscapes, but man absolutely

Vegetation-
units or plant-
communities.

depends upon them in his primitive relations to nature. In their more obvious forms, therefore, the units of vegetation have common names in all languages, and these are everywhere preserved in the names of places. *Wood, moor, heath, marsh*, are some of the commonest and most obvious examples. Now it is to be observed that most of these names refer to something more than the vegetation alone. A moor is an area supporting certain kinds of plants, but it also implies the presence of a peat-soil on which those plants flourish. Heathland nearly always involves a relatively poor and dry soil. A marsh is an area where the soil is always wet. In other words a vegetation-unit is always developed in a *habitat* of definite characteristics.

To look at the matter from the opposite standpoint, synthetically instead of analytically, certain kinds of plants are always found associated together under definite conditions of life, and such groupings may be called *plant-communities*. A plant-community is simply a vegetation-unit regarded as an aggregation of species and individuals instead of as a division of the whole vegetation of the region. Whichever standpoint we adopt, the connexion with habitat is a fundamental part of the conception. This way of considering the distribution of plant-life is called *ecological plant-geography*, from the Greek *οἶκος*, a house (habitat), in contradistinction to the floristic plant-geography, referred to above, which is concerned primarily with the distribution of species.

Ecology includes more than the study of vegetation-units or plant-communities; it deals with the whole of the relations of individual plants to their habitats. This latter branch evidently cannot be sharply separated from physiology; and may in fact be justly considered as a part of that subject. It has been aptly called by Professor Schröter of Zurich *autecology*, to distinguish it from *synecology* or the study of plant-communities.

The present book attempts to describe the principal kinds of plant-communities or units of vegetation met with in the British Isles. During the last twelve years a great deal of work has been done in observing and describing these vegetation-units, and their relationships. The work is far from complete even in the matter of mere description, and this book necessarily carries many evidences of the incompleteness. Yet enough is known to justify the attempt at a preliminary sketch of the subject, which it is believed will interest botanists and lovers of nature, as well as students of scientific geography.

It may be said that we ought not to occupy ourselves with synecology till we have a complete or an approximately complete knowledge of autecology, but this is a mistaken notion. It might as reasonably be contended that we ought not to study the phenomena presented by the nations and races of men before we know all about the physiology and psychology of the individual man. As a matter of fact the study of synecology is considerably in advance of autecology (which is indeed still in a very backward state of development), and the progress made has amply justified the attention devoted to the wider though less fundamental branch of the subject. The plant-community, in fact, offers a convenient mode of approach to the study of plant-life in relation to habitat. The systematic description and classification of vegetation affords a natural framework in which autecological studies will find their proper place.

There has recently been a great deal of discussion as to the nomenclature of ecological phyto-geography or synecology, and nothing like general agreement yet exists as to the proper naming and classification of the different categories of vegetation-units or plant-communities. One of the main subjects of contention is the use of the term *plant-formation*, which we

**Nomenclature
and classifi-
cation of
vegetation-
units.**

originally owe to Grisebach¹. It is not intended to enter here into a discussion of this question, for which the literature must be consulted². The uses of the terms *plant-formation*, *plant-association* and *plant-society* in this book are those adopted by the Central Committee for the Survey and Study of British Vegetation. Whatever may be the ultimate fate of these terms it will be generally conceded that their consistent use in the description of the types of vegetation of a given region will afford a useful test of their appropriateness.

The plant-formation, the plant-association, and the plant-society.

THE PLANT-FORMATION

A plant-formation is the natural vegetation occupying a habitat with constant general characters which determine the communities of plants occurring in that habitat³.

The characters, or as they are often called the *ecological factors*, of the habitat, which influence vegetation, are often classed as *climatic* and *edaphic*.

Climatic factors are those primarily dependent on the climate of the region in which the plant-formation is developed, such as temperature, precipitation (i.e. rainfall, snowfall, dew, etc.), humidity of the air and wind.

¹ Grisebach, H. R. A., "Ueber den Einfluss des Klimas auf die Begränzung der natürlichen Floren." *Linnæa*, xii. 1838.

² See especially Schimper, A. F. W., *Pflanzengeographie auf physiologischer Grundlage*, Berlin, 1898 (English translation, *Plant Geography upon a Physiological Basis*, Oxford, 1903-4); Clements, F. E., *Research Methods in Ecology*, Lincoln, Neb., U.S.A., 1905; Warming, E., *The Ecology of Plants*, Oxford, 1909; Moss, C. E., "The Fundamental Units of Vegetation," *New Phytologist*, ix. 1910 (issued separately by the *New Phytologist*, Botany School, Cambridge); Ch. Flahault and C. Schröber, *Phytogeographical Nomenclature*, Zurich, 1910.

³ This of course is not a logical definition but only a preliminary description. The conception of a plant-formation, as understood in this book, can only be made fully clear by reference to the examples dealt with in Part II.

Edaphic factors, on the other hand, depend upon the features of the soil in which the plants grow, such as water-content, food-content, aeration, the presence and amount of humus and of certain minerals, acidity, and so on¹.

Not all the features of a habitat can be reckoned as effective ecological factors. Thus two soils, alike in many respects, may differ in others, such as the presence or amount of certain salts. But unless the differences have an actual effect on the vegetation they cannot be considered as ecological factors. Similarly one locality may have twice the rainfall of another, and yet the same type of soil may bear the same plant-formation in both.

The effective ecological factors which separate one formation from another we shall call the determining, differentiating or *master-factors*.

In the British Islands the most striking effect of climate is seen on the higher mountains. The various climatic factors involved in differences of altitude determine for instance a limit above which woodland does not extend; and the rock-vegetation near mountain summits is another effect, though partly an indirect effect, of increased altitude (see Chapter XIV). There is also a considerable difference in the climate of the eastern and western portions of Great Britain, and this is probably related to the prevalence of moors in the west as opposed to heaths in the east.

Characteristic but subordinate features of other plant-formations also depend on climate, for instance the abundance of ferns in the woods of the west and north as contrasted with their paucity in the east and south-east. Certain species of plants are confined to parts of the country characterised by a definite climate, and their absence elsewhere may often be due to climatic factors,

¹ It must be understood that nothing approaching a detailed treatment of ecological factors, and of their relations to one another, is possible in the present work.

though a strict determination of the various cases is lacking. But these phenomena, interesting as they are, do not count in the determination of the fundamental units of vegetation, the plant-formations, and we may fairly say that, on the whole, the plant-formations of the British Isles are *mainly* determined by edaphic factors, *i.e.* by soil.

Many plant-formations are easy to determine, because they are limited by quite obvious habitats to which very definite and characteristic plant-communities correspond. Such are for instance the two chief "maritime" formations, those of the sand dunes and of the salt marshes.

The moor-formations are also well characterised, if we take the word "moor" in its current German sense to apply to types of vegetation developed on deep peat¹. Two principal formations with essentially different plant-communities may be distinguished, that on peat relatively rich in mineral salts and neutral or alkaline in reaction—"fen" as it is called in this country (*Niedermoor* of Weber, *Flachmoor* of various authors)—contrasting strongly with the formation on peat poor in mineral salts and acid in reaction—the moor proper (*Hochmoor* of German writers). Whether we should distinguish a third formation—the "transition-moor" (*Uebergangsmoor*)—is open to question.

The vegetation of chalk and limestone, of the non-calcareous clays and loams, of the sands relatively rich in plant-foods, and of the sands and gravels relatively poor in plant-foods and developing an acid humus, fall into different plant-formations. Each of these types of soil bears vegetation with characteristic features and characteristic species of plants, though many of the species are common to several. There are however certain

¹ This use is not, however, in accord with the current use of the common English word "moor." For a discussion of the subject see Chapter IX.

superficial difficulties in determining the nature and limits of these formations, difficulties mainly due to human interference with natural vegetation.

In the days before the face of the country was changed by the activity of man woodland prevailed over practically the whole area of the types of soil mentioned, with the exception, probably, of parts of the first and last, *i.e.* of the chalk and limestone and of the poorer sands. At the

present day, cultivated crops, "permanent pasture" which has been "laid down" and plantations, occupy, of course, the greater portion of the country, but apart altogether from these the natural vegetation of each type of soil is actually varied. Besides woodland each type has a characteristic "scrub" or bushland, and a corresponding grassland or, in the case of many sands, a heathland.

These different types of plant-community on the same soil have no doubt originated mainly from the clearing of the original woodland and the pasturing of sheep and cattle. This prevents the regeneration of the woodland, and of most of the shrubs also, if the pasturing is sufficiently heavy and continuous, while it encourages the growth of grasses. Thus the plant-formation determined by the particular soil, and once represented by woodland, shows a series of phases of degeneration or retrogression from the original woodland, brought about by the activity of man. The intimate relationship of the various phases ||§ ~~are~~ clearly seen in the associated plants. The woodland proper has of course a ground vegetation consisting of characteristic shade plants, but the open places, and the "drives" or "rides" of the wood, are occupied by many of the species found among the scrub and in the grassland, while those true woodland plants which can endure exposure to bright light and the drier air outside the shelter of the trees often persist among the grasses of the open. In some cases where grassland is

not pastured the shrubs and trees of the formation recolonise the open land, and woodland is regenerated¹.

Besides these degenerative processes, due to human interference, there are others due to "natural" causes, which are for the most part little understood.

The natural process of the development of formations on new soils has also to be taken into consideration. The formation which is to occupy a new soil rarely springs into being fully constituted. It normally passes through a series of phases of development (primary succession), each phase exhibiting a definite *plant-association* (see below). Clements has given a very interesting account of this primary succession of associations (called by him "formations") in the case of several American formations; while the primary successions met with on sand-dunes, on salt-marshes, and on the borders of inland lakes where peat accumulates, have long been familiar to European plant-geographers. Clements² has shown that primary succession follows definite laws, and has pointed out that the pioneer species generally form an association in which but few species occur and which does not completely cover the soil (open association), while the succeeding associations are mixed in character and the final association is closed and often dominated by a single species, or by a few similar species.

Primary succession must take place universally where new land habitable by plants is formed, but in a country like our own, where geological changes are slow and insignificant, there is little opportunity for observing it

¹ This very brief summary of the relation of woodland, scrub and grassland or heathland omits all reference to complicating factors. Some of these are discussed under the different formations in Part II.

² *The Development and Structure of Vegetation*, Lincoln, Neb., U.S.A., 1904; *Research Methods in Ecology*, Lincoln, Neb., 1905. See also Moss, *op. cit.*

except on the sea-coast where new land is constantly being formed in certain places, on the edges of certain lakes where the land is gaining on the water, and to some extent on the talus of cliffs, and on the detritus of mountains.

The colonisation of waste ground, such as derelict building sites, of ballast heaps, etc., furnish, it is true, very interesting and instructive studies in the succession of plant-communities; but owing to the peculiar nature of the substratum in many of these cases, and also owing to the supply of seed available, these successions do not often lead to the establishment of communities belonging to the normal plant-formations of the country, and such land forms a battle-ground for aliens and casuals.

In the normal primary development of a formation, as in the retrogressive processes before mentioned, the associations involved show intimate relations and transitions one to another, and the whole set of associations has a definite flora dependent on the type of soil. It is for these reasons that we consider the entire set of plant-communities on a given type of soil, in the same geographical region, and under given climatic conditions, as belonging to one formation, in spite of the diversity of the dominant plant-forms in the different associations.

The plant-formation thus appears as the whole of the natural and semi-natural¹ plant-covering occupying a certain type of soil, characterised by definite plant-communities and a definite flora. The "wilder" formations, those less modified by man, for instance sand-dunes, salt-marshes, heaths and moors, are quite easily determined, but where human agency has been extensively at work, a careful study of the flora and vegetation and of their relations to the soil is needed before the formation can be accurately determined. In some cases we cannot as yet

¹ *i.e.* owing its present form to human activity though not planted by man.

decide with certainty, in others we may never be able to decide, where to draw the limits of the original formations. For instance, much of our heathland is undoubtedly degenerate forest, but in other cases it is probably primitive, existing on soil which does not naturally bear woodland at all. Let us suppose that a tract of primitive heathland (which must be counted as a separate formation) adjoined a tract of woodland on a light sandy soil. If the woodland is extensively cleared the heath community will undoubtedly invade its area, and the original limits of the two formations will be obliterated. The same is true of chalk pasture. There is evidence that some of our chalk downs are primitive grassland, that is, were never covered by forest; but there are many tracts of chalk pasture which certainly occupy the sites of old beech and ash woods that have disappeared under the axe or from other causes. It is difficult or impossible in the present state of our knowledge to draw the limit between the two cases, which may be represented by identical associations.

When habitats and their corresponding plant-communities are separated by characters less important than the master-factors determining formations, the term *sub-formation* is employed to designate a division of a formation, based on these less important factors. A sub-formation however exhibits the same features (of succession etc.) as a formation and is to be distinguished carefully from an association.

THE PLANT-ASSOCIATION

The plant-association is the vegetation-unit next below the plant-formation. Plant-associations are in general the most obvious plant-communities that we recognise in the field. Thus each of the types of vegetation, woodland, scrub and grassland, *within a given formation*, is a plant-association, and so is each definite phase in the primary development of a formation.

The highest type of association within a formation (often woodland), to which development tends, is called the *chief association* of the formation. In the absence of disturbing factors, such as the interference of man, landslips, and so on, the chief association will ultimately occupy the natural formation-area to the exclusion of the other associations, which may be collectively designated *subordinate associations*¹. But other associations may attain to a considerable degree of stability as the result of an interference with the normal course of development, even apart from continuous human interference.

In some cases smaller differences of habitat, of scarcely sufficient importance to warrant the recognition of distinct associations, may nevertheless bring about certain changes in the vegetation. Communities thus differentiated may be called *sub-associations*. In other cases where there is no definite segregation of distinct communities, but the vegetation varies in character, we may speak of different *facies* of the association.

A plant-association, especially a chief or other stable association, is generally dominated by a single social species (*e.g.* in many woodland associations), or by several social species of the same or similar plant form, as in grassland. These *dominant species* determine the physiognomy of the association and largely also (by their habit and mode of growth, by the protection they afford, the shade they cast, and so on) the *associated species* found among or beneath them².

¹ Moss, "The Fundamental Units of Vegetation," *New Phyt.* Vol. ix. p. 38.

² The technical name of an association is formed by the addition of the suffix *-etum* to the stem of the generic name of the dominant species, followed by the specific name in the genitive. Thus a wood dominated by the pedunculate oak is a *Quercetum Roburis*, a name which is really an

The association has a very definite and usually a much more restricted flora than the formation, largely owing in the case of closed associations to the special conditions determined by the dominants. Transitions between different associations of the same formation are constantly met with, and in these a mixture of both vegetation and flora occurs, a fact which serves to knit the various associations together and to emphasise the unity of the formation to which they belong.

THE PLANT-SOCIETY

Locally within an association there occur more or less definite aggregations of characteristic species or of small groups of species, and these, which appear as features within the association, may be recognised as smaller vegetation-units or *plant-societies*. Sometimes their occurrence may be due to local variations of the habitat, at other times to accident and the gregarious habit originating from a general scattering of seed in one place or from the social growth of a rhizomic plant¹. While a plant-formation is always made up of associations, an association is not necessarily or even generally made up of societies, which are essentially local discontinuous phenomena.

Thus of the three orders of vegetation-unit or plant-community which we recognise, the largest, the formation, is absolutely determined by habitat. Transitions between

abbreviation of *Quercetum Querci Robur*. A qualifying adjective is sometimes tentatively added.

¹ It is a question whether it would not be better to separate these two causes of the formation of societies within an association, and to restrict the term society to the aggregations due to the latter alone. In this way we should obtain a more logically coherent conception. But the more detailed analysis of vegetation has scarcely progressed far enough at present to justify a finer classification of plant-communities.

formations are found only where intermediate habitats occur, and are, on the whole, rare and restricted in area, because the great habitats depending on soil are essentially distinct units, except in those cases in which a fundamental and progressive change in the habitat is going on, *e.g.* in the gradual conversion of an aquatic into a terrestrial habitat. In such cases we have to recognise the gradual supplanting of one habitat by another. Man has, in general, no power to change the formation, except by changing the whole character of the habitat, *e.g.* by draining marsh land, or by substituting planted crops for the natural vegetation.

The association, on the other hand, is determined by minor differences of habitat or by the course of succession, and is often completely changed when human interference takes place. Transitions between associations are very frequent, owing to the gradual nature of progressive and retrogressive changes, and to the variation from place to place of the minor features of the habitat.

Finally, plant-societies are minor features of vegetation, and their presence in certain spots is generally determined by some biological peculiarity of a species, not by the habitat as such.

The classification of the units of vegetation here adopted cuts across the superficial classification based on plant-form, physiognomy, or mere topography. Thus we do not divide vegetation into groups of tree-formations, shrub-formations and herb-formations, because species belonging to all these plant-forms, and associations dominated by these species, actually occur in one and the same general type of habitat.

Habitat must be the basis of any natural classification of vegetation because it is on similarities and differences of habitat that vegetation ultimately depends. It is true that plant-forms have an important relation to habitat,

a relation which depends on the phenomenon of adaptation, but it is not true that plant-form runs everywhere *pari passu* with habitat. The net of adaptation is not so close-meshed, nor is it drawn so closely round the manifold of organic form, as to bring about a rigidly exact correspondence of this kind. In broad outline the correspondence exists, and we may classify the sum-total of the plant-formations of the world by the plant-form of the dominant species of their chief associations. Such a classification is the expression of the fundamental climatic zonation of the world and of the great mountain complexes.

But a classification of this kind lies outside the scope of a book devoted to the vegetation of a comparatively small country. Our primary task in the present work is to determine the formations themselves, and if we used plant-form as the basis we should associate units of vegetation which are naturally distinct, and divorce others which are naturally associated. Thus we should bring together all deciduous tree-associations in this country and separate them from the naturally related grass- or heath-associations. Such a classification would be quite barren, leading nowhere, because it would ignore habitat.

PART I

THE CONDITIONS OF VEGETATION IN THE BRITISH ISLES

CHAPTER I

THE PHYSICAL CHARACTERS AND CLIMATE OF THE BRITISH ISLANDS

THE British Islands stand on the "continental shelf" of north-western Europe. The depth of the seas (English Channel and North Sea) separating them from the neighbouring countries of the Continent nowhere reaches 200 metres and very rarely exceeds 100 metres. On the west of Scotland and Ireland the floor of the Atlantic Ocean slopes rapidly down to a depth of 2000 metres and in the course of a few hundred miles depths of over 4000 metres are reached.

Thus the British Isles are physiographically simply a slightly detached part of north-western Europe, and their separation took place in very recent geological times. This fact is reflected in the flora, which is for the most part identical with that of the adjacent parts of the continent from which it is derived.

Floristically the British Isles are comparatively poor, for many continental species fail to reach them, and they

**Similarity of
flora and
vegetation to
that of the
Continent.**

have few, if any, endemic species¹. Their isolation has not been sufficiently prolonged nor are their climatic conditions sufficiently distinct for the evolution of a distinctive flora. The most interesting floristic groups are certain species confined to the east and south-east, which are mid-European forms not found in northern Europe; the "arctic-alpine" species of the Scottish mountains, of which a few occur also on the mountains of northern England, North Wales and Ireland; the species confined to Ireland and south-west England, some of which are found in western France, while others (notably *Arbutus Unedo*) are Iberian or Mediterranean plants; and finally a small group of American species found in Ireland. It will be seen that all these groups are simply extensions (occasionally discontinuous extensions) of continental floras to the nearest parts of the British Isles. Into the question of their mode of migration we cannot enter here.

With regard to vegetation too, it is doubtful if we have any plant-formations unrepresented on the Continent, though it is impossible to be certain till a more systematic comparison has been made.

In spite of their comparatively small size the British Isles show a considerable variety of physio-
Geology and graphical features corresponding with the
orography. very extensive series of geological formations represented.

Considering the island of Great Britain (Scotland, England and Wales) alone it may be said that the older and harder (Palæozoic and metamorphic) rocks, forming

¹ *i.e.* species in the aggregate sense; in the last (10th) edition (1908) of *The London Catalogue of British Plants* there are however about 30 species and 100 varieties of flowering-plants and ferns, exclusive of the genera *Rubus* and *Hieracium*, described by modern British systematists and not recorded from other countries. Besides these there are about 30 "endemic" *Rubi* and 70 "endemic" (mainly arctic-alpine) *Hieracia*.

by far the greatest bulk of the high land and all the hills over 1500 feet (c. 500 metres) in height, occupy the northern and western part of the country, while the midland, southern and eastern portions are composed of the newer and softer (Mesozoic or Secondary, Tertiary, post-Tertiary and Recent) deposits, which form flat or undulating plains broken only by comparatively low hills (Figs. 1 and 2).

If we draw a straight line from Hartlepool on the Durham coast of the North Sea southwards to Leicester, and another from Leicester south-westwards to the Dorsetshire coast of the English Channel we find that the country lying to the west of these lines is very largely composed of Palæozoic rocks, that about three-quarters of it has an elevation of over 500 feet (c. 150 metres), while practically the whole of the Scottish "Highlands," forming more than one-sixth of the total area, considerable regions of the "Southern Uplands" of Scotland, of northern England, of North Wales, and small areas in south-western England reach a height of over 1500 feet (c. 460 metres).

Elevations of more than 2500 feet (c. 760 metres) are rare except in the Scottish Highlands, where there is one considerable *massif* (the Cairngorm group in Perthshire) which has an extensive area exceeding that altitude, while there are several summits reaching above the same level in the Southern Uplands, in northern England and in North Wales.

The highest altitudes attained are Ben Nevis (4406 ft. = 1343 m.) in the Western Highlands, Ben Macdhui (4296 ft. = 1309 m.) and Braeriach (4248 ft. = 1294 m.) in the Cairngorm group, Ben Lawers (3984 ft. = 1214 m.) in the Central Highlands, and many other Highland peaks over 3000 feet; Snowdon (3560 ft. = 1084 m.) and Scafell Pike (3210 ft. = 978 m.) in North Wales and the Lake District respectively (both districts possessing several

FIG. 1. The British Isles: showing the distribution of Archæan and Palæozoic (harder) rocks (unshaded), and Secondary, Tertiary and post-Tertiary (softer) rocks (shaded). Glacial deposits are ignored.

Comparison with Fig. 2 shows that the great mass of the ground over 500 feet and all of that over 1500 feet is formed of the older rocks.

FIG. 2. The British Isles: showing the distribution of high ground. Below 500 feet (unshaded); between 500 and 1500 feet (diagonally shaded); between 1500 and 2500 feet (cross-hatched); above 2500 feet (black). The extent of high ground has been somewhat exaggerated owing to smallness of scale; not all the isolated summits above 2500 feet are indicated.

other peaks above 2000 ft.); several hills in the Pennine range over 2000 feet; and High Wilhays on Dartmoor in Devon (2039 ft. = 621 m.).

To the east of the imaginary line mentioned the contrast is extremely striking. Palæozoic rocks are not represented at the surface, the gently undulating plains are broken by comparatively few ranges of hills exceeding 500 feet (c. 150 m.) in height; only the Cleveland *massif* in north Yorkshire exceeds 1000 feet (c. 305 m.), and there are no elevations reaching 1500 feet (c. 460 m.).

Ireland, which is mainly composed of Palæozoic rocks, has its hilly regions in the north, west and south, enclosing an extensive central plain of an elevation less than 500 feet. The highest altitudes are found in Macgillicuddy's Reeks (3414 ft. = 1040 m.) in the south-west, but there are several other mountains exceeding 2000 feet (610 m.).

The mild "oceanic" climate of the whole of the British Islands is determined in the first place by the great length of coast-line compared with the total area, and the consequent general dampness of the air, which tends to lower the temperature in summer and to raise it in winter. This effect is of course a direct function of proximity to the sea, as can be seen very strikingly by an examination of maps recording the mean maximum temperatures for January and the mean minimum temperatures for July. The lines indicating equal values are in both cases concentric about the land masses¹.

The second great factor is the direction and character of the prevailing winds. Owing to the nearly constant position throughout the year of the north-Atlantic area of low barometric pressure, in the neighbourhood of Iceland, the prevalent winds during the whole year are from the south-west, *i.e.* they are warm moisture-laden winds coming from the warm regions of the mid-Atlantic and

¹ Bartholomew's *Physical Atlas*, Part III. *Meteorology*, 1899, p. 11.

traversing a great extent of ocean. These winds, impinging on the colder elevated land of the west coasts, are diverted upwards into colder strata of air, forming dense mists and clouds and leading to considerable rainfall on the western slopes and summits of the hills.

Thus much of the west coast of Great Britain, most of the Scottish Highlands and Southern Uplands, and most of western Ireland receive between 40 and 60 inches (*c.* 1000 to 1500 mm.) of rain *per annum*, while there are large areas in the western Highlands, in Wales, and in south-west Ireland, and smaller ones in the Southern Uplands and the Cumbrian mountains, which have a rainfall of over 60 inches (*c.* 1500 mm.). Considerable areas in the western Highlands, and smaller patches in most of the other regions mentioned, receive more than 80 inches (*c.* 2000 mm.), while the annual rainfall in particular stations reaches very high figures. Thus Seathwaite in Cumberland has 177 inches (*c.* 4500 mm.), the highest record in Europe, while Ben Nevis in the western Highlands has 151 inches (*c.* 3835 mm.).

On the eastern side of the mountains the air descends again to lower and warmer levels, and the annual rainfall rapidly falls off. The central plain of England, much of the south-east, a narrow strip of land running along the north-east coast as far as the Firth of Tay, and other strips bordering the Moray and Pentland Firths, have a rainfall between 25 and 30 inches (*c.* 625 to *c.* 750 mm.). Thus Brighton has 28·33 inches, Birmingham 26·54, Newcastle 27·81 inches, St Andrews 28·45 inches. Finally the Fenland extending inland from the estuary of the Wash, as well as adjoining country to the north and south, a strip of east Essex and south-east Suffolk north of the Thames estuary, and various small strips further north along the eastern coast of Great Britain, have an annual rainfall below 25 inches. The lowest recorded

Spatial distribution of rainfall.

FIG. 3. Distribution of mean annual rainfall in the British Isles.

means are 19·1 inches (485 mm.) at Spurn Head on the Yorkshire coast, 20·6 inches (523 mm.) at Shoeburyness on the Essex coast, 22·4 inches (569 mm.) at Ely, etc. These areas of lowest rainfall all lie on flat eastern coastlands and the immediately adjoining flat country (Fig. 3).

Seasonal distribution of rainfall. The seasonal distribution of rainfall in the British Isles shows no very marked features, the rain in all stations being fairly well distributed between the different seasons. The autumn months (September, October and November) are the rainiest months over most of the country. In the mountainous regions of the west however the heaviest rainfall occurs in the winter months (December, January and February). The driest months are February and March in many parts of the east, April and May over most of the country and June in the east of Ireland, south-west England and some parts of eastern Scotland.

Throughout the year the climate of the country is characterised by the very frequent passage of a series of barometrical depressions of mild cyclonic type, mostly coming from the west, and the anticyclonic periods of dry weather are comparatively few and quite uncertain in occurrence.

Sunshine, cloud and mist. Cloud and mist are very prevalent. An examination of a sunshine or cloudiness map of Europe shows at once the deficiency of mean annual sunshine in the British Isles as compared with western Europe generally. Only the south, and parts of the east and south-west, coasts receive more than 1500 hours of bright sunshine per annum, while nearly the whole of France and much of central Europe receives more than 1750 hours per annum. Nearly the whole of Scotland and parts of England and Ireland get less than 1250 hours in the year, an amount exceeded everywhere else in Europe except in Scandinavia. In May nearly the whole of the British Isles receives less

than 200 hours in the month, while western Europe generally, except Denmark and Scandinavia, receives more than 200. A comparison of these figures with those of rainfall shows that the British Isles as a whole are considerably cloudier in proportion to their rainfall than is the case in most of western Europe.

The effect of the warm south-west winds on the islands as a whole, and especially on the west coasts, is also well seen in the distribution of the isotherms (lines of equal temperature), especially during the winter months (Fig. 4). The course of the January isotherm of 5° C. (41° F.) is particularly instructive. This isotherm, which has a mainly east and west direction through southern Europe, turns northwards in south-western France, crosses the English Channel, bending north-westwards to the Dorsetshire coast, continues into South Wales, pursues a northerly course to a point between the Isle of Man and the Scottish coast, makes a great bend to the south-westwards including the whole of central and north-eastern Ireland, and then returns to the islands off the western Scottish coast, through which it runs due north into the northern seas.

Thus the whole of south-western England, the western coasts of Wales, the whole of southern and western Ireland and the western islands of Scotland have a mean January temperature as high as that of western and parts of southern France, while Cornwall and the extreme south-west of Ireland has a mean January temperature as high as that of the Mediterranean coast of Provence (Riviera). It is this fact of course that accounts for the successful cultivation in the open air of many Mediterranean and subtropical plants, particularly of many evergreens, in these parts of the country, and probably also for the occurrence of *Arbutus Unedo* in the Killarney woods. Many native herbaceous plants too,

**Distribution
of tempera-
ture. Winter
isotherms.**

FIG. 4. Course of January isotherms in western Europe, showing the influence of the warm air current from the Atlantic on the western coasts. Data taken from Bartholomew's *Physical Atlas*, Part III. *Meteorology*, 1899.

whose sub-aerial parts disappear during the winter in other parts of the country, commonly flourish during the whole winter in the south-west. Frost and snow are rare in these regions, and in some places almost unknown. On the other hand a considerable portion of eastern England and of eastern Scotland have a mean January temperature of less than $3\cdot3^{\circ}\text{C.}$ (36°F.).

The summer temperatures show a very different distribution. The south and east of England have the warmest summers, the July isotherms above $16\cdot5^{\circ}\text{C.}$ ($61\cdot5^{\circ}\text{F.}$) showing a concentric arrangement round an area of mean maximum of nearly 18°C. (64°F.) situated in the neighbourhood of London, *i.e.* about the centre of south-eastern England. Kew Gardens lies within the small area of maximum summer temperature, and it is here that many flowers and fruits requiring a comparatively high summer temperature can be brought to the greatest perfection. The lower July isotherms—east and west in general direction—bend very sharply northwards over the land both in England and Ireland, and correspondingly southwards as they approach the North Sea, the Irish Sea and the Atlantic Ocean, showing precisely the opposite behaviour in this respect to that exhibited by the January isotherms. The temperature falls off steadily northwards, the northern Hebrides showing a mean temperature of $12\cdot78^{\circ}\text{C.}$ (55°F.), which gives a mean range between January and July of only $7\cdot8^{\circ}\text{C.}$ (14°F.) as opposed to a range of $14\cdot5^{\circ}\text{C.}$ (26°F.) in London.

The general features of the climate of the British Isles may be summed up by saying that while the general type of climate is “insular,” *i.e.* showing in a marked degree the moderating effect both on summer heat and on winter cold of the close proximity of the sea, this effect is far more marked on the western coasts, which are also very much wetter

**Summer
isotherms.**

**Summary of
climate.**

than the eastern and central portions of the country. The east central district of England (say from London northwards to the Wash) shows the nearest approach to a continental climate: the lowest rainfall, the hottest summers and the coldest winters.

Some of the general effects of the geographical variation of the British climate on vegetation in relation to temperature have already been alluded to. With regard to rainfall one general effect on the distribution of plant-formations is the prevalence of moors dominated by various peat-forming species of Cyperaceæ, such as cotton grass (*Eriophorum*), and *Scirpus cæspitosus* (as well as the "grass moors" dominated by *Molinia cærulea*, *Juncus squarrosus* and *Nardus stricta*), on the western side of the country, and their absence in the regions of low rainfall on the eastern side, where deep peat is only formed under special edaphic conditions. On the other hand heaths on shallow, dry, peaty soils, dominated by the common ling (*Calluna vulgaris*), are commonest in the regions of lower and medium rainfall in the centre, south and east.

The agricultural effects are equally marked. The mild climate of the British Isles with its comparatively cool summers and well distributed rainfall is particularly well suited to grass, and indeed the country is deservedly famous for the richness and beauty of its pastures. A direct result of this is the flourishing condition of the pastoral industries, and the fine quality of the British beef and mutton. The damper climate and milder winters of western England and Ireland are the best suited to grass growing, and it is here as well as in the western midlands and parts of the north that the bulk of the pasture is found, and the cattle-raising industry particularly flourishes. In several of the western and midland counties there are more than twenty head of

Effects of
climate: on
distribution
of plant-
formations.

Grassland.

cattle and in Ireland twenty-three to the hundred acres of land of all kinds.

The great sheep-regions are the hillside pastures, such as the Southern Uplands of Scotland, the hillsides of Wales and the Chalk Downs of southern England. In these areas there are from 50 to 100 sheep to every hundred acres of land.

In some of the midland and western midland counties, such as Leicestershire, Warwickshire, Shropshire, Worcestershire and Gloucestershire, the area of permanent pasture exceeds half the total area of the county, and is more than double the total area of arable land. In Somerset the permanent pasture occupies about two-thirds of the area of the county and is more than four times the area of arable land.

These figures contrast very strikingly with those for the eastern counties, *e.g.* Cambridgeshire, where the proportions are reversed, the arable land exceeding two-thirds of the whole area and being more than three times that of the permanent pasture¹. In Norfolk, Suffolk, Essex, Huntingdonshire, and Lincolnshire the area of arable land exceeds, and sometimes considerably exceeds, half of the total area of the county, while it approaches or exceeds twice the area of permanent grass.

This eastern district with the large proportion of arable land is also the region where most wheat is grown, the area under wheat in any given year varying from one-sixth to one-quarter of the total area under arable crops. Eight of these eastern counties including Lincolnshire provide about 42 per cent. of the total wheat area of Great Britain, while the total of

¹ If the small patches of permanent pasture round the villages, which it is necessary to maintain for the grazing of farm animals and of cows for the local supply of milk, etc., were subtracted, the total would be very greatly reduced.

their land areas is only 11 or 12 per cent. of the whole island.

Considerably more than half the rest of the wheat area, *i.e.* about 33 per cent. of the whole, is found in the eastern midland, the western midland and the south-eastern groups of counties, whose total land areas make up between 19 and 20 per cent. of the land area of the island. Here again the average area under wheat in a given year is about one-sixth or one-fifth of the total area under arable crops, but, as already pointed out, the total arable area is very much smaller proportionally than in the eastern counties. A great deal more wheat used to be grown in the midland and south-eastern counties, but with the great decline in prices which occurred between 1875 and 1895 this region suffered a more severe reduction in its wheat area, as in its total arable area, than the eastern counties¹. Though not perhaps quite so favourable for wheat, the climate of much of this region does not differ very markedly from that of the eastern counties. The midlands, however, contain a large proportion of heavy clay land, and this "strong soil" though quite good for wheat, and at one time considered as typical wheatland, requires a great deal of labour and does not pay to plough when the price of wheat is low. Consequently much of this land has been gradually laid down to permanent pasture.

Of the 25 per cent. of wheatland remaining to be accounted for the bulk occurs in the north and south-west of England, while the west and north of Scotland show areas which are practically negligible, the Orkneys, and Shetlands, Caithness and Sutherland (extreme north),

¹ The decrease in the area under wheat between 1875 and 1895, which was 42·75 per cent. in the eastern and 52·56 per cent. in the north-eastern counties, was nearly 60 per cent. in the south-east and over 60 per cent. in the midlands, though the wheat area was much smaller in the latter regions than in the former at the beginning of this period.

Argyll and Bute (extreme west), as well as some of the counties situated in the Southern Uplands, growing no wheat at all. According to W. G. Smith¹ "wheat ceases to be a regular crop of the farm at an altitude where the mean July temperature is below 56° F. [13·3° C.] and the rainfall exceeds 32 to 34 inches (about 800 to 850 mm.) per annum."

The total amount of wheat grown in Ireland is insignificant, but the province of Leinster, containing the driest part of the country and having the warmest summers, possesses the largest acreage.

It is thus seen very clearly that most of the British wheat is grown in the regions of low rainfall and comparatively warm summers, while the regions of high rainfall and the coolest summers grow no wheat at all.

Barley, of which the total British acreage is now rather below that of wheat, is not so dependent on climatic conditions, but a large proportion is grown in the wheat-producing counties of England, though Wales and the east of Scotland have a good deal more barley than wheat, and no Scottish county shows absolutely none.

Oats, the third great cereal crop, mature well in far damper and cooler summers than either wheat or barley. In some recent years the acreage in Great Britain has been nearly double that of wheat, but in 1909, owing to a considerable increase in the wheat area and a slight decrease in the area under oats, the proportion was not quite so high. The distribution of the crop is very different. While the eastern counties grow considerable quantities of oats, the acreage is well below that of either barley or wheat. In the south-west, on the other hand, the acreage under oats approximately equals that under wheat and barley together, while in the north-west it is

Other
cereals.

¹ W. G. Smith, 1904, p. 627.

nearly three times as great. In Wales and south-eastern Scotland it is nearly twice as great, in eastern and central Scotland it is more than three times as great, while in northern and western Scotland the oats crop, though absolutely smaller than in the east and centre, is the only important cereal crop. Its limits are only fixed at the higher altitudes in the north by the early autumn frosts, which kill the plant before the grain is mature.

In Ireland the crop of oats enormously exceeds all the other cereal crops put together. The Irish acreage under potatoes is also very large, greatly exceeding the acreage of all the cereals together, except oats.

The rye crop is quite insignificant compared with the other cereals, though a little is grown in nearly every county except those of the extreme north of Scotland.

CHAPTER II

THE SOILS OF THE BRITISH ISLES

THE geological structure of the British Isles and particularly of England, is extremely varied, practically all the great geological formations being represented. The soils derived from these rocks are of course likewise very various, but for practical purposes, so far as they determine vegetation, they may be divided into comparatively few categories, according to their outstanding physical and chemical characters. Thus geological formations of widely different ^{Walcot} ~~scale~~, and often differing also in lithological constitution, weather to form soils of the same essential physical and chemical type, bearing the same kind of vegetation.

The main types of soil and their general characters are well known, but a short summary may be given here.

1. *Sand*. The typical sand is composed of relatively coarse particles of silica more or less mixed with other constituents. It is derived either from a recently formed loose sandy deposit that has never been consolidated, of which an extreme case is the blown sand of the sea-coast and of some inland regions, or from a coarse-grained sandstone, or from a crystalline rock, such as granite, containing much quartz. Sand forms an open light soil, little retentive of water. It is typically poor in lime,

though calcareous sands occur. Where surface-moisture accumulates, *e.g.* owing to the occupation of certain kinds of vegetation, acid peaty humus is formed, apparently largely owing to the deficiency of lime. Very fine-grained sandstones weather to a soil indistinguishable physically from clay, and bearing the same kind of vegetation.

2. *Loam.* This is formed of a mixture of sand and clay and results from the weathering of impure sandstones and similar rocks and from mixed alluvial deposits. It is more retentive of water than the purer sands, and where a fair proportion of lime is present forms the best agricultural soils.

3. *Clay.* The purer clays are mainly formed of hydrated aluminium silicate, are typically fine-grained, and very retentive of moisture. They crack when dry and form close heavy soils. Clay deposits, bearing typical clay soils, form the "rock" of much of the midlands of England. When clay is very deficient in lime it may, like sand, if kept wet, accumulate an acid peaty humus.

4. *Siliceous soils of the older rocks.* The older, non-calcareous rocks, which have become indurated and compacted by pressure, though composed of the same lithological constituents as the more recent sediments, often yield soils which have somewhat different characters from those of the newer sediments. Though technically they may be classified into sands, loams and clays, according as the particles are mainly coarse, a mixture of coarse and fine, or mainly fine, yet they often differ in respect of the vegetation they bear from the soils produced by more recent deposits. This is true of the majority of the Palæozoic and also of the metamorphic and igneous rocks. Thus the older Palæozoic shales and slates, which correspond lithologically with the more modern clays, do not bear the same vegetation as the clays, and the same may be said of the quartzites and many of the older sandstones and grits, which correspond

with the newer sands and friable sandstones. One feature in which these old rocks generally differ from the newer is that the soils they form are on the whole shallower, owing to the greater resistance to disintegration of the harder rocks, and this certainly affects the vegetation in an important manner. But we are still very ignorant of the effects of these soils upon plants, and a great deal of work is required before we shall be in a position to formulate a scientific classification of soils in their relations to vegetation.

The problem is also complicated by the fact that the older rocks are exclusively developed in the north and west of the British Isles, where the climate differs decidedly, as we have seen, from that of the south and east, and we cannot as yet present a satisfactory analysis of the factors due to climate as it affects the vegetation, not only directly, but through the soils. The combination of soils very poor in lime with high atmospheric humidity undoubtedly leads to the marked acidity which is so characteristic a feature of many of the soils of the north and west and has a most important influence in determining the vegetation. The natural drainage channels become clogged with mosses, impeding free drainage and tending to keep the soil constantly damp, while aeration is hindered, and acid peaty humus accumulates.

5. *Calcareous soils*, i.e. soils containing a fairly large proportion of lime, are mainly derived from limestones, calcareous sandstones, and highly calcareous marls¹. They are mostly light open soils, except in the case of the heavier marls, but become sticky when wet, somewhat like clay. The influence of lime on the soil is certainly very great, though its effect upon vegetation and its relation to other factors are still very obscure.

¹ Marl is properly a mixture of clay and lime, but the term is sometimes loosely used in geology for ferruginous clays which may contain very little lime, e.g. the Keuper marl and other Triassic marls.

Calcareous soils accumulate "mild" as opposed to acid humus. Calcareous loams and marls are very favourable for agriculture; the lime is said to cause the clay particles to flocculate and thus makes the soil lighter and more open.

Very shallow-soiled limestones possess a characteristic dry soil, supporting a characteristic grass-vegetation.

6. *Organic soils* derived from plant-remains are of various types and differ very much in their effect on vegetation:—

(a) *Mild humus* such as is normally found on the floor of woods, and in meadows, has a neutral or alkaline reaction, and is well aerated by earthworms, etc.

(b) *Mild peat*. When there is excess of water, as on the margins of lakes, and a deficiency of oxygen, but lime and other bases are present in quantity, the humus accumulates and forms a purely organic soil or peat, whose water gives an alkaline reaction. This peat may reach a great depth and is the characteristic "black soil" of the fens (see p. 211).

(c) *Acid humus* is formed on soils deficient in lime, where the surface is moderately damp and oxidation is deficient.

(d) *Acid peat*. Under certain conditions of moisture and deficiency of oxygen, acid humus accumulates so that a pure peat soil is produced, and if the conditions are maintained this acid peat soil may reach a great depth, giving the characteristic "moor" soil (in the narrower sense, Chapter IX) and supporting the characteristic moor plants¹.

¹ The distinction here given between "mild" and "acid" humus and peat corresponds to a difference well known to agriculturalists, and having a most important effect on vegetation. It is not by any means certain however that the acid and alkaline reactions of the soil water which is found in extreme cases is the really important differentiating factor of the two classes of habitat. The researches of Van Bemmelen and the recent

7. *Salty soils* containing a considerable percentage of sodium chloride (common salt) or certain other soluble mineral salts, are very unfavourable for the majority of plants. They are characteristically inhabited by a special ecological class of plants—the *halophytes*. In this country they occur mainly in the mud flats of tidal estuaries which are covered by the high spring tides. Sand in immediate proximity to the sea, and spray-washed cliffs, are also often impregnated with salt and bear a halophilous vegetation.

8. *Rock*, *i.e.* hard rock not covered by loose earth, can hardly be called a soil in the ordinary sense. Where it forms horizontal or comparatively slightly inclined surface, the products of weathering, largely through the agency of lichens, mosses and algæ, quickly cover it with soil in most cases, but vertical or very steep rock faces which cannot hold soil are inhabited only by these plants, which can adhere to the bare rock face, and by an occasional higher plant which has succeeded in colonising a small thin patch of soil formed by a lichen or alga. Rock clefts in which soil accumulates often have a special vegetation of their own. The vegetation of rocks is influenced very much by the chemical and physical constitution of the rock, and also by such factors as available moisture, exposure, etc.

The talus of cliffs and rocks and “mountain top detritus” (p. 302) form other classes of substratum allied

work of Baumann (*Mitteil. d. bayrischen Moorkulturanstalt*, 1909 and 1910) has shown that humus is to be regarded as a colloid complex, and that its properties are determined by the special laws governing the behaviour of colloids to other bodies. The old conceptions of “humins” and “humic acid” do not, apparently, correspond with real chemical bodies, and the most important character of humus in relation to other chemical substances in the soil and to plants is whether it is “absorptively saturated” (mild humus) or “unsaturated” (acid humus). On these lines we may expect a real increase in our knowledge of the all-important relations of humus to plant life, a subject which has hitherto been very obscure.

to rock but with special characters influencing the vegetation (see Chapter XIII).

A detailed account of the distribution of British soils would be out of place in this book, even if the necessary data, which would have to be derived from a systematic soil-survey, were available. But some account of the general distribution of soils in relation to the geological formations may be given.

As we have already seen (p. 17) the east and south-east of England, as well as much of the Midlands, are entirely composed of Secondary, Tertiary, post-Tertiary and Recent deposits, while the north, west and south-west, Wales, and nearly the whole of Scotland and Ireland are formed of metamorphic, Palæozoic, and intrusive igneous rocks. Very considerable areas of these older rocks however, especially in Scotland and the north of England, as well as some of the newer ones in the Midlands and east, are covered by deposits of glacial drift left by the retreating ice. This drift may form a heavy "boulder clay" or it may be sandy or loamy.

The archæan and Palæozoic rocks and the igneous formations of various ages, include all the hardest rocks, and they have been far more elevated and folded by earth-movements than any of the later ones. For these reasons they form all the mountainous land in the country, while the more recent formations, including the glacial deposits, are for the most part comparatively soft and yielding, have been but little elevated or disturbed, and form flat or undulating plains broken only by ranges of low hills.

Many of the hard older rocks, such as limestones, sandstones, flags, slates, etc., and also many of the crystalline, metamorphic and igneous rocks, weather with difficulty, and consequently form very shallow or comparatively

General distribution of geological formations.

Soils derived from rocks of different ages.

shallow soils, unsuitable for agriculture. On the other hand, the soft "rocks" (many of them really clays and sands, and therefore not rocks at all in any other sense than that of technical geology) of the south and east give rise to deep soils. It is largely for this reason, apart from the climatic factors already described (pp. 20-31), that the east, the south and the Midlands of England are the great agricultural regions of the British Isles. Many softer rocks, such as shales, are however interbedded with the harder members of the Palæozoic formations. These often occupy the valleys and sometimes form quite good agricultural land.

Considered as a whole, however, the Palæozoic, metamorphic and igneous rocks, with their thin soils, are very largely under natural or semi-natural grassland used for grazing, or bear woodland of definite and characteristic types, or are strictly "waste" land, *i.e.* covered with heath or moor on peat or peaty soil (see Chapters IV, XIII). Waste-land is not nearly so common on the newer and softer rocks, being mainly confined to the poorer sands bearing heath or heathy woodland. The loamy and clay soils are used for agriculture or laid down in permanent pasture. The woods are generally patches left mainly for the local supply of "small wood" and are almost invariably used for game preserves.

THE SOILS OF SCOTLAND

By W. G. SMITH

The metamorphic, Palæozoic and igneous formations, which constitute nearly all the rocks of Scotland, contain no extensive deposits of limestone covering wide areas and comparable with the Mountain Limestone, Oolites or Chalk of England. Localised bands of limestone

are, it is true, fairly abundant and widely distributed, but taken as a whole both the rocks and the widespread glacial drift derived from them are non-calcareous, and carry types of vegetation characteristic of "siliceous" soils.

The soils of the lowlands up to about 1000 feet (c. 300 m.) have been almost entirely deposited by moving water or ice, and the solid rock is exposed only here and there. Glacial drift also frequently occurs above this altitude up to 2000 feet (c. 600 m.) in depressions or on terraces among the hills, while the summits and steeper slopes are largely covered by local rock-débris. It is probably safe to assume that about three-quarters of the surface-soil below 2000 feet is composed of this transported material, an assumption supported by observations on the vegetation, since the limits of the different vegetation-units by no means follow, at the lower elevations, the limits of the rock-formations.

Most of the glacial "boulder clay," and to some extent also the sands and gravels, show a tendency to form an acid humous soil or an acid and relatively pure peat. These humous and peat soils occur at all altitudes up to about 3300 feet (c. 1000 m.), and according to their different characters give rise to the different prevailing types of "moorland" vegetation so characteristic of the country. Thus *Calluna*-heath occurs on the drier humous soils, *Calluna*-moor on the drier peats, moors characterised by *Eriophorum*, *Scirpus cæspitosus* or *Sphagnum* on deep wet peat, wet grassland or grass moor characterised by *Molinia cærulea*, *Nardus stricta* and *Juncus squarrosus* on the peaty soils with more mineral content but still forming acid peaty humus, and dry grassland on the less peaty and drier soils. On the whole the wet moors and wet grasslands are typical of the wetter climate of the west, while the heaths, *Calluna*

moors and dry grasslands prevail in the drier climate of central and eastern Scotland¹.

Something like two-thirds of the surface of Scotland lies more than 1000 feet (c. 300 m.) above sea-level, and therefore above the agricultural area, which only in a few places reaches this altitude and rarely exceeds it. The great bulk of this elevated area is known as "the Highlands," the great hill complex which contains the highest summits in the British Isles (p. 17). The Highland area occupies practically the whole of the northern half of Scotland, except the broad shelf of low country fringing the North Sea (Fig. 2, p. 19).

The Highlands fall naturally into two districts, separated by a chain of lochs² lying in a deep trench (Glenmore—the big glen) which cuts across the country from north-east to south-west and marks the line of a great fault.

The North-western Highlands form a wild, remote, and mountainous region, though its average altitude is not so great as that of the Central and Eastern Highlands lying south and east of Glenmore. This northern region is much cut up by deep fjord-like sea-lochs, and by deep inland valleys, so that areas exceeding 2000 feet (610 m.) are small and detached, though numerous. The country is built up of schists, quartzites and granites; the high plateaux are in places covered with glacial deposits, and these with deep peat, from which the isolated ranges and summits rise abruptly. Though lime-containing soils are by no means absent, and sometimes influence the vegetation, the mantle of deep, highly acid, peat passes

¹ Cf. the vegetation map accompanying M. Hardy's "Esquisse de la Géographie et de la Végétation des Highlands d'Écosse," *Scottish Geographical Magazine*, 1906.

² These lochs are connected by the Caledonian Canal, which joins the North Sea and the Atlantic.

uniformly over everything alike and is uninfluenced by changes in the rock types. In the extreme north and along the east coast the rainfall is comparatively low (30 to 40 inches=76 to 101 cm.), and here as in the Central and Eastern Highlands *Calluna*-moor (the driest type) and heath are more prevalent. In the west, which has a very high rainfall, mostly over 60 inches (152 cm.) and with large areas over 80 inches (203 cm.), the moors are largely dominated by *Scirpus caespitosus*.

The whole area is naturally very thinly populated, and is difficult of access, except along the east coast where there is a fringe of cultivation. From what is known of its botany it appears to be poor floristically.

The Central and Eastern Highlands, lying south and east of the valley of Glenmore, likewise consist mainly of schistose metamorphic rocks, more variable in kind than those of the North-west Highlands. Granites occupy large areas. The district is characterised by possessing extensive continuous areas exceeding 2000 feet (c. 600 m.) in altitude, while considerable tracts above 3300 feet (c. 1000 m.) rise ultimately to several summits of 4000 feet (c. 1200 m.) or more. In this mountain mass glacial deposits are limited to the valleys, so that the influence of the lithology on the vegetation is much more evident than in the north-west. The western part of the area has a similar climate to that of the North-west Highlands, and bears similar vegetation, but the central and eastern portions are somewhat drier, and *Calluna*-moor and heath and the drier grasslands are prevalent. *Calluna* is commonly dominant below 2000 feet (c. 600 m.) and *Vaccinium Myrtillus* at higher levels.

Locally the quartzose schists are replaced by limestones, and by chloritic and mica-schists, etc., which introduce edaphic and topographical features favourable to the presence of "arctic-alpine" species at the higher altitudes. The Central Highlands include the richest

localities in Britain for these species; among them may be mentioned the Cairngorm mountains on the north, and the Lochnagar group on the south of the Dee valley, forming the eastern region of the Central Highlands. To the south-west of these regions Ben Lawers and the neighbouring hills in Breadalbane have attracted many botanists by the variety of their flora. Robert Smith pointed out that these floristically rich areas are accompanied by considerable tracts of mountain grassland of a comparatively dry type, which occurs on soils formed from rocks richer in minerals than the quartzitic schists which form the basis of the ericaceous "moors"¹ (heaths).

The Central Lowland Plain of Scotland is an extensive tract of comparatively low country, only occasionally exceeding 650 feet (c. 200 m.) in elevation, and stretches from the Firth of Clyde, on the west coast, eastwards over a low watershed to the eastern coastlands of the Firths of Forth and Tay, with a considerable extension north-eastwards along Strathmore (the great valley). This great transverse depression, separating the Highlands on the north from the Southern Uplands in the south, includes the greater part of the agricultural and industrial areas of Scotland, and contains the largest cities, Glasgow and Edinburgh, as well as many other important centres such as Perth and Stirling.

The soils are almost all of glacial or alluvial origin, and although very fertile near the coasts, there are extensive tracts of glacial "till" or boulder-clay which are generally unproductive as farmland and are now left uncultivated as wet grassland or peat-bog. The best areas of farmland are largely on the lower ground near the coasts; in the valleys among the lowland hills the farmland is restricted to the bottoms and lower slopes of the valleys, though sheep-grazing extends all over the

¹ Robert Smith, 1900.

grassland of the lower hills. The most fertile lands, where some of the best farming in Great Britain is carried on, are largely on loamy glacial drifts derived partly from the Old Red Sandstone, as in the Lothians round Edinburgh, especially at Dunbar, where the narrow strip of coastland is probably the most expensive and most highly farmed land in the world, in the Fife peninsula between the Firths of Forth and Tay, and in Strathmore. These allow of the inclusion of wheat, the finer strains of barley, potatoes, oats and turnips in the regular rotation of crops. This land is practically restricted to the relatively dry east coast, and forms a band of varying width, extending northwards along the eastern edge of the Central Highlands as far as the shores of the Moray Firth, at the north-eastern extremity of the Caledonian Canal.

On the west coast the Ayrshire or southern side of the Firth of Clyde is almost the only tract of high fertility, owing to the favourable topography and the mild spring; early potatoes are here an important crop. Outside these fertile areas a zone is reached in which wheat is grown to a small extent only, but barley of the hardier varieties and potatoes are still included. On the less productive soils and amongst the hill-valleys, these quickly disappear and only the hardier oats and turnips, and sometimes rye, are left; the cultivation of these last, combined with cattle-raising, marks the limit of the arable land. On the fertile coastlands grass and forage crops are as a rule laid down for short periods only, but as the soils become less productive the permanent grassland increases, till at the higher altitudes beyond the arable limits the enclosed farmlands consist of grazing grounds alone.

Above the enclosed grassland comes unenclosed natural grassland, or moorland. Even the latter is sometimes grazed, but it is mainly used as shooting moors for grouse (*Lagopus scoticus*) and other hill game, while

in the Highlands the extensive areas of the higher mountain moors are entirely reserved as "deer-forests" or ranges for the red deer (*Cervus elaphus*).

The Southern Uplands extend from the Central Plain southwards to the English border. They consist of Ordovician and Silurian siliceous rocks with local intruded igneous masses. The hills have steep slopes and broad rounded summits, rarely exceeding 2000 feet (c. 600 m.) and generally covered with grassy or heathy moorland which provides grazing for large numbers of sheep. This region and the somewhat similar Welsh hills are the two most important sheep-grazing areas in Great Britain, sustaining in both cases a proportion approaching or exceeding one sheep to every acre of land of all kinds. The Southern Uplands are girt by broad lowland coastal belts on both east and west. In the valleys of the Tweed, Nith and Clyde and their tributaries agriculture and manufactures connected with wool are largely carried on.

**Southern
Uplands.**

southwards to the English border. They consist of Ordovician and Silurian siliceous rocks with local intruded igneous masses.

THE SOILS OF IRELAND

By GRENVILLE A. J. COLE

The general geological structure of Ireland is easily comprehended. A great low-lying plain, based upon Carboniferous Limestone, forms the entire centre of the country. This plain reaches the Irish Sea on the east, at Dublin, and touches the Atlantic here and there on the west; but much of the west coast, as well as the north and south of the country, is mountainous. In the extreme west and north-west this mountainous country is formed of very old metamorphic rocks pierced here and there by granite. In the south-west Millstone Grit forms some of the hilly

**Geological
structure.**

country, but most of the southern mountains are formed of Old Red Sandstone, which occupies a large area, and also rises from under the limestone of the southern portion of the central plain to form isolated mountain ranges. In the north-east and south-east there are considerable areas of Ordovician and Silurian rocks, in the centres of which rise lofty mountains of granite. Finally, the extreme north-east is a plateau country of basalt overlying chalk and Trias; these are almost the only rocks of later date than the Palæozoic existing in the country, with the exception of glacial deposits which overlie the older rocks in many places.

In sharp contrast to Scotland, with its almost uniformly siliceous soils, by far the greater part of the rock on which the soils of Ireland are based is the Carboniferous Limestone, which forms the great central plain, extending from Dublin on the east coast right across the country to Galway on the Atlantic, and from Fermanagh on the north to the borders of Co. Cork in the extreme south. Most of the glacial drift with which this plain is largely covered contains much lime, and it is to this calcareous soil, together with the equable moist climate, that the excellent Irish grasslands, justly famed for cattle-raising, are due¹. Conspicuous among the glacial accumulations are the dry grass-covered gravel ridges known as "eskers." In Co. Cavan and other places "drumlins" of boulder-clay with steep rounded flanks furnish loamy and often stony soils. In spite of their form, the drumlins are often selected

¹ In 1910 there were 23 head of cattle to every hundred acres of land of all kinds in the whole country, while in some counties this number was considerably exceeded; thus Co. Meath in Leinster had 38 head to the hundred acres. These figures compare with (in 1909) less than 16 for England and only 6 for Scotland. Some of the English counties however, in the Midlands and west, show high figures, *e.g.* Cheshire 28, Leicester 27, Cornwall 25; Anglesey in Wales had nearly 32.

for arable land, rising as they do above the moister levels of the plain.

The direct decay of the limestone often produces a stiff clay soil on which water lies. Where the limestone is very pure, it is liable to yield only a sparse mud or sand, which is carried away as soon as it appears on the surface, leaving barren slabs and terraces of limestone. These rise into very striking regularly terraced limestone hills in Clare and Galway. On the wetter lowlands, where water does not run off, broad peat bogs resting on old lake-marl or water-logged limestone have accumulated.

Ridges of Old Red Sandstone, such as the Slieve Bloom and Galty ranges (summit of Galtymore, 3015 feet = c. 920 m.), frequently rise through the limestone plain. These usually form barren heaths, but support good coniferous plantations. In the cores of the Old Red Sandstone hills Silurian shales often appear, weathering out into hollows occupied by farm lands and surrounded by the Old Red Sandstone scarps. Throughout the southern counties, from the west of Kerry to the centre of Waterford, long east-and-west ridges of Old Red Sandstone and Carboniferous slate prevail. Fertile clay-covered belts of Carboniferous Limestone occupy the long depressions of the northern part of this area, and these support finely developed woods by the sides of the rivers. The sandstone and slate uplands, in contrast, commonly form moorland, and culminate in the rugged scenery of the Reeks of Kerry, of which the highest summit reaches 3414 feet (c. 1040 m.).

The granite of the Leinster chain along the south-eastern coast of Ireland forms thin soils bearing moorland¹, in marked contrast with the clays worn from the Ordovician foothills

Old Red Sandstone.

Granites and Ordovicians.

¹ In the north of this chain the moorland is dominated by *Calluna* on the slopes and by *Scirpus cæspitosus* on the summits. See Pethybridge and Praeger, 1905.

on either side, which support good arable land. Along both flanks of this chain the soils are much modified by the presence of glacial boulder-clay, which has imported limestone blocks into regions otherwise poor in lime.

In the north-east a broad hummocky Ordovician and Silurian area stretches from the centre of Co. Longford through Co. Down, and farmers have taken full advantage of its loamy soils.

On the Atlantic coast, in the extreme west of Co. Galway and Co. Mayo, and through a large part of Co. Donegal in the north-west, the old quartzitic metamorphic rocks, pierced here and there by granite, provide very little soil, and acid peat is a common feature of the impermeable surfaces. Where mica-schist prevails, however, as in eastern Donegal and Co. Londonderry, rich orange loams are formed, which are much more favourable for agriculture.

Finally the red-brown soil of Co. Antrim in the north-east is largely derived from basalt, and is locally modified by glacial drift. The quarries in the Chalk underlying this basalt easily supply lime where it is required on the arable land.

**Old meta-
morphie
rocks.**

**Basalt and
Chalk.**

THE SOILS OF ENGLAND AND WALES

The range and variety in the geological structure, and therefore in the soils, of England and Wales, which form the southern portion of the island of Great Britain, are much greater than in those of Scotland and Ireland.

“Broadly speaking the northern and western parts of England and the greater part of Wales are formed of the older rocks known as primary or Palæozoic. These were considerably folded and disturbed before the newer rocks were laid down. Resting on their upturned

**The Palæozoic
rocks of
England and
Wales.**

edges, or abutting against them, lie the Secondary strata¹."

The geological structure of the north of England is mainly dominated by the great Pennine anticline, forming a broad ridge of high land running north and south, and sharply cut off on the south by a great east and west fault. The centre of this anticline is formed by Carboniferous or Mountain Limestone, on whose flanks lie the Millstone Grit, a coarse sandstone, and then the Coal Measures, which largely determine the position of the great industrial districts of the north. To the north-west of the Pennine axis lies the mass of still older rocks forming the Cumbrian (or Lake District) group of mountains.

The west of Wales consists mainly of Cambrian and Ordovician rocks, flanked on the east by Silurians, while in the south is a great basin of Carboniferous rocks, edged by a rim of Mountain Limestone and containing the important South Welsh coalfield. The south-western peninsula of England (Devon and Cornwall) consists of rocks of Devonian and Carboniferous age with great masses of intrusive igneous rock (largely granite).

Isolated patches of ancient rocks occur here and there in the midlands, *e.g.* the midland coalfields and the rocks of Charnwood Forest. Here and there rocks of pre-Cambrian (Archæan) age appear at the surface, but their total extent in England and Wales is comparatively insignificant.

The general effect on the physiognomy and soil-characters of the country produced by the older rocks of the north and west has already been described, and it would not repay us to consider the different formations in detail.

The limestones form an outstanding series with very marked soil-characters and vegetation. By far the thickest and most extensive is the

Limestones.

¹ H. B. Woodward, *The Geology of England and Wales*, Second edition, p. 26, 1887.

Carboniferous or Mountain Limestone, developed in the north of England, in North and South Wales, and in the Mendip Hills of Somerset; the vegetation of the English areas of this has been carefully studied¹.

The Cambrian, Silurian and Devonian series all have numerous limestone bands occurring at intervals between other types of rocks; the vegetation of these however has been scarcely investigated at all. The Magnesian Limestone of Permian age occurs in Nottinghamshire, Yorkshire, and other northern counties.

The limestones generally form elevated land masses or ridges, the valleys and slopes being usually occupied by adjacent shales. On very steep slopes and crags, where the products of chemical erosion by water containing CO_2 are at once carried away, the rock is left bare with characteristic plants occupying any spot where a little soil can collect. On less steep slopes it is covered by a very thin soil occupied by a special type of natural grassland ("calcareous pasture"). Where the insoluble products of chemical erosion are able to accumulate, as on flat summits, on gentle slopes and in valleys, a deeper soil results. On flat ground the lime is often almost completely washed out of this surface soil, with the result that a heath vegetation occupies the area. Sometimes "limestone pavement" (p. 160) is formed on flat ground. On slopes and in valleys scrub and woodland of characteristic type occur.

The rocks other than limestones (sandstones, grits, mudstones, slates, shales, schists and various crystalline rocks) are of extremely various physical character and lithological composition, and the vegetation they bear is modified not only by these factors, but also by the exposure and slope of the ground, water supply, drainage and other factors. In general, as already mentioned, they are characterised

¹ Smith and Rankin, 1903; Lewis, 1904; Moss, 1906.

by comparatively shallow or very thin soils, and these are frequently poor in mineral plant-food, but numerous exceptions occur, *e.g.* in soils produced by the disintegration of rocks rich in certain minerals. At high altitudes, apart from crag and cliff, the soil is covered by various types of "siliceous pasture" or by moorland; at lower altitudes, where trees and shrubs can successfully establish themselves, by woods of the oak and birch series, or their corresponding scrub.

Generally speaking the Palæozoic, metamorphic and igneous rocks are not fertile (apart from climatic conditions), but various important exceptions occur. Thus the Old Red Sandstone of Herefordshire yields a strong loamy soil which is fertile, and largely under good permanent pasture, with many orchards and hopyards. The limestone bands (called "cornstones") which occur in it form however the richest land. The diabases, tuffs (volcanic ash) and slaty volcanic rocks, forming red soils, of the Ashprington series of the Middle Devonian near Totnes in south Devon, support some of the best arable and grassland in the district. Again the Magnesian Limestone of Permian age forms a good light dry arable soil¹. This comparatively soft limestone is however sometimes included in the secondary (Mesozoic) series.

The secondary rocks which rest on or abut against the primary groups enumerated, form a much more regular series. Speaking generally they dip regularly to the south-east, one under the other, so that their outcrops are arranged in a succession of bands crossing England from north-east to south-west, and occupying more than half the area of the country. The north-eastern ends of these bands bend northwards, and occupy the eastern part of northern England to the east of the Pennine ridge, running out successively to the north-eastern coasts of Yorkshire and Durham.

**Secondary
rocks.**

¹ H. B. Woodward, *op. cit.*

The oldest member of the series is the Trias. This forms a broad area, broken by islands of older rocks, in the very centre of the country. Besides its long northward outcrop on the eastern flank of the Pennines, extending to the Durham coast, and its southward outcrop—narrow and somewhat interrupted—to the coast of Devon, it has an important north-westward extension, separating the Palæozoic rocks of the Pennines from those of North Wales, and reaching the Irish sea on the coasts of Cheshire and Lancashire¹. Speaking broadly the Trias forms low ground: to the north the plain of York, to the north-west the plain of Cheshire, and in the centre the Central Plain of England. It has two main divisions in England, the Bunter, consisting of sandstones, and the Keuper, mainly of marls, the “*Muschelkalk*” of the Continent being absent from this country. The Bunter sandstones form a poor soil, woodlands of the oak-birch series and heathland, as in Sherwood Forest in Nottinghamshire and Delamere Forest in Cheshire, occurring on these beds. The Keuper marls form fine meadow and pasture land, for instance in Cheshire.

The Lias comes next, extending from the coast of Dorset to the coast of Yorkshire. Like the Trias, its greatest extension is in the Midlands, where it forms part of the plain of central England. The Lias consists of clays, marls, shales, and more or less pure limestone bands, and, locally, some sand and sandstone. It forms mainly flat country, with low escarpments, representing the limestone bands, in places. The clays and marls give fertile agricultural country, with rich pasture-lands.

The vegetation of the Keuper and Liassic marls of Somerset has been studied by Moss²; he found that (ash-)oak-hazel wood (see p. 182) and calcareous pasture,

¹ With small isolated tracts occupying the Eden valley in Cumberland and the Vale of Clwyd in Wales.

² Moss, 1907, p. 50.

with ash wood on the limestone exposures, were the natural types of vegetation.

The Oolites, which follow the Lias, also run from the coast of Dorset to the coast of Yorkshire.

Oolites. Their outcrop occupies a broader band of country than the Lias, the greatest breadth being in the east midlands, where however the eastern division is overlaid by the alluvium and peat of the Fen District.

The Oolites are partly composed of comparatively hard rock forming hill-ranges, the most important of which, the Cotswold Hills in Gloucestershire, and the Cleveland Hills of north-east Yorkshire, attain a height of over 1000 feet (305 m.). The Oolite hills of the south, notably the Cotswolds, are very pure limestones, but as the outcrop is traced northwards the limestones partly give place to rocks of a different lithological character, while the north-east Yorkshire representatives of the series are mainly non-calcareous.

The vegetation of these last has been studied by W. G. Smith, whose results are not yet published, but it may be stated in a general way that the valley sides of the Cleveland district are clothed with ash-oak woods (indicating the outcrops of limestone) and with oak woods, while the plateaux of the summits bear extensive heaths. The limestones of the Cotswolds carry beechwood and calcareous pasture. The agricultural value of the Oolites varies very much according to the very variable local character of the rock. In the stratigraphically upper portion of the Oolite series are extensive belts of clay (Oxford clay and Kimeridge clay) which are very heavy soils, expensive to work, and are largely under permanent pasture.

Cretaceous series. The Oolites are followed by the Cretaceous series, which occupies a broad belt of country extending from the Dorsetshire to the Norfolk coast, and bending north-westwards, appears again in Lincolnshire and south-east Yorkshire.

The Lower Greensand, whose outcrop is a narrow interrupted belt at the base of the series, forms in places a distinct sandstone escarpment. This rock varies much in lithological character, and its vegetation is complicated. It is followed by the Gault, a heavy clay, sometimes calcareous, which may bear the damp type of oakwood, and is now largely pasture-land.

The Chalk, the most important member of the Cretaceous series, is on the whole a very pure soft limestone forming more or less elevated masses of characteristic gentle rolling contours (downs) and fairly steep escarpments. The Chalk occupies a large area in southern and eastern England. In no case does the Chalk attain a height of 1000 feet (305 m.), though it often exceeds 500 feet.

The Chalk plateaux of the south are often overlaid by large areas of a deposit known as "clay-with-flints," which is of variable composition, usually a loam, sometimes a heavy clay and sometimes sandy, and typically contains numerous flints. It is supposed to represent the insoluble residue of the dissolution of a great depth of overlying chalk, though in some cases it may be the remains of Tertiary formations which once lay on the top of the Chalk. The Clay-with-flints is generally very deficient in lime. It is largely arable land, which is much improved by liming or treatment with the artificial manure known as basic slag¹. The natural vegetation is oakwood of various types corresponding to the various soils. Heath is sometimes developed on the lighter poorer soils.

Where the chalk itself forms the immediate subsoil, the soil itself is extremely thin, often only 2 to 5 inches (c. 5 to 12 cm.) in thickness, and is frequently extremely poor in lime. In the south-east the natural vegetation is beechwood on the slopes of the escarpments and valleys; towards the south-west this passes into

¹ Mainly phosphate of lime.

ash-wood (see p. 167). Pasture, supporting large flocks of sheep, covers large areas of the summits and many of the slopes of the chalk downs.

The arable land in which wheat is regularly included in the crop-rotation forming the "wheat-country" mentioned on pp. 28-29, is largely situated on the Chalk and the overlying thin soils already described. The characteristic agricultural method is based on what is called the "Norfolk four-course system," in which wheat is followed by a "root-crop" (turnips or swedes), this by barley, and the barley by a "seed-crop," generally leguminous, such as alsike (*Trifolium hybridum*) and white (*T. repens*) or red clover (*T. pratense*), or a mixture of clover and rye-grass (*Lolium perenne*). Oats are often substituted for wheat on the lighter lands, and numerous other variations exist. This rotation essentially depends on the "folding" of sheep on the "green" crops and the manuring of the ground by their droppings for the following cereal crop. This is the characteristic feature of the agriculture of southern and eastern England. The typical pasture of the South Downs of Sussex, and of Salisbury Plain in Wiltshire, supports great numbers of sheep, and in the down farming the sheep feed sometimes on the pastures, sometimes in the folds. The Chalk of the North Downs (Surrey and Kent), and of Cambridgeshire, Norfolk, Yorkshire and Lincolnshire, has very much less (often practically no) open "sheepwalk," the Chalk country in the four last-mentioned counties being almost entirely arable.

**The Wealden
anticline.**

The outcrop of the Cretaceous rocks is not confined to the main belt running from south-west to north-east; there is an important extension caused by a line of uplift running eastwards from Wiltshire, through the counties of Hampshire and Sussex, and across the English Channel to the neighbourhood of Boulogne in France. This line of elevation, known

as the Weald anticline, determines the geological structure of the whole of south-eastern England. It brings up the chalk on its northern and southern flanks to form the North Downs running through Surrey and Kent, and the South Downs in Sussex, respectively, while exposed by the removal of the Chalk, which once connected the two ranges of downs, are the Lower Cretaceous beds of the Wealden area surrounding the axis of the uplift. These beds are largely different from and much thicker than the strata occupying the corresponding stratigraphical position along the main outcrop. The Gault is similar, but the Lower Greensand is much more developed, at least on the north side of the Weald, than it is on the main Cretaceous outcrop. At the western end it consists of coarse massive sandstones, forming hills of some height (in one place nearly reaching 300 m.), which bear woodland of the oak-birch series and extensive heaths, and are very poor agriculturally, while further east the sandstone contains more fine particles and also thin beds of limestone, and is good agriculturally, as is also the narrow belt of the same formation fringing the southern edge of the Weald.

Below the Lower Greensand come the Wealden beds proper, developed only in that area. First
The Wealden beds. a broad belt of Weald Clay forms a plain overlooked on the northern side by the bold escarpment of the Lower Greensand. The Weald Clay gives a heavy clay soil for the most part, though it contains narrow bands of limestone and some loamy beds. It bears the damp type of oakwood characteristic of clays and loams.

In the centre of the Weald come the so-called Hastings beds, divisible into the Tunbridge Wells Sand and the Ashdown Sand, separated by the Wadhurst Clay, and often themselves interbedded with narrow bands of clay. These beds form relatively high ground, particularly the

Ashdown Sand, which makes the so-called "Forest Ridge," a heathy ridge in the very centre of the Weald, still largely covered with oak and birch wood. The Tunbridge Wells Sand is partly very fine grained, like a clay, and largely bears the damp type of oakwood.

The Chalk of the main outcrop, from southern Oxfordshire north-eastward, dips below the overlying Tertiary beds and appears again at the surface in the North Downs. In the same way the Hampshire Chalk dips below the Tertiaries in the south of the county and the north of the Isle of Wight to reappear in the Central Downs of the island. These two great chalk basins, known as the London and Hampshire basins respectively, contain all the English Tertiary deposits, except those which skirt the east coast overlying the Chalk of Norfolk and Suffolk, and which really form a north-eastward extension of the London basin.

Tertiary series.

Of the Eocene beds which form the bulk of these deposits the London Clay is the most important. It yields a stiff soil with the usual clay characters. Below it are the alternating sands and clays which give variety to the fringe of country between the chalk and the London Clay, while above it, forming extensive tracts on the borders of Berkshire, Hampshire and Surrey, and isolated patches to the north of London, is the very light Bagshot Sand, bearing heath, and now very largely subspontaneous Scots Pine. The Bagshot beds of the Hampshire basin show a greater complexity of alternating sands and clays.

Eocene beds.

The Oligocene beds which come next are confined to south Hampshire and the Isle of Wight, while the Miocene are absent from this country altogether.

Oligocene and Pliocene beds.

The Pliocene strata are the Tertiary beds which fringe the chalk on the east coast, and are thus entirely East

Anglian. These deposits are nearly horizontal and occupy a considerable extent of country, though they have no great thickness. They are mainly composed of sand and gravel ("crag") with very thin bands of clay, and are largely covered with heath of various types. It is doubtful if this part of the country was ever occupied by forest.

Quaternary deposits—
Glacial Drift. "The Quaternary deposits form a distinct group scattered irregularly over the country, and resting indifferently on any of the rocks from the oldest upwards¹." Very important among these quaternary deposits, just as is the case in Scotland and Ireland, are the extensive sheets of ice-formed drift dating from the glacial period, and of very variable composition, consisting sometimes of non-calcareous clay (as in many parts of the north of England), sometimes of highly calcareous clay (such as the "chalky boulder-clay" of eastern England), and sometimes, though less frequently, of sandy and gravelly material. These sheets of drift completely cover the older rocks over large tracts of country, particularly in the north, centre, and east, and of course entirely determine the character of the soil, and therefore the vegetation, of these regions. In places the nature of the drift, and therefore of the soil, changes within very short distances.

In the north of England the Coal Measures of Northumberland and Durham are largely covered by drift (stiff clay or sand and gravel), and the same is true of the Coal Measures and Trias of south Lancashire and Cheshire. In the vale of York there are deposits of boulder clay resting on the Trias, and also extending up the coast from Flamborough Head northwards. Throughout Wales there are deposits of glacial drift in various places, and in the south-west of England there are various deposits of local occurrence which seem to contain evidence of ice-transport.

¹ Woodward, *The Geology of England and Wales*, p. 26.

On the midland Trias there are extensive deposits of drift containing erratics, some coming from the north, and some from the Jurassic and Cretaceous rocks further east. Eastwards this drift passes into the chalky boulder clay, which covers a wide extent of country, reaching northward along the coast into Lincolnshire and Yorkshire, and occupying wide areas of the surface in south Norfolk, Suffolk, Essex, Cambridgeshire, Bedfordshire and Huntingdonshire. Nowhere however does it come so far south as the Thames valley. This heavy calcareous clay forms wide sheets on the higher ground, and sometimes extends to the valleys on a level with the alluvium, but it has been largely removed from the valley sides and escarpments. It forms a heavy soil and is largely under cultivation. The natural woodland is of the ash-oak type owing to the relatively high lime-content of the soil (see p. 181) and is treated as (ash-)oak-hazel copse.

There are numerous other Quaternary deposits of various age and the most various composition, some of glacial and many of unknown origin¹. Perhaps the most important of these is the "clay-with-flints" already referred to (p. 53), which very frequently covers the chalk plateaux and, being generally non-calcareous, quite alters the character of the vegetation. The derived sands and gravels resting on the chalk, and covering considerable areas on the borders of Norfolk and Suffolk round Brandon, Thetford and Mildenhall, are largely occupied by heath.

Recent alluvium, laid down by existing rivers, again varies very greatly in composition. In mountain country it often consists of coarse sand and gravel, while in the flood plains of the level country it consists typically of fine clayey silt. It is

¹ There is no evidence of glacial action in south-eastern England south of the Thames valley.

often difficult or impossible to obtain any direct evidence as to the natural vegetation of such soils because they are generally extremely fertile, and entirely under cultivation or in permanent pasture. In the neighbourhood of great cities, which are frequently situated on the flood plains of the lower courses of big rivers, these rich alluvial soils are extensively used for market gardening.

Travelling seawards down the course of such a river, we pass from the plain of river alluvium to the salt mud associated with the tidal estuary.

Maritime soils.

The natural vegetation is halophilous (p. 332), but when the tide is kept out by sea walls, and the land is drained, it makes admirable pasture. "The Marshland," occupying the northern (seaward) portion of the old estuaries of the Ouse, Nen, Welland and Witham and lying round the Wash, their common estuary, now much reduced in size, is the most extensive area of this kind in the country.

Blown sand, forming sand-dunes, which support a very characteristic vegetation (p. 339), occurs wherever a constant supply of sand is thrown up by the sea above highwater mark, and thus comes under the action of the wind.

Shingle or pebble beaches thrown up above high-tide mark also have a vegetation of their own, allied to that of sand-dunes but with distinct characters. The best known and most extensive are the Chesil Bank in Dorsetshire, Dungeness in Kent, and Orfordness in Suffolk.

Finally, among recent deposits, we have the sharply characterised organic soils of which the peat soils, formed where vegetable remains accumulate in the presence of water and with deficient oxidation (p. 35), are by far the most important. The kind of peat formed on the edges of water comparatively rich in mineral salts is often accumulated in the upper

Peat soils.

parts of tidal estuaries which are silting up, and of which the lower parts are accumulating tidal mud. The most extensive area of this kind of peat forms the region known as "the Fenland," lying to the south of "the Marshland" and corresponding with the upper portions of the old estuaries of the Ouse, the Nen, the Welland, the Witham, and their tributaries. The upper parts of the old estuaries of the Bure, Yare and Waveney in east Norfolk, form other areas of the same kind, much less extensive, but less altered from their original condition.

The present surface-peat of the upper parts of other old estuaries, *e.g.* the peat of the Somersetshire "levels" and round Morecambe Bay (north Lancashire), is of the heathy type (*i.e.* much poorer in mineral salts), though in some cases this surface-peat is built up on old peat of the former type (see p. 246).

The hill peat, so common on the badly drained slopes and plateaux of the Pennines, in Wales and in Scotland and Ireland, is of the acid type, poor in mineral salts. Much of this peat has been formed on the sites of ancient forests.

The constant variation from place to place of the English soils will be obvious from the foregoing account. It is clearly impossible briefly to summarise their distribution. Some of the most important areas of the various kinds of soil are given below.

Organic soils. Mild peat of upper parts of old estuaries fed by waters rich in bases. Acid peat of hill plateaux and slopes in the north and west, and lowland moors.

Sands and gravels. Blown sand of various places on the coast. Valley and plateau gravels overlying various secondary and tertiary rocks. Pliocene "crag," etc.—east Norfolk and Suffolk. Bagshot sand—mainly south-west of London—and other Eocene sands of the Hampshire basin. Lower Greensand—Weald and the east Midlands.

Bunter sand—Sherwood and Delamere Forests, Forest of Arden, etc.

Clays. Boulder clay (e.g. of south Lancashire and Cheshire). London clay (London and Hampshire basins). Gault clay—east and south Midlands and Weald. Jurassic clays (Kimeridge and Oxford clays)—east and south Midlands.

Other "siliceous" soils (see pp. 33, 122)—Archæan, Palæozoic, metamorphic and igneous rocks (other than limestones) of the north and west.

Marls. Chalky boulder clay (mainly overlying chalk)—East Anglia and east Midlands. Liassic marls—Midlands and south-west England. Keuper marl¹—Midlands and south-west England.

Limestones. Chalk (main outcrop and Weald)—southern and eastern England, Yorkshire and Lincolnshire wolds. Oolitic limestones—Cotswold region, etc. Magnesian limestone—Nottinghamshire, Yorkshire, etc. Carboniferous (mountain) limestone—Pennines, Mendips and Wales. Devonian limestones of Devonshire. Silurian limestones—borders of South Wales.

Alluvium. Mixed soils largely of fine texture—flood plains of rivers and on sites of old estuaries.

¹ Not always calcareous.

PART II

THE EXISTING VEGETATION OF THE BRITISH ISLES

CHAPTER I

THE DISTRIBUTION OF THE CHIEF FORMS OF VEGETATION

WE can gain some idea of the actual extent of natural and semi-natural vegetation in the different countries of the United Kingdom from the annual statistics of the Board of Agriculture and of the Irish Department of Agriculture. From the returns for 1909 and 1910 we may construct the following table:

*Percentages of total land-areas under cultivation and
under natural and semi-natural vegetation.*

	England	Wales	Scotland	Ireland (1910)
Arable land (including orchards, etc.) ...	32·8	15·3	17·7	16·0
Permanent grassland ...	42·9	43·2	7·8	
Mountain and heath used for grazing ...	7·5	27·9	47·7	68·8
Waste land and land under houses, gardens, etc. ...	11·5	9·7	22·2	13·8
Woods and plantations (1905)	5·3	3·9	4·6	1·5

Of these heads we may count the two first as "cultivation," though a great deal of permanent pasture that is not regularly manured consists of more or less modified semi-natural plant-communities. It is impossible to say how much of the land under trees is to be reckoned as plantation in the narrower sense of the word, *i.e.* plantations on previously open land, but there is good reason to believe that the great bulk of British woodland is semi-natural, in the sense of representing types of wood originally native to the country¹. Mountain and heathland used for grazing is certainly to be reckoned as bearing essentially natural vegetation. The next heading includes two very dissimilar categories, on the one hand land so barren and remote that it is removed altogether from the pastoral industry, and on the other hand the land covered by cities, towns, and villages of all sizes and by isolated houses with their parks and gardens. It is unfortunately impossible from any published or accessible data to determine the relative extents of these two categories of land, but we shall be safe in inferring that while the latter must form a relatively large proportion in England, the former must greatly preponderate in Wales, Scotland and Ireland.

Thus we arrive at the following approximate percentages:

	England	Wales	Scotland	Ireland ²
Cultivated land (including "permanent grass")	75	59	25	? 20 to 30
Land under natural or semi-natural plant-communities ...	15 to 20	40	70 to 75	? 70 to 80

These figures are necessarily of the roughest description.

¹ See "The Woodlands of England," by C. E. Moss, W. M. Rankin and A. G. Tansley, *New Phytologist*, Vol. ix. 1910, pp. 114—118.

² It is unfortunately quite impossible to say what proportion of the pasture land of Ireland (amounting to more than two-thirds of the whole area) is under approximately natural vegetation, but it is probably very large.

To a large extent in England, and probably to a much greater extent in Wales, much of the permanent grassland is not regularly manured and should be transferred to the second heading as forming semi-natural plant-communities; so we may say in a very general way that somewhere about one-quarter of England, one-half of Wales, three-quarters of Scotland and perhaps as much of Ireland, bear natural plant-communities more or less modified by the activities of man.

Comparing these proportions with those obtaining in the neighbouring continental countries¹ we find that France probably has a distinctly larger proportion of land with a natural or semi-natural plant-covering than England, but still a fraction of the same order, that is to say something in the neighbourhood of one-quarter to one-third, while Germany must have at least one-third, Holland decidedly over one-quarter, Belgium probably the same, and Denmark distinctly less than one-quarter. Norway, on the other hand, has more than 96 per cent. of her area uncultivated, including permanent grassland.

When we turn to the way in which these fractions are made up, however, we find very striking differences. Germany has over 25 per cent. of her area covered with woods and plantations, Norway 22 per cent., France about 17 per cent., while Holland and Denmark each has about 7 or 8 per cent., England between 5 and 6 per cent., Scotland less than 5, Wales less than 4, and Ireland only $1\frac{1}{2}$ per cent. Thus Germany, Norway and France have an immensely greater proportion of their uncultivated and unmanured areas under forest than have Holland and Denmark or England, while Scotland, Wales and

¹ The statistics of the different countries are, to a large extent, impossible to compare, so that the proportions given are necessarily even rougher than those for the British Isles, and are intended only to give the most general idea of the relations.

Ireland, with their very large proportional areas of uncultivated land and very small areas of forest, have a much greater proportion of unreclaimed mountain and moor than any country, save Norway, in north-western Europe.

The uncultivated land bearing natural or semi-natural plant-communities certainly does not, except in certain cases, bear exactly the same vegetation as it did before man began, with increasing civilisation, to modify it on a large scale. There is no doubt that by far the greater part of the British Isles was originally covered with forest: in England the whole of the east, south and midlands, except perhaps some of the chalk downs and some of the poorer sands, and of the north and west probably everything but the summits of the higher hills¹;

Former
extension
of forest.

¹ There is still considerable difference of opinion as to the normal altitude formerly reached by woodland in the British Isles. So far north as the Central Highlands of Scotland thin wood of *Pinus sylvestris* still occurs in places up to 2000 feet (c. 600 m.) and even higher. There is evidence from the remains preserved in the peat that woodland once existed in many places at such levels. Thus Lewis has described a bed containing *Alnus rotundifolia* and *Viburnum Opulus* at a height of over 2000 feet in the Northern Pennines (see p. 269) and a forest bed of *Pinus sylvestris* in the counties of Banff and Inverness at a similar height (*Scottish Geogr. Mag.* 1906, p. 249). He attributes the disappearance of woodland in the latter case (as in many others throughout Scotland) to a change of climate—the reappearance of glaciation after an interglacial period—but this interpretation is not universally accepted. The altitude to which woodland extends depends of course not only on the general climate, but also on the total height of the mountain mass on which it is developed. Thus we should expect a higher altitude to be reached by woodland in the Highlands of Central Scotland, a compact *massif* with several summits exceeding 4000 feet (1220 m.), than on the narrower and lower ranges of the Pennines, and this is actually the case with the woods existing at the present time. Varying conditions of exposure also play a part in determining the local height to which woodland attains. It is certain that the upper limit of existing woodland has been considerably depressed, as in many European countries, during the historical period, largely no doubt by the browsing of animals pastured in the zone lying immediately above the forest.

in Wales the alluvial plains of the larger rivers and the valley sides up to similar altitudes; in Scotland the great central lowland plain, the flat shores of the northern firths on the east coast, and the sides of the valleys running into the heart of the Highlands; in Ireland presumably the central plain and the hill country up to a considerable altitude.

We are justified in making these statements by the climatic conditions that obtain in these areas, conditions which bring them well within the natural forest region of north-west Europe, and by the widespread and abundant evidence of the remains of trees in the peat which covers, in the west and north, large tracts of the country indicated above.

Not only therefore has practically all the arable and "permanent grassland" been taken from the original forest area, but much also of the so-called "natural pasture," heathland and moorland, has been derived from forest. A human community, directly it passes into the first stages of civilisation and increases numerically, is the natural and inevitable enemy of the tree-communities of the countries it inhabits. Man cuts down trees for building his houses and for his firing, to make room for his crops, and to make new pasture for his flocks and herds. These in their turn by browsing in the woods eat off the tree seedlings, and may thus prevent the rejuvenation of the woods and cause their eventual death. It has been pointed out that "the western sea-board of France, the British Isles, Flanders, Holland, Schleswig-Holstein, and Denmark are practically the most poorly wooded portions of Europe." This is attributed to the mild winters of the countries bordering the Atlantic and adjacent seas, which permit of grazing and browsing throughout the year¹.

¹ A. C. Forbes, *The Development of British Forestry*, London, 1910, p. 7.

But perhaps the most widespread and rapid destruction of forests in a country like our own has been incidental to military operations. An organised force trying to crush a less organised one is obliged to destroy the cover which the latter would use to hide in after a temporary defeat, and from which its members would emerge to harass their enemies as opportunity offered. The Roman generals in the first century of the Christian era were probably the first great destroyers of our forests on a large scale, and on the Pennines, where the records of these forests are preserved in the hillside peat, there is evidence of their destructive activity¹. The various expeditions on which the English kings of the Middle Ages embarked, when they were striving with varying success to subdue the wild tribesmen of Wales and Scotland, were responsible for much of the forest destruction in these countries, while in Ireland similar causes were constantly at work.

Many of the existing larger areas of woodland in the south of England and the Midlands are old "Royal Forests" reserved during the Middle Ages for the king's hunting. Though much restricted in area and diminished in number some of these still exist as unenclosed forest land, and a few belong to the Crown, *e.g.* the New Forest and the Forest of Dean. The name "forest" is still applied to areas at one time reserved for royal hunting, even when the areas so called are largely or entirely destitute of trees, *e.g.* Dartmoor Forest.

The wholesale destruction of forests in countries with a cool and wet climate, such as much of the western and northern parts of the British Isles possesses, leads very rapidly, in situations where surface water can collect, to the formation of bogs and of deep peat; this preserves the remains of many of the destroyed trees, but effectually

**Fate of the
land denuded
of forest.**

¹ C. E. Moss, "Peat-Moors of the Pennines," *Geographical Journal*, 1904, p. 3 of separate issue.

prevents the return of the forest, and is of little use to man in any way. On steeper and drier slopes, heath develops on the poorer soils, and grass, used for hill pasturage, on the better soils, which have been denuded of forest.

In the drier south and east, the fate of the soil from which forest has been cleared is different. Such of the land as was not actually tilled would be used, so far as it became naturally colonised by grass, for the pasturage of the numerous flocks and herds of this more thickly populated part of the country, and would thus be turned into grassland, which trees can only invade sporadically. The poorer sandy soils would be colonised by the heaths and other plants which flourish on such soils, and would come to bear a vegetation akin to that of the moors, but on a drier soil and not forming deep peat. In some cases such heaths are partially or completely re-invaded by woodland of the appropriate type. This is possible because the more barren heaths afford no pasturage, and the plant-community is of more open type and therefore more easily colonised by trees of suitable kinds.

With the exception of the Royal Forests, the heathy woodlands and a few others (notably the **Coppice-with-standards.** beechwoods of the chalk), the woods which remained in the south, after the earlier and extensive clearings, took the form of regularly exploited "coppice-with-standards." This semi-artificial type of wood no doubt originated by partial felling of the trees of the original forest and the cutting of the shrubs for small wood. The increased access of light would lead to increased growth of the shrub layer, and it became the custom regularly to harvest the straight coppice shoots springing from the cut "stools" of the trees and shrubs, once every 10 or 15 years, while the few standard trees were felled occasionally. The supply of coppice-wood and timber so obtained was largely employed for the

local uses of the country side, the timber for building, furniture, carts, farm implements, tools, etc., the coppice-wood for firing, fencing, hurdles, stakes, hop-poles and the like. The great majority of the existing woods, and especially the oak-woods of the south and east and of the adjoining midlands, still remain in this form, and are still used for these purposes, but the primary object for which their owners now usually maintain them is the preserving of pheasants.

The woods of the west and north, with local exceptions, are mostly in the less artificial condition of "high forest," and many of these are properly forested, *i.e.* exploited for their timber. This is especially the case in parts of the north of England and of Scotland, where modern scientific forestry is to some extent pursued, and extensive planting experiments are carried on. There are also of course widespread plantations in the south, very largely of conifers (such as larch), that are not native to the country, also of oak, ash, beech, etc., and in some cases planted coppices; but there is good reason for believing that the great majority of the English woods are essentially semi-natural plant-communities, the remnants, modified mainly by coppicing, sometimes by partial replanting, of the original forests which once covered the country. As we shall see in the sequel the different existing types of wood are very closely connected with the soils on which they occur.

In the British Isles generally, but more especially in the south of England, the practice of forestry is in an extremely backward condition. This is largely due to the fact that very few of the woodlands are owned by the State. The great majority are in private hands, and their owners nearly always prefer the preservation of game to the proper economic development of their estates. Further, the large amount of capital that has to be sunk in the development of forests for many years before a return is forthcoming,

**Backward
condition of
forestry.**

70 *Distribution of Chief Forms of Vegetation*

naturally deters the landowner, whose liquid capital resources are limited, from embarking on schemes of serious forest development, the monetary return from which would only benefit his grandsons and great-grandsons. The State might, no doubt, do a great deal more than it does by properly developing the few forests it already possesses, and by acquiring suitable land for afforestation. The characteristic English distrust of the scientific expert, and an unwillingness to embark on far-reaching schemes except under the pressure of absolute necessity, are largely responsible for our failure to develop the country in this direction. There are however signs of an improvement in this respect; meanwhile the majority of our woodlands are from the forester's point of view a scandal and a disgrace.

The south-eastern corner of England, one of the most backward parts of the country in the matter of forestry, is, curiously enough, by far the richest in woodland. Kent, Surrey, Sussex, Hampshire and Berkshire, comprising between them 3,886,296 acres of land and water, had in 1905, the date of the last return, no less than 448,540 acres of woodland, equal to 11·5 per cent., or more than double the percentage for England as a whole, and constituting more than a quarter of the whole area of English woodland. This preponderance in woodland is due partly, though by no means wholly, to the extensive heath woods developed on the light sands of the Weald, of the Lower Greensand, and of the Eocene series.

Cambridgeshire and Huntingdonshire are the English counties poorest in woodland, together having only 1·4 per cent. of their areas occupied by woods and plantations. This is partly due to the fact that these two counties contain a large part of the woodless fenland. The whole of East Anglia, Lincolnshire, the East Riding of

**Abundance
of woodland
in the south-
east.**

**Poverty of
East Anglia
and the
Midlands.**

Yorkshire, and much of the Midlands are however very poor in woods, and this is no doubt connected with the fact that these parts of the country have the greatest proportion of agricultural land (see p. 28). The apparently well-wooded character of the Midlands, as seen for instance in passing through the country by train, is due entirely to the large number of trees in the hedgerows separating the comparatively small fields into which the prevailing pasture land is divided. Seen from a distance the trees and hedges blend and give an entirely false impression of woodland.

We may now summarise the existing natural and semi-natural vegetation of the country classified according to the physiognomy of the landscape it determines, rather than according to the natural plant-formations dealt with in the sequel.

1. The existing woodland is very restricted in area as compared with that of most continental **Woodland.** countries (excepting the regions bordering the Atlantic, the English Channel and the North Sea, which are also very poor in woodland); but that which still remains represents for the most part the more or less modified remnants of the primitive forests which once covered most of the country. There is very little untouched primitive forest left, but some of the remoter hill woods, *e.g.* on the Pennines and in Scotland, may be regarded as practically primitive forest. Most of the woods of the country, at any rate of England, are however to be regarded as semi-natural woods, retaining the essential characters and the flora of the primitive woods from which they are derived. The majority of the woods of southern England, treated as coppice-with-standards, a very old form of exploitation, are at the present time mostly uneconomical and are often badly neglected. The best forestry is to be seen in the north of England, in Scotland, and in the Chiltern beech forests.

2. Natural and semi-natural grassland covers a very large area of the country. The strictly
Grassland. natural grassland, in the sense that it has never been clothed with forest, below the altitudinal forest limit, is probably confined to certain areas of the Chalk, to sub-maritime pasture derived from salt-marsh, and perhaps to some of the grassy heaths of East Anglia. Above the forest limit and below the arctic-alpine zone it occupies the less poor of the drier soils. The semi-natural grassland is partly derived from woodland by the removal of the trees below the wood-limit on the drier hill slopes, and is continuous with and often indistinguishable from adjacent natural grassland which probably never bore trees. Semi-derelict poor pasture, and permanent pasture which has been "laid down" from arable land and is not manured, may also be considered as semi-natural grassland, though it has been derived from manured land and not straight from woodland. The pastures characteristic of many alluvial plains is also at least semi-natural: in some cases such grassland may never have borne trees and so be strictly natural. But the grasslands of the country have as yet been quite insufficiently studied from the standpoint of their vegetation and relationships.

3. Heathland is developed on the poorer sandy soils, especially in the south-east of England, but
Heathland. also on similar areas further north, and on well-drained hillsides, over sandstones, etc., poor in nutritive salts and in lime. Some of the existing heathland is quite possibly primitive, some is probably derived from woodland by natural causes (see p. 90), but a great deal has certainly been derived from cleared woodland on the poorer soils.

4. Moorland (on deep peat with low mineral content) is developed in regions of relatively high
Moorland. rainfall, such as hill slopes and plateaux in the north and west (upland moor); also on the sites of

old lakes, etc., where the water-supply is poor in mineral food (lowland moor); and generally where surface-water poor in soluble mineral salts has accumulated. The hill moors are partly formed above the wood limit, and partly replace woodland, as may be proved from the abundant remains of trees buried in the peat. Moor covers wide areas of hill country in the north of England, and in Scotland and Ireland. It is related to heathland on one side and to the damper grasslands on the other. Much of what is called moorland in common parlance is really heathland, *i.e.* developed on shallow peat over a coarse porous soil.

5. Fenland (on deep peat with high mineral content)

Fenland. is developed on the edges of lakes and estuaries where considerable quantities of nutritive salts are present. It bears a very different vegetation from moorland, though some species are common to both, and transitions occur. By far the largest area of fen was formed round the upper part of the old estuary now represented by the Wash, the common estuary of several rivers. It lies in the counties of Lincoln, Norfolk, Huntingdon and Cambridge. The soil of the lower part of this old estuary (the area near the present coast) is formed of marine silt, and was no doubt at one time salt-marsh. This is sometimes distinguished as the "Marshland" as opposed to the "Fenland" or "the Fens" *par excellence*. The whole area is almost entirely drained and under arable cultivation. Considerable areas of fen occur in east Norfolk in the old estuaries of the Bure, Yare and Waveney, which have now silted up, and these fens are still largely in a natural condition. Their formation from the shallow lakes or "broads," probably the remains of the waters of the old estuaries, may be studied in detail (Chap. X). Fenland has a special characteristic type of woodland of which the alder (*Alnus rotundifolia*) is the dominant tree.

6. Salt-marshes are developed on the tidal mud of protected bays and estuaries, and their
Maritime vegetation, like that of fen, is land-forming.
vegetation. If the sea is kept out and the land drained salt-marsh makes excellent pasture and often excellent arable land.

7. Sand-dunes are developed wherever on the coast there is a constant supply of blown sand derived from the sand thrown up above the average limit of high tide. The ultimate form of sand-dune vegetation in this country is generally grassland, sometimes heath. The British sand-dunes, though they often bear shrubs, are rarely colonised by trees, perhaps because of the scarcity of suitable seed-bearing trees in the neighbourhood.

8. Shingle beaches are formed from pebbles thrown up by high tides. Considerable areas exist at Dungeness in Kent, Orfordness in Suffolk, and Chesil Bank in Dorsetshire, while various smaller areas occur at numerous other places along the coast. The shingle-beach vegetation is quite characteristic. Much of it is very closely allied to sand-dune vegetation; in other cases where it lies on silt, to which the tide has access, it bears many salt-marsh plants.

CHAPTER II

THE PLANT-FORMATION OF CLAYS AND LOAMS

THESE soils may be defined as heavy or medium in texture, containing a large proportion of fine particles and a small proportion of coarse sand. Chemically they are either very poor or comparatively poor in lime. On one side they pass into the lighter sandy loams as the proportion of coarse sand increases, and on the other into the marls and calcareous clays with an increase in lime-content. In places where the ground-water is stagnant, as in hollows or on undrained flats, they become marshy and tend to give an acid reaction.

The distribution of such soils in England is very wide and extensive, particularly in the Midlands and the south-east, where the Secondary and Tertiary geological formations are mainly developed. Some of the more extensive clays are the Oxford and Kimeridge Clays of the Jurassic formation, the Weald Clay, the Gault, the London Clay, and the non-calcareous Boulder Clays of the north. The Clay-with-flints overlying the Chalk varies from a heavy clay to a light loam. The shales, which represent the clay-formations of the older rocks, bear a vegetation which, while resembling that of the clays in many respects, differs in important characters, and is considered as belonging to a different plant-formation.

The clays and loams, forming as they do many of the

plains and valleys of the country, were no doubt among the first soils to be disforested and cultivated, so that very little purely natural vegetation remains on any of them. Nowadays they are very largely under permanent pasture.

Pedunculate oakwood association (*Quercetum Roburis*). There can be little doubt that practically the whole of the clays and loams were at one time covered with oak-forest. All the woods still existing on these soils that have any claim to be considered natural or semi-natural are oakwoods, or clearly derived from oakwoods¹, except on wet ground, along streamsides, etc., where they pass into woods of the alder-willow association. Very few, if any, of these oakwoods have been left untouched by human interference, the great majority having been heavily exploited for timber in the past. During the last four centuries oak was in special demand for shipbuilding, and the extensive oak-forests of the Weald, and the south-east generally, suffered severely during this period, which witnessed the rise of the English navy and mercantile marine, because they were within easy reach of the Thames, the Medway, and the southern harbours in the neighbourhood of Portsmouth. The iron contained in the sands of the Wealden area has also been responsible, during the whole of the Middle Ages, for much forest destruction in this region. The iron was smelted and the iron articles were wrought in charcoal furnaces, and the primitive forests were destroyed wholesale for charcoal-making. Many place-names of the Weald, "Cinderhill Wood," "Hammer Wood," "Forge Coppice" and the like,

¹ Hornbeam (*Carpinus Betulus*) is dominant on clay and loamy soils in some parts of south-eastern England, and since this tree casts a deeper shade than the oak it is possible that the ground flora is affected sufficiently to admit of the separation of a hornbeam association. But no hornbeam wood has yet been studied thoroughly enough to admit of this being done at present.

still bear testimony to this extensive industry. In the absence of a proper system of forestry the result has been that the woods have mostly degenerated very seriously, and really good standard trees are now the exception.

The dominant tree is *Quercus Robur* L. (= *Q. pedunculata* Ehr.), which is the characteristic English tree of heavy and medium damp soils, though it also occurs freely on deep sands.

In the south of England and the Midlands the great majority of the oakwoods are in the form of copse (coppice-with-standards), the standards being generally oaks, and the coppice hazel, oak, ash, birch, etc. The standard oaks are generally far apart, so that their crowns do not touch and no close canopy is formed, but each tree has a free branching habit. This is supposed to be a relic of the old method of growing oak, which aimed at producing curved timber and "knee-pieces," useful in shipbuilding, as opposed to the long straight timber produced by trees grown in close canopy. In several of the various statutes designed to check the rapid exhaustion of the English oakwoods during the later Middle Ages, it is decreed that in coppicing "twelve standels" should be left to the acre, a number which would leave ample room for each tree to develop its full crown without interfering with its neighbours. The shade cast by the standard oaks in such a wood is not nearly so deep as that cast by oaks grown in close canopy, and the shrub-layer has thus plenty of light to develop fully (Plate I b).

In many of the existing copsewoods there are less than twelve oaks to the acre—some consist simply of coppice with an occasional standard, some of coppice alone. Many of these woods are very degenerate owing to their careless exploitation. When the soil is left exposed to the sun and wind, by excessive felling of standards or clearing of coppice, the humus layer is destroyed, and the soil either

becomes very weedy or cakes hard and becomes almost bare of vegetation. Under such conditions the natural regeneration of the wood from self-sown seed is checked or arrested, and unless the wood is properly taken in hand it degenerates to scrub and grassland. Such woods have often been extensively replanted with oak, ash and hazel, and sometimes with conifers. As was pointed out in the last chapter these oak-hazel copsewoods are not now commercially remunerative¹, though they are useful as furnishing a source of small wood, and to some extent of timber, for the local uses of the countryside, but their main importance in the eyes of their latterday owners is found in their use as pheasant-covers; the gamekeeper, not the woodman, is the important guardian.

The most abundant shrub of the coppice is the hazel (*Corylus Avellana*), and in very many cases
Shrub-layer. the coppice consists almost wholly of this plant. It is possible that the hazel was the dominant member of the shrub-layer in the primitive oakwoods from which the existing woods are derived, and it is pretty certain it was very abundant. Thus in certain fragments of uncoppiced woodland, supposed to represent remains of the old oak-forest of the Weald, the hazel is one of the commonest shrubs, though it is exceeded in numbers by sloe and hawthorn; but *pure* hazel coppice is probably an indication of planting. Hazel is a particularly good coppice shrub, making excellent and rapid growth from the stools, and the coppice shoots are used for a great variety of purposes. Among the coppice are found however various other species of shrub, such as willow (*Salix caprea*, *S. cinerea*) and dogwood (*Cornus sanguinea*), etc. Oak is often an abundant constituent of the coppice, as would be expected in copse derived from primitive

¹ It is even stated to be doubtful if oak in any form can be grown remuneratively in England in the present state of the market (Forbes, *The Development of British Forestry*, 1910, p. 192).

Phot. S. Mangham

- a. *Quercus Robur* (in close canopy). *Corylus Avellana*, *Crataegus monogyna*, *Rubus* spp., *Pteris aquilina*, *Digitalis purpurea*. Staffhurst Wood, Surrey, on Weald clay.

Phot. S. Mangham

- b. Oak-hazel wood; oaks in open canopy. *Corylus Avellana* (second year coppice), *Cnicus palustris*, *Euphorbia amygdaloides*, *Teucrium Scorodonia*, *Pteris aquilina*. Chevening Park, Kent, on clay-with-flints.

Pedunculate oakwood association (*Quercetum Roburis*).

oak-forest. The bark of coppiced oak formerly had a high value for tanning hides in the process of making leather. Ash (*Fraxinus excelsior*) and birch (*Betula tomentosa* and *B. alba*), frequent or abundant constituents of natural oakwood, are also often found among the coppiced shrubs, and so is maple (*Acer campestre*). Beech (*Fagus sylvatica*) and Spanish chestnut (*Castanea sativa*, planted) are occasionally met with, but are far more characteristic of the dry oakwoods.

Other very abundant members of the shrub-layer of the damp oakwood are hawthorn (*Cratægus monogyna*), sloe or blackthorn (*Prunus spinosa*), briars (*Rosa canina*, *R. arvensis*) and brambles (*Rubus fruticosus* agg.). These do not of course form coppice shoots and are largely absent from well-kept coppice.

The ground vegetation of the damp oakwood is conditioned very largely by the amount of light it obtains during the growing season. Under the shade of oak growing in close canopy, or of old (10—20 years) and well-grown hazel coppice, the vegetation is very open and consists exclusively of species which can endure deep shade (Plate I a, II a).

Ground vegetation.

In about 14 square yards (about 9·3 square metres) of oakwood, with the trees about 35 years old and growing in close canopy, in which the shrubs (hazel, sloe and hawthorn) were too deeply shaded to produce abundant foliage, the following species were found forming an open association, with much bare soil between the plants, on good mild humus above a loamy soil.

Trees.

Quercus Robur (3, and 2 seedlings).

Shrubs.

Prunus spinosa (several shrubs and many seedlings).

Cratægus monogyna (several shrubs and seedlings).

Corylus Avellana (1 shrub, 1 seedling).

Rubus sp. (several with trailing shoots).

Climbers.

Hedera Helix (abundant, trailing).

Lonicera Periclymenum (climbing on the oaks and trailing on the ground).

Tamus communis (one plant).

Herbs (in order of abundance).

Viola Riviniana (very abundant).

Pteris aquilina.

Euphorbia amygdaloides.

Teucrium Scorodonia.

Primula vulgaris.

Fragaria vesca.

Stellaria Holostea.

Bromus sterilis.

Ajuga reptans.

Lamium Galeobdolon.

Oxalis Acetosella.

Lathyrus montanus.

Dactylis glomerata.

Potentilla sterilis.

} One plant
of each.

The presence of such species as *Pteris aquilina* and *Teucrium Scorodonia* shows that the soil was distinctly light in this particular wood.

In more open situations many other species are found which cannot tolerate the deepest shade, though they may fairly be considered as woodland species.

Degenerate woods are often successfully invaded by plants from neighbouring associations, frequently by weeds from arable land and roadsides, and also show all transitions to the associations of scrubs and grassland.

The ground vegetation of regularly cut coppice shows a periodicity depending on the sudden change from the deep shade of old coppice to the brightly lighted conditions obtaining when the coppice has been cut, followed by a gradual return to shade as the coppice shoots grow up. In the first season after coppicing the vegetation generally shows no conspicuous change, but in the second and third years the ground becomes covered with an active vegetation, consisting partly of strong shoots sent up by plants whose underground parts have been lying dormant or vegetating but weakly, partly of plants produced by the germination of dormant seeds, and sometimes of new invaders from without. The continuous carpets of conspicuous social early-flowering species, such

as primrose (*Primula vulgaris*), bluebell (*Scilla non-scripta*), wood anemone (*Anemone nemorosa*), dog's mercury (*Mercurialis perennis*), red campion (*Lychnis dioica*), creeping bugle (*Ajuga reptans*), yellow archangel or weasel-snout (*Lamium Galeobdolon*), which arise in this way, form one of the best-known and most attractive features of our coppice-woods. Gradually, as the coppice grows up, this vegetation diminishes in vigour, till the paucity of species and individuals characteristic of old coppice is re-established.

The following is a fairly full, though it does not pretend to be an exhaustive, list, of the *Quercetum Roburis*, or damp oakwood of clays and loams.

Tree layer.

× <i>Quercus Robur</i> (=Q. pedunculata)	f d	<i>Fagus sylvatica</i> (generally planted)	l
<i>Fraxinus excelsior</i>	f	<i>Ulmus glabra</i> Huds. non Mill.	o
<i>Betula tomentosa</i>	f	<i>Taxus baccata</i>	r to o
<i>B. alba</i>	f	<i>Smaller trees.</i>	
<i>Populus tremula</i>	o to f	<i>Ilex Aquifolium</i>	o to a
<i>P. canescens</i>	l	<i>Pyrus Malus</i>	f
<i>Alnus rotundifolia</i>	l	× <i>Acer campestre</i> (generally coppiced)	f to a
× <i>Carpinus Betulus</i>	d l or l d	<i>Pyrus torminalis</i>	l
<i>Prunus Avium</i>	f		

Shrub layer.

× <i>Corylus Avellana</i>	a	<i>Juniperus communis</i>	o
× <i>Crataegus monogyna</i>	o a	× <i>Rubus spp.</i>	a
× <i>Prunus spinosa</i>	a	<i>Rosa canina</i>	a
<i>Salix caprea</i>	f	<i>R. arvensis</i>	a
<i>S. cinerea</i>	f	<i>Ligustrum vulgare</i> (often planted)	o
<i>S. aurita</i>	l	<i>Ulex europæus</i> (an invader)	o
<i>Cornus sanguinea</i>	o to f	<i>Rhamnus Frangula</i>	r
<i>Viburnum Opulus</i>	o		

Climbers.

<i>Lonicera Periclymenum</i>	a	<i>Calystegia sepium</i>	f
<i>Hedera Helix</i>	a	× <i>Tamus communis</i>	f

Ground vegetation (no single species generally dominant).

<i>Anemone nemorosa</i>	lsd	<i>R. Ficaria</i>	a
<i>Ranunculus auricomus</i>	lab	<i>R. repens</i>	f
× <i>Epipactis atrorubens</i>			6

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<i>Cardamine flexuosa</i>	o	<i>Veronica Chamædrys</i>	a
<i>C. pratensis</i> (Kent)	la	<i>V. montana</i>	f
<i>Viola Riviniana</i>	a	<i>V. officinalis</i>	a
<i>Lychnis dioica</i>	a	<i>Melampyrum pratense</i>	a
<i>Stellaria Holostea</i>	a	<i>Lathræa squamaria</i>	lf
<i>Arenaria trinervia</i>	a	<i>Nepeta Glechoma</i>	a
<i>Hypericum perforatum</i>	f to ab	<i>Teucrium Scorodonia</i>	la
<i>H. hirsutum</i>	o	<i>Prunella vulgaris</i>	a
<i>Geranium Robertianum</i>	f	<i>Stachys Betonica</i>	f
<i>Oxalis Acetosella</i>	f	<i>S. sylvatica</i>	f
<i>Vicia sepium</i>	a	<i>Lamium Galeobdolon</i>	la
<i>V. Cracca</i>	f	<i>Polygonum Hydropiper</i>	la
<i>Lathyrus montanus</i>	a	<i>Ajuga reptans</i>	a
<i>Spiræa Ulmaria</i>	o	<i>Rumex viridis</i>	a
<i>Geum urbanum</i>	a	<i>Euphorbia amygdaloides</i>	l
<i>Fragaria vesca</i>	l	<i>Mercurialis perennis</i>	la
<i>Potentilla erecta</i>	l	<i>Urtica dioica</i>	la
<i>P. sterilis</i>	la	<i>Daphne Laureola</i>	l
<i>Circaea lutetiana</i>	a	<i>Listera ovata</i>	f
<i>Sanicula europæa</i>	f	<i>Orchis mascula</i>	o
<i>Angelica sylvestris</i>	f	<i>Allium ursinum</i>	l
<i>Heracleum Sphondylium</i>	a	<i>Scilla non-scripta</i>	lsd
<i>Adoxa Moschatellina</i>	lf	<i>Luzula pilosa</i>	a
<i>Asperula odorata</i>	o	<i>Arum maculatum</i>	la
<i>Valeriana sambucifolia</i>	o	<i>Carex sylvatica</i>	la
<i>Dipsacus sylvestris</i>	o	<i>C. lævigata</i>	lf
<i>Scabiosa Succisa</i>	a	<i>Anthoxanthum odoratum</i>	la
<i>Solidago Virgaurea</i>	o	<i>Milium effusum</i>	o
<i>Arctium spp.</i>	a	<i>Deschampsia cæspitosa</i>	a
<i>Cnicus palustris</i>	f	<i>Arrhenatherum elatius</i>	f
<i>Lactuca muralis</i>	o	<i>Melica uniflora</i>	a
<i>Primula vulgaris</i>	a	<i>Dactylis glomerata</i>	a
<i>Lysimachia nemorum</i>	lf	<i>Bromus giganteus</i>	f
<i>L. Nummularia</i>	o	<i>B. ramosus</i>	f
<i>Vinca minor</i>	ld	<i>B. sterilis</i>	f
<i>Centaurium umbellatum</i>		<i>Brachypodium gracile</i>	
(= <i>Erythræa Centau-</i>		(= <i>B. sylvaticum</i>)	■
<i>rium</i>)	a	<i>Pteris aquilina</i> (on light	
<i>Myosotis arvensis</i> (= <i>M.</i>		soils)	lsd
<i>intermedia</i>)	a	<i>Lastrea Filix-mas</i>	f
<i>M. sylvatica</i>	l	<i>L. aristata</i> (= <i>L. dilatata</i>)	l
<i>Scrophularia aquatica</i>	f	<i>L. spinulosa</i>	l
<i>S. nodosa</i>	o	<i>Athyrium Filix-fœmina</i>	l

Phot. A. G. Tansley

- a. Oakwood association (prevernal aspect). *Primula vulgaris*. Staff-hurst Wood, Surrey, on Weald clay.

Phot. A. G. Tansley

- b. Oaks and neutral pasture. *Quercus Robur* (characteristic habit grown in the open), *Taxus baccata*. Edge of wood, same locality.

No attempt has been made in the above list to separate the vegetation of woods on heavy clays from those on light loams, although there are very considerable differences, because the data at present available are insufficient to carry out such a separation satisfactorily. The woods on light loams have something in common with the dry oakwoods (p. 92), though the fresh moist soil distinguishes them. Such plants as *Anthoxanthum odoratum*, *Pteris aquilina*, *Scilla non-scripta*, *Anemone nemorosa*, *Veronica officinalis*, *Teucrium Scorodonia* belong to these oakwoods of lighter soils.

SUBORDINATE (RETROGRESSIVE) ASSOCIATIONS (Plate II b)

On the edges of damp oakwoods which have been carelessly exploited a scattered scrub is commonly found with spaces of turf between the clumps of bushes, and an occasional isolated oak-tree. This vegetation represents degenerate oakwood from which the trees have nearly or quite disappeared, and in accordance with the principles laid down in the introduction must be reckoned as belonging to the same formation. The genetic relationship of this scrub and grassland with the oakwood association is quite obvious to any careful observer, and the floristic relationship is also clear, as will be seen immediately.

Scrub association. This may consist of any of the species of the shrub-layer of the damp oakwood, but *Cratægus monogyna*, *Prunus spinosa*, *Rubus* spp., *Rosa* spp., and *Ulex europæus* are much the most abundant. It will be noticed that all of these are spiny species, and the dominance of such species is probably due to the fact that they are protected by their spines from browsing animals; since this kind of land is very commonly used for pasturage. The bushes often form dense impenetrable clumps, which appear to possess a considerable degree of permanence, and, in the shelter of these, less protected shrubs often

flourish. Shade plants of the oakwood association are also often found within the shelter of the bushes.

Neutral grassland association (*Graminetum neutrale*). This is the ultimate phase of degeneration of damp oakwood. It consists of a close turf of grasses with associated herbaceous plants. The term "neutral" is intended to express the fact that this type of grassland is free from the characteristic plants of calcareous pasture on the one hand and of acid heath pasture on the other. Neutral grassland is practically always heavily grazed, and this of course must modify its composition and character to some extent, but as yet it has scarcely been studied. Many of the "commons" and village greens of central and southern England consist of the neutral grassland (pasture) association with or without the scrub described above. The severe grazing that such land usually suffers, apart from the greater exposure to light and drought, scarcely allows of the persistence of many members of the ground vegetation of the oakwood, but in places which escape such treatment woodland plants, *e.g.* *Scilla non-scripta*, *Anemone nemorosa*, *Primula vulgaris* and others, may be found in such grassland.

The following is a list of species found in neutral grassland (including meadowland)¹. As in the case of the list for damp oakwoods, it includes species found on a fairly wide range of soils in respect of texture and

¹ Manuring of various kinds has of course a very important effect on the vegetation of grassland. Pasturage itself always involves manuring by the dung and urine of the animals, while the effect of artificial manuring varies according to the kind and amount of the manure employed. Very extensive data for the study of these effects have been collected as the result of the long-continued experiments at the Rothamsted Experimental Station. In general it may be said that heavy long-continued manuring reduces the number of species occurring in the grassland, while special kinds of "one-sided" manuring sometimes lead to the introduction of fresh species. A comparative study of the British grasslands from the ecological standpoint is very much needed.

dampness. Probably the association should be divided into more than one sub-association, but the *data* to hand are insufficient to justify such a division. The words "damp" and "dry" are prefixed to the names of the species whose proclivities in regard to soil-moisture are apparently most marked.

<i>Dominant Grasses.</i>			Lotus corniculatus	a
	Lolium perenne		Vicia tetrasperma	o
dry	Cynosurus cristatus		V. angustifolia	o
	Anthoxanthum odoratum		Lathyrus Nissolia	o
	Dactylis glomerata		L. pratensis	a
	Holcus lanatus	dry	Potentilla erecta	o
damp	Alopecurus pratensis	dry	P. reptans	a
	Bromus mollis	dry	P. mixta	l
	Festuca duriuscula		P. anserina	la
<i>Other Grasses.</i>			Alchemilla vulgaris	r
	Agrostis tenuis (vulgaris) f		Agrimonia Eupatoria	f
	A. alba f		A. odorata	o
	Poa pratensis f	damp	Saxifraga granulata	l
damp	P. trivialis la	dry	Conopodium denudatum	la
	Phleum pratense f	dry	Pimpinella Saxifraga	f
	Arrhenatherum elatius f		Anthriscus sylvestris	l
			Silva flavescens	o
dry	Ranunculus bulbosus a		Heracleum Sphondylium	f
	R. acris a	dry	Daucus Carota	o
	R. repens a	dry	Galium verum	o
damp	Cardamine pratensis la		Dipsacus sylvestris	f
	Polygala vulgaris o		Scabiosa succisa	a
	Cerastium triviale a		S. arvensis	f
	C. glomeratum a		Bellis perennis	a
	Stellaria graminea o	damp	Pulicaria dysenterica	f
	Hypericum perforatum f		Achillea Millefolium	a
	H. tetrapterum o	damp	A. Ptarmica	l
	Malva moschata o		Chrysanthemum Leu-	
dry	Linum catharticum la		canthemum	la
	Geranium pratense o		Tussilago Farfara	la
	Genista tinctoria l	dry	Senecio Jacobæa	a
	Ononis repens o		S. erucifolius	o
	Trifolium pratense a		Cnicus palustris	a
	T. medium o		Hypochaeris radicata	a
	T. repens a		Crepis virens	a
dry	T. dubium a		Leontodon hispidum	f

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	<i>L. autumnalis</i>	a		<i>Prunella vulgaris</i>	a
dry	<i>Hieracium Pilosella</i>	la	damp	<i>Ajuga reptans</i>	a
	<i>H. boreale</i>	f		<i>Plantago lanceolata</i>	a
	<i>Taraxacum officinale</i>	a	dry	<i>P. media</i>	o
	<i>Tragopogon pratense</i>	la		<i>Rumex Acetosa</i>	a
dry	<i>Campanula rotundifolia</i>	l		<i>Spiranthes spiralis</i> (=S.	
	<i>Primula veris</i>	la		<i>autumnalis</i>)	o
	<i>Centaurium umbellatum</i>	la		<i>Orchis mascula</i>	la
	<i>Myosotis arvensis</i> (=M.		damp	<i>O. maculata</i>	la
	<i>intermedia</i>)	a		<i>Narcissus Pseudo-nar-</i>	
damp	<i>Veronica serpyllifolia</i>	a		<i>cissus</i>	l
	<i>V. Chamædrys</i>	a		<i>Colchicum autumnale</i>	l
	<i>V. officinalis</i>	a		<i>Carex ovalis</i>	f
	<i>Euphrasia officinalis</i> (agg.)	a		<i>C. flacca</i> (=C. <i>glauca</i>)	a
	<i>Bartsia Odontites</i>	a	damp	<i>C. pallescens</i>	l
	<i>Rhinanthus Crista-galli</i>	la		<i>C. panicea</i>	f
	<i>Melampyrum pratense</i>	f		<i>Ophioglossum vulgatum</i>	o
dry	<i>Thymus Serpyllum</i> (agg.)	la		<i>Equisetum arvense</i>	o
	<i>Nepeta Glechoma</i>	f			

Juncetum communis. On low-lying clayey soils the ground-water frequently approaches the surface and where this is the case the typical pasture or meadow-land passes into an association nearly always marked by a predominance of species of *Juncus*, *J. conglomeratus* and *J. effusus*, frequently with *J. articulatus*, *J. bufonius*, and *J. glaucus*. Other species found in this association are :

<i>Ranunculus flammula</i>	a	<i>E. palustre</i>	f
<i>R. repens</i>	a	<i>Hydrocotyle vulgaris</i>	a
<i>R. sceleratus</i>	f	<i>Galium palustre</i>	f
<i>R. hederaceus</i>	f	<i>G. uliginosum</i>	l
<i>Caltha palustris</i>	f	<i>Gnaphalium uliginosum</i>	f
<i>Nasturtium</i> spp.	f	<i>Bidens cernua</i>	o
<i>Cardamine pratensis</i>	a	<i>B. tripartita</i>	o
<i>Lychnis Flos-cuculi</i>	a	<i>Petasites officinalis</i>	f
<i>Stellaria uliginosa</i>	o	<i>Senecio aquaticus</i>	f
<i>Lotus uliginosus</i>	f	<i>Lysimachia nummularia</i>	l
<i>Spiræa Ulmaria</i>	la	<i>Scrophularia aquatica</i>	a
<i>Callitriche stagnalis</i>	a	<i>Veronica scutellata</i>	
<i>Epilobium parviflorum</i>	f	and <i>var. hirsuta</i>	l

<i>Pedicularis sylvatica</i>	l	<i>C. panicea</i>	f
<i>Mentha aquatica</i> , etc.	a	<i>C. lævigata</i>	o
<i>Polygonum Hydropiper</i>	a	<i>C. Goodenowii</i>	f
<i>P. amphibium</i>	f	<i>C. flava</i> (agg.)	f
<i>P. Persicaria</i>	a	<i>Alopecurus fulvus</i>	r
<i>Orchis maculata</i> (agg.)	f	<i>A. geniculatus</i>	f
<i>Iris Pseudacorus</i>	o	<i>Glyceria fluitans</i>	f
<i>Triglochin palustre</i>	o	<i>Deschampsia cæspitosa</i>	f
<i>Eleocharis palustris</i>	f	<i>Poa trivialis</i>	f
<i>Carex vulpina</i>	f	<i>Equisetum maximum</i>	o
<i>C. remota</i>	f	<i>E. palustre</i>	f
<i>C. ovalis</i>	f	<i>E. limosum</i>	o

This association forms a transition to the herbaceous marsh association (p. 207).

CHAPTER III

THE VEGETATION OF THE COARSER SANDS AND SANDSTONES¹

Physical characters of sands and sandstones. THE very fine-grained sands and sandstones have much in common physically with clays, since they are close-textured and retain a large proportion of water. In the case of fine-grained sands, such as alluvial sands, and soft fine-grained sandstones which weather so as to produce a considerable depth of soil, the vegetation is of the same general type as that dealt with in the last chapter. The impure sandstones, containing a large proportion of clay particles in addition to the grains of silica, give rise on weathering to sandy loams, which also bear the same general plant-covering; if, on the other hand, there is a large proportion of lime, as in the calcareous sandstones, the vegetation is altered and belongs to the type characteristic of calcareous soils. But the fairly pure, coarse-grained sands and the geologically more recent sandstones have a well-defined vegetation of their own.

Coarse sandy soil is a dry soil, because it has little water-capacity, a feeble power of holding up ground-water by capillarity and suffers from rapid evaporation.

¹ The vegetation of the harder, *i.e.* older, (Palæozoic) sandstones and grits is treated separately (Chapter V).

It is also frequently poor in nutritive salts. In a very dry climate such a soil is particularly unfavourable to vegetation because it cannot form humus. In a climate with a considerable rainfall the surface-layers of soil tend to be very poor in soluble nutritive salts because these salts are washed out by the percolation of rainwater. Owing to the deficiency in lime and other bases such soils tend to form and accumulate acid humus which immediately affects the vegetation, as we shall see in the sequel. Under certain circumstances however, when there is a high level of well aerated ground-water and a fair proportion of soluble salts, mild humus is formed and the soil may be very fertile, as in the case of many alluvial sands, which form good meadowland, and are excellent for certain kinds of cultivation.

The more recent (Secondary, Tertiary and post-Tertiary) coarse-grained sands and sandstones occur almost exclusively in the southern and eastern parts of England and in the Midlands. Some of the more extensive and characteristic examples are the Bunter Sandstone of the Trias (Midlands), the Lower Greensand (Cretaceous) in the eastern Midlands and south-east, the Ashdown Sand belonging to the Wealden series, the Bagshot and other Eocene sands of the London and Hampshire basins, the Pliocene "Crag" of East Anglia, and various "valley" and "plateau gravels" deposited at intervals during post-Tertiary times, and resting on different older rocks.

The most generally characteristic feature of the vegetation of these newer sands and sandstones is the prevalence of heathland. On some of them indeed (e.g. the East Anglian sands) no woodland which has really good claims to be considered natural has yet been recognised, and it may be that *Calluna*-heath and grass-heath (heath pasture) is

**Distribution
of the newer
sands and
sandstones.**

**Heath and
woodland.**

the highest type of plant-community these soils have developed, though it is also possible that they have been completely disforested. But in many cases there is a well-marked natural woodland-type characteristic of coarse sandy soils. Such woodland generally alternates with heathland or dry grassland, which often occupies its edges and open places within the wood and bears the same relation to the wood that neutral pasture bears to damp oakwood. In other words much heathland as well as dry heathy grassland is clearly degenerate woodland of a certain type, while other heathland is possibly primitive. It is frequently difficult or impossible to decide whether the heathland is primitive or has been derived from woodland.

The occupation of a sandy soil by the heath-community is connected with an important modification of the habitat by the accumulation of a comparatively dry acid peaty humus (*Trockentorf*) in or on the surface soil. The formation of this characteristic type of humus excludes many species of plants from the flora, and at the same time introduces a well-defined vegetation of its own. These facts make it necessary to recognise the existence of a new plant-formation, the heath-formation, allied to the moor-formation but characteristic of a drier climate or of drier edaphic conditions. Where woodland degenerates into heath we must therefore recognise a case of succession in which one formation is replaced by another.

The researches of Wollny, P. E. Müller, Ramann, Graebner and others have made it probable that the fundamental cause of the degeneration of woodland into heath in north-west Germany (and it is natural to extend their conclusions to south-east England, which has much the same climate, and often repeats the same edaphic features) is the slow washing out or leaching of the sandy soil.

A brief account of the main features of this process may be quoted. According to Graebner, **Degeneration of woodland.** "when there is a rainfall of 70 cm. (28 inches) or more... the surface-layers are being continually impoverished in mineral salts by washing out or 'leaching,' and the typical plants of the forest-floor are thus starved and give way before the invasion of mosses and shade-bearing heath plants. The matting together of the surface-layers of soil by the rhizoids and rootlets of the invaders prevents the access of oxygen to the soil, and leads to the accumulation of 'acid humus' or 'dry peat' (*Rohhumus*) in place of the original mild humus of the woodland soil. Thus we have the formation of a type of wood with a heathy vegetation, poor in species, on a soil composed of a mixture of sand and dry acid humus or peat. Finally, according to Graebner, either by the leaching of the soil to such a depth that the roots of the trees can no longer obtain enough food, or by the formation below the surface of a layer of 'Ortstein' (moor pan), *i.e.* a hard layer of sand bound together by humous compounds, which the roots of the trees cannot penetrate, the rejuvenation of the wood is rendered impossible, the gaps formed by the dying of the old trees are not filled up, and the forest is eventually replaced by heath¹."

If we assume that this secular process of the impoverishment of sandy soils has been going on since the glacial period, it is easy to see that, acting on a series of soils of varying original constitution, it will produce a vegetation showing many local differences at any given period.

While some very barren sands may have been originally colonised by heath, others which originally bore woodland may have become occupied by heath before the beginning of the historical period; others again have

¹ Moss, Rankin and Tansley, 1910 : pp. 132, 133.

certainly degenerated into heathland during the last few centuries, while yet others are only now beginning to show the changes preparatory to this transformation.

It is generally admitted that the process is greatly accelerated by the extensive felling of trees and clearing of woodland on these soils. Clearing leads to the rapid destruction of the mild woodland humus, and thus facilitates the entrance of the pioneers of the heath vegetation. This factor has certainly been fully operative in the conversion of many of the British woodlands to heath.

We will now see how far the plant-associations of our sandy soils can be interpreted in the light of these general considerations.

THE PLANT-FORMATION OF SANDY SOIL

Dry sandy oakwood association (*Quercetum arenosum Roburis et sessilifloræ*). This association is developed on many of the sands and sandstones mentioned. The soil is much poorer in humus than that of the damp oakwood on clays and loams, and the association is much poorer floristically. The following is a list of the more characteristic and commoner species.

<i>Tree layer. Dominant.</i>		<i>Other trees.</i>	
✓ Quercus Robur (= Q. pedunculata), or		Betula tomentosa	a
Q. sessiliflora (mainly shallow soils), or		× B. alba	f
Q. Robur and Q. sessiliflora co-dominant (and hybrids)		× B. pubescens	f
		Populus tremula	o
		× Ilex Aquifolium	a
		Pyrus Aucuparia	f
		Pyrus Aria	o
× Fagus sylvatica	ld		
<i>Shrub layer.</i>			
Cratægus monogyna	a	Rubus rusticanus, etc.	f
Prunus spinosa	f to a	Ulex europæus	o
Rubus Idæus	f	Cytisus scoparius	f
		Lonicera Periclymenum	a

Phot. S. Mangham

a. *Betula tomentosa*, *Pteris aquilina*, *Holcus mollis*, *Anthoxanthum odoratum*, etc.

Phot. R. S. Adamson

b. *Quercus Robur*, *Pteris aquilina*, *Holcus mollis* (May).

Dry oakwood (*Quercetum Roburis arenosum*).
Gamlingay Wood, Cambs., on glacial sandy loam.

Ground vegetation.

<i>Anemone nemorosa</i>	lsd
<i>Viola Riviniana</i>	a
<i>Hypericum pulchrum</i>	f
<i>H. perforatum</i>	f
<i>Oxalis Acetosella</i>	f
<i>Sedum Telephium</i>	o
<i>Potentilla erecta</i>	a
<i>P. sterilis</i>	f
<i>Epilobium angustifolium</i>	la
<i>E. montanum</i>	f
<i>Conopodium majus</i>	f
<i>Galium saxatile</i>	f
<i>Solidago Virgaurea</i>	f
<i>Hieracium vulgatum</i> (agg.)	f
<i>H. boreale</i>	f
<i>Ruscus aculeatus</i>	f

<i>Centaureum umbellatum</i>	(= <i>Erythræa Centaurium</i>)	o
<i>Digitalis purpurea</i>		f
<i>Veronica officinalis</i>		a
<i>Melampyrum pratense</i>		f
<i>Teucrium Scorodonia</i>		a
<i>Rumex Acetosella</i>		f
<i>Convallaria majalis</i>		r
<i>Scilla non-scripta</i>		lsd
<i>Luzula pilosa</i> (= <i>L. verna-</i> <i>lis</i>)		f
<i>X. Holcus mollis</i>		ld
<i>Agrostis vulgaris</i>		a
<i>Anthoxanthum odoratum</i>		f
<i>Pteris aquilina</i>		ld
<i>Blechnum Spicant</i>		f

The species especially associated with the heath-formation which are often found in the dry oakwood (see p. 99) are excluded from this list.

It will be seen that this association, though frequently with the same dominant, differs decidedly from the damp oakwood association. Thus *Quercus Robur* is often associated with *Q. sessiliflora* (which is practically never found in the typical damp oakwood on clays and loams) while the beech often forms pure societies, reducing the undergrowth to a minimum. The birches are typically more abundant (Plate III a), while *Pyrus Aucuparia* is characteristic. On the other hand the association has many fewer species of trees and shrubs. The ash and the hazel (except apparently where planted¹) are generally scarce or absent. The same may be said of practically all the other damp oakwood shrubs, except the hawthorn (*Crataegus monogyna*) and the sloe or blackthorn (*Prunus spinosa*).

The ground vegetation also is much poorer and is

¹ Oak-hazel copse is found pretty frequently on fairly dry soil accompanied by the typical dry oakwood ground flora. This is probably due to planting.

naturally characterised by absence of the great number of woodland species which frequent damp soils. Societies of *Pteris aquilina*, *Holcus mollis* (Plate III b), and *Scilla non-scripta* are characteristic. *Potentilla erecta*, *Digitalis purpurea*, *Hypericum pulchrum*, *Galium saxatile* and *Solidago Virgaurea* are also specially characteristic.

Changes in the level of the ground-water, owing to the slope of the ground, sometimes lead to the alternation of the damp and dry oakwood associations in the same wood within very short distances.

SUBORDINATE ASSOCIATIONS

Just as in the case of the formation of clays and loams, so here, there are retrogressive associations, consequent on clearing of the woodland, and represented by scrub and grassland. These are largely represented on the sandy "commons" of southern England just as the neutral pasture and corresponding scrub are represented on the commons on clay soil.

Scrub-association. This is dominated by the shrubs of the dry oakwood whose spines protect them from destruction by browsing cattle, *i.e.* *Cratægus monogyna*, *Prunus spinosa*, *Ulex europæus* and *Rubus* spp. The association consequently closely resembles the corresponding member of the plant-formation of clay and loam.

The gorse (*Ulex europæus*) is perhaps the most abundant and characteristic member of the scrub association. It is frequently a pure dominant on the sandy commons referred to, forming a close scrub under the shade of which little can grow. The gorse actively spreads from seed and forms a progressive society colonising the grass heath association, where it flourishes much more vigorously than under the partial shade of the dry oakwood.

Grass heath association (*Graminetum arenosum*). This association generally forms a close short turf,

commonly dominated by the so-called "heath grasses," *i.e.* those inhabiting sandy soil. The tracts of country occupied by this association are often called "heaths¹," although the true heath plants (*Calluna*, *Erica*, etc.) may be entirely lacking, but all transitions are found between the grass heaths and the *Calluna*-heaths. It seems probable that the difference is determined in the first place by the amount of lime and other soluble salts in the sandy soil.

The association is characterised by a great number of dicotyledons, very largely annual, and often early flowering ephemeral species. Sometimes indeed these are so numerous that the grasses cannot be said to be dominant at all. Many of these species are central European forms which in this country are confined to south-eastern England.

On very dry grass heaths no close turf is formed and much open soil is exposed. Such places are frequently invaded by weeds from neighbouring sandy arable land.

The following is a list of species occurring in the grass heath association:—

<i>Ranunculus bulbosus</i>	f	<i>Arenaria serpyllifolia</i>	f
<i>Corydalis claviculata</i>	o	<i>A. tenuifolia</i>	r
<i>Cardamine hirsuta</i>	f	<i>Sagina procumbens</i>	f
<i>Erophila verna</i> (agg.)		<i>S. apetala</i>	f
(= <i>Draba verna</i>)	a	<i>S. ciliata</i>	o
<i>Teesdalia nudicaulis</i>	o	<i>S. subulata</i>	r
<i>Viola Riviniana</i>	a	<i>Stellaria graminea</i>	f
<i>V. canina</i> (= <i>V. ericetorum</i>)	o	<i>Hypericum pulchrum</i>	f
<i>Polygala vulgaris</i> (agg.)	f	<i>H. humifusum</i>	o
<i>Dianthus Armeria</i>	r	<i>H. perforatum</i>	f
<i>D. deltoides</i>	r	<i>Malva rotundifolia</i>	f
<i>D. prolifer</i>	vr	<i>Linum catharticum</i>	f
<i>Cerastium arvense</i>	o	<i>Geranium molle</i>	f
<i>C. triviale</i>	a	<i>G. pusillum</i>	o
<i>C. semidecandrum</i>	la	<i>G. dissectum</i>	f
<i>Moenchia erecta</i> (= <i>Cerastium</i>		<i>Erodium cicutarium</i>	f
<i>quaternellum</i>)	l	<i>Ulex europæus</i>	la
<i>Spergularia rubra</i>	f	<i>Cytisus scoparius</i>	la

¹ This term is even used in East Anglia for tracts of chalk pasture, *e.g.* Royston Heath, Newmarket Heath.

<i>Ononis repens</i>	f	<i>L. autumnale</i>	a
<i>Medicago lupulina</i>	f	<i>Taraxacum erythrospermum</i>	f
<i>M. denticulata</i>	r	<i>Carduus nutans</i>	o
<i>M. arabica</i>	r	<i>Cnicus lanceolatus</i>	f
<i>M. minima</i>	r	<i>Carlina vulgaris</i>	la
<i>Trifolium subterraneum</i>	o	<i>Jasione montana</i>	la
<i>T. procumbens</i>	o	<i>Campanula rotundifolia</i>	o
<i>T. dubium</i> (= <i>T. minus</i>)	f	<i>Calluna vulgaris</i>	o
<i>T. filiforme</i>	f	<i>Erica cinerea</i>	o
<i>T. arvense</i>	f	<i>Centaureum umbellatum</i>	
<i>Lotus corniculatus</i>	a	(= <i>Erythræa Centaureum</i>)	f
<i>Ornithopus perpusillus</i>	la	<i>Myosotis collina</i>	f
<i>Vicia lathyroides</i>	o	<i>M. versicolor</i>	f
<i>V. angustifolia</i> , <i>var. Bobartii</i>	f	<i>Veronica officinalis</i>	a
<i>Prunus spinosa</i>	f	<i>V. arvensis</i>	f
<i>Rubus spp.</i>	a	<i>V. verna</i>	vr
<i>Potentilla sterilis</i>	f	<i>Euphrasia officinalis</i> (agg.)	a
<i>P. erecta</i>	a	<i>Teucrium Scorodonia</i>	la
<i>P. argentea</i>	o	<i>Thymus Serpyllum</i> (agg.)	la
<i>Alchemilla arvensis</i>	f	<i>T. ovatus</i>	f
<i>Rosa spp.</i>	f	<i>Plantago Coronopus</i>	o
<i>Saxifraga tridactylites</i>	la	<i>P. lanceolata</i>	a
<i>Sedum acre</i>	o	<i>Scleranthus annuus</i>	la
<i>S. anglicum</i>	o	<i>Rumex Acetosella</i>	a
<i>Pimpinella Saxifraga</i>	f	<i>Allium vineale</i>	o
<i>Conopodium majus</i> (= <i>C.</i> <i>denudatum</i>)	a	<i>Scilla autumnalis</i>	vr
<i>Daucus Carota</i>	f	<i>Luzula campestris</i>	a
<i>Galium verum</i>	la	<i>L. multiflora</i>	o
<i>G. saxatile</i> (= <i>G. hercynicum</i>)	la	<i>Carex arenaria</i> (rare inland but)	ld
<i>Achillea Millefolium</i>	a	<i>C. divulsa</i>	o
<i>Filago minima</i>	o	<i>C. binervis</i>	l
<i>Gnaphalium sylvaticum</i>	o	<i>C. pilulifera</i>	o
<i>Bellis perennis</i>	a	<i>C. verna</i>	f
<i>Senecio Jacobæa</i>	la	<i>Anthoxanthum odoratum</i>	la
<i>S. sylvaticus</i>	l	<i>Agrostis canina</i>	la
<i>Hieracium Pilosella</i>	a	<i>A. setacea</i>	la ¹
<i>H. boreale</i> (agg.)	f	<i>A. tenuis</i> (= <i>A. vulgaris</i>)	ld
<i>H. umbellatum</i> (agg.)	o	<i>Aira caryophyllea</i>	f
<i>Hypochæris radicata</i>	a	<i>A. præcox</i>	f
<i>H. glabra</i>	a	<i>Deschampsia flexuosa</i>	la
<i>Leontodon hispidum</i>	f	<i>Sieglingia decumbens</i>	la
<i>L. nudicaule</i> (<i>hirtum</i>)	o	<i>Festuca ovina</i>	la
		<i>Pteris aquilina</i>	ld

¹ South-west England.

The East Anglian "heaths," particularly those in the neighbourhood of Mildenhall, Brandon and Thetford, include considerable stretches of dry grassland which are not however quite typical grass heaths, such plants as *Agrostis canina* and *Deschampsia flexuosa* and several other typical grass heath species being absent. The soil often contains appreciable quantities of lime. These areas of grassland alternate with true (*Calluna*) heath. The region has a low rainfall (less than 25 inches *per annum*) and exhibits the nearest approach to steppe-conditions to be found within the British Isles. The vegetation tends to be sparse and the tufts of ling or grass are often wide apart, the intervening spaces bearing a scattered vegetation of ephemerals. It is doubtful if this area ever bore natural woodland.

The existence of widespread steppe conditions, subsequently to the glacial period, is now generally recognised. Between the glacial period and this steppe period, a fairly warm epoch intervened, with the coast-line not far from its present position. In the steppe period a considerable elevation occurred, and much of the North Sea was land. Such a period was favourable to the accumulation of loose sands, like those of the Mildenhall district, and there is evidence that the formation of these sands has been going on for some time. A steppe flora must have been widely distributed during the steppe period, and as we find fossil steppe mammalia in England, we should expect that steppe plants also occurred here. If we have survivors of the glacial flora under suitable conditions, we should expect survivors of the more recently arrived steppe flora also. The Mildenhall sandy tract has several plants not found elsewhere in Britain and these may well be the survivors of that flora¹.

The following plants are confined, or nearly confined, within the British Isles, to this region :—

<i>Silene Otites</i>	<i>Veronica verna</i>
<i>S. conica</i>	<i>V. triphyllos</i>
<i>Holosteum umbellatum</i>	<i>Muscari racemosum</i>
<i>Medicago Falcata</i>	<i>Ornithogalum umbellatum</i>
<i>M. sylvestris</i>	<i>Carex ericetorum</i>
<i>Artemisia campestris</i>	

¹ The editor is indebted for this paragraph to Dr J. E. Marr.

CHAPTER IV

THE HEATH FORMATION

**Distribution
of the heath
formation.** THE great heath formation of north-west Europe is typically developed on relatively poor sandy and gravelly soils whose climate is wetter than that which gives rise to steppe. The steppe climate is too dry for tree growth, apart from local edaphic conditions, but the heath formation exists side by side with woods and in many cases has arisen as the result of the degeneration of woodland.

Heath is developed in north-west Germany, Jutland and the Baltic islands, Belgium and Holland, northern and western France and southern and eastern England and Scotland. Most of the German, Belgian and southern and eastern English heaths occur in regions with an annual rainfall between 25 inches and 40 inches (c. 60 to 100 cm.), but the Cornish heaths and those of the eastern Highlands of Scotland often receive a rainfall of between 40 and 60 inches (c. 100 to 150 cm.) in the year. We do not accurately know what is the upper limit of rainfall consistent with the formation of heathland; above the minimum (c. 25 inches) the heath formation is mainly determined by the nature of the soil, though the scarcity of heaths on the western side of Scotland, northern England, Wales and Ireland where there are considerable tracts of country with an annual

rainfall exceeding 60 inches probably has a real significance¹. The Scottish heaths develop a deeper layer of relatively pure acid humus, up to 8 or 12 inches (20 to 30 cm.) according to Hardy, and have much in common with the *Calluna* moor of the Pennines (see p. 113).

At the other extreme we have the East Anglian heaths with an annual rainfall of 25 inches or less, and a minimum of dry peat formation. Between these extremes come the heaths of the south-eastern counties and those of the New Forest and Dorsetshire, with a layer of dry peat seldom more than a fraction of an inch in thickness passing down into sand darkened by humus. The surface layer of dry peat is largely formed by lichens and mosses (e.g. *Cladonia rangiferina*, *Polytrichum piliferum*, and other species) which are the pioneers in reconstituting the heath association on bared soil, as can be well seen where the vegetation is destroyed by digging for gravel.

It is possible that the heath formation originally colonised many tracts of the poorer English sands, e.g. the Pliocene "crag" and some of the more recent Quaternary sands and gravels of East Anglia and the south, perhaps also the Eocene Bagshot sand. If so, these sands, or at any rate parts of them, have never borne natural woodland.

But apart from this possibility there is no doubt that the heath formation is constantly successfully invading and eventually replacing the natural woodland of many sandy soils. The causes and course of this process have already been briefly discussed.

Within the dry oakwood association, more or less isolated patches of heath vegetation are often found, with bilberry (*Vaccinium Myrtillus*), the characteristic heath grass *Deschampsia flexuosa*, and in well-lighted spots the ling (*Calluna vulgaris*). Though sometimes, no doubt, the occurrence of these plants is dependent on local

¹ See Hardy, 1905 : p. 103.

conditions, it may often be interpreted as the first step in the degeneration of the dry oakwood association and its replacement by the heath formation. Thus heath plants are frequently found invading the edge of an oakwood whose centre still shows the typical dry oakwood association. When the entire ground vegetation is of the heath type it is doubtful if the oaks can perpetuate themselves indefinitely from seedlings, and the wood is then doomed.

Oak-birch heath association (*Quercetum ericetosum*). The initial association of the heath formation in its transition from dry oakwood is a very characteristic partially open and generally mixed wood of oak, birch, and in south-eastern England frequently beech, in which the oaks are gradually losing their dominance, and typical heath plants form the ground vegetation. Except where the beech is locally dominant, this kind of woodland allows far more light to reach the ground than does the typical oakwood. The foliage of the birches casts a lighter shade, and the trees are often separated by considerable intervals which are occupied by the heath association. Occasionally areas are met with in which the plants of the ground vegetation of the oakwood still maintain themselves, e.g. *Holcus mollis*, *Scilla non-scripta*, *Anemone nemorosa*, *Oxalis Acetosella*, etc. This variation in facies is characteristic of transitional (intermediate) associations in general, and particularly of associations that form the first stage of a succession in which a new formation is supplanting one already occupying the ground.

Another feature of the oak-birch heath association is its frequent invasion by the Scots pine (*Pinus sylvestris*), which may sow itself freely from neighbouring plantations (Plate IV a), and frequently perpetuates itself in the mixed woodland, whose openness is favourable for such colonisation.

Phot. S. Mangham

- a. *Quercus Robur*, *Betula tomentosa*, *Fagus sylvatica*, *Pinus sylvestris*, *Pteris aquilina*, *Calluna vulgaris*. Ashdown Forest, Sussex, on Ashdown sand.

Phot. S. Mangham

- b. *Betula tomentosa*, *Pyrus Aria*, *Fagus sylvatica*, *Calluna vulgaris*, *Pteris aquilina*. Toy's Hill, Kent, on Hythe Beds, Lower Greensand.

Oak-birch heath association.

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Oak-birch heath association.

Tree layer (dominance often incomplete).

Quercus Robur	}	ld	Pyrus Aucuparia	f
Q. sessiliflora (and hybrids)			Castanea sativa (locally planted, rarely subspontaneous)	l
Betula alba (= B. verrucosa)			Quercus Cerris (occasionally planted, very rarely subspontaneous)	r
B. tomentosa (and hybrids)			Prunus Cerasus	o
Fagus sylvatica			Pyrus Malus	o
Pinus sylvestris (local, subspontaneous)			P. Aria	o
Ilex Aquifolium	a			

Shrubs.

Cratægus monogyna	a	Cytisus scoparius	o
Prunus spinosa	a	Rhamnus Frangula	o
Ulex europæus	la	Juniperus communis	l
Rubus Idæus	o	Salix caprea	f
R. cæsius	o	S. cinerea	f
Rubus spp.	f	S. aurita	f
		Lonicera Periclymenum	a

Ground vegetation. As we should expect in the case of an association which represents a transition from one formation to another the ground vegetation shows a medley of forms, some belonging to the dry oakwood, many to the heath association, while species of the grass heath also occur, since dry oakwood in process of degeneration, but in which the dry peaty humus characteristic of true heath has not been everywhere established, naturally tends towards the association of grass heath. No attempt will therefore be made to give a complete list of the ground vegetation of oak-birch heath, but a few of the most characteristic and abundant species may be cited.

Calluna vulgaris (where the light is sufficient)	d	Deschampsia flexuosa	a
Vaccinium Myrtillus (in shade)	d	Agrostis canina	o
Erica cinerea	ld	Teucrium Scorodonia	a
Pteris aquilina	a and ld	Potentilla erecta	a
		Polygala serpyllacea	f
		Melampyrum pratense	a

<i>Galium saxatile</i>	a	<i>Scutellaria minor</i>	(damp
<i>Scabiosa succisa</i>	a	places)	o
<i>Solidago Virgaurea</i>	f	<i>Epilobium angustifolium</i>	la
<i>Veronica officinalis</i>	a	<i>Orchis ericetorum</i>	f
<i>Viola Riviniana</i>	a	<i>Molinia cærulea</i>	f
<i>Blechnum Spicant</i>	f	<i>Wahlenbergia hederacea</i>	o

While the oak-birch heath type of woodland frequently shows a complete mixture of the various trees (Plate IV), the birches are frequently the only trees over considerable areas (Plate V). They are often hardly dominant in the strict sense because when in open association they scarcely affect the ground vegetation. This local purity of the birch may be due to felling of the oak (many of these woods having been at one time extensively depleted of oak for charcoal and for ship-building) after which the vacant ground is rapidly colonised by birches. The birches also often successfully colonise open heathland. In both of these ways birch heath (*Betuletum ericetosum*) originates.

The beech is also often locally dominant, as in the dry oakwood from which oak-birch heath is derived. When this is the case the ground vegetation is much modified owing to the deep shade cast by the trees. *Vaccinium Myrtillus* (not flowering) and *Leucobryum glaucum* are often the only plants persisting under the shade of the beech, and the ground is frequently quite bare. Both this community (which may be called *Fagetum ericetosum*) and the birch heath are best considered as societies of the oak-birch heath association.

The oak-birch heath is a very picturesque type of woodland and covers wide areas in south-eastern England; it is specially characteristic of much of the Lower Greensand fringing the northern and western edges of the Weald, and of the Ashdown sand in the centre of the Weald (Plate V b). It is also found in Sherwood Forest (Nottinghamshire) and in Delamere Forest (Cheshire),

Phot. S. Mangham

- a. Looking west from Press Ridge Warren, Ashdown Forest, Sussex, on Ashdown sand. *Betula tomentosa*, *B. alba*, *Pinus sylvestris*, *Pteris aquilina*.

Phot. S. Mangham

- b. Birch wood, Press Ridge Warren. *Betula tomentosa*, *B. alba*, *Pteris aquilina*.

Oak-birch heath association.

both on the Bunter sandstone. We do not know how long this association can maintain itself unchanged, but there seems good reason to believe that it is in course of degeneration to the heath association.

Heath association (*Callunetum arenosum*). The heath association is a stable association, either
Heath soils. resulting, as has been already explained, from the further degeneration of oak-birch heath or developed *de novo* on the poorer sands. The gravelly or relatively coarse sandy soil on which it is nearly always based is characterised by its dark humous surface layers, and generally covered by a thin layer of relatively pure dry peat giving an acid reaction. In some heath soils a hard continuous layer (moorpan, Germ. *Ortstein*, Fr. *alios*) occurs at a distance varying from some inches to a few feet below the surface and often some inches in thickness. This consists of sand or gravel bound into a compact stratum either by humous compounds (*Ortstein* proper of Graebner) or by iron oxide (*Raseneisenstein*). It is formed at the junction of the surface layers of leached sand (often paler in colour) and the unaltered sand below. The shallowing of the soil caused by the formation of moorpan is very inimical to the growth of trees, and heaths and moors in which hard pan is present cannot be afforested unless the pan is broken up or at least holes are made in it for the roots of the young trees to penetrate. Pan is sometimes formed in woodland soils which are undergoing degeneration and may play an important part in the process, but it does not occur in all heaths and there seems no doubt that the process of degeneration described above can take place in its absence. In some of the heaths of southern England, *e.g.* on the Hythe beds of the Lower Greensand, the part of pan is played by a layer of hard chert a few feet below the surface (Plate VII b). This limits the growth of the trees of the oak-birch heath (particularly of the oaks, which are very

stunted), and this association easily passes over into pure heath¹.

Very occasionally in the south of England the heath association is developed on fine sand or even on clay, but the reasons for this have not been fully investigated². In the north and west of Britain heath is developed over a great variety of siliceous rocks, all of which however give a light sandy or gravelly soil. According to Hardy the association is not developed at an altitude greater than 2000 feet (c. 600 m.)³.

The association, in its pure form, is typically treeless, the dwarf shrub Ericaceæ, generally with linear "ericoid" (*Erica* spp.) or leathery leaves (*Vaccinium* spp., *Arctostaphylos*), being the dominant plant-forms. *Vaccinium Myrtillus* with deciduous leaves and assimilating stems is an exception. The ling (*Calluna vulgaris*) is by far the most widespread and abundant species, frequently covering wide areas as the sole dominant (Plate VI b). With it are often associated other Ericaceous dwarf shrubs, of which *Erica cinerea* (in the drier areas) and *Vaccinium Myrtillus* may be dominant over considerable tracts.

Under the dense shade of *Calluna* very few species can exist. Dwarfed plants of *Vaccinium Myrtillus* and *Viola Riviniana*, which do not flower, mosses such as species of *Polytrichum* and *Hypnum*, and lichens such as *Cladonia*, are commonly found forming a subordinate layer of vegetation, and where the mantle of ling closely covers the ground, very little else occurs. Where the Callunetum is not closed, however, especially in damper

¹ Beech however seems to flourish quite well above chert which is developed near the surface, and this may sometimes account for the local dominance of beech in the oak-birch heath association on these beds.

² In some cases it may be due to stagnation of the soil water and the consequent formation of acid humus. In others it appears to be correlated (Rayner, Jones and Tayleur, *New Phyt.* Vol. x., in the press) with excess of magnesium in the soil.

³ Hardy, 1905, p. 107.

Phot. S. Mangham

- a. Heath association invaded by *Pinus sylvestris*. *Calluna vulgaris*, *Ulex europaeus*. Pool with *Potamogeton polygonifolius* and *Sphagnum subsecundum* surrounded by *Juncus acutiflorus*, *J. effusus*, etc. Near Wych Cross, Ashdown Forest, on Ashdown sand.

Phot. S. Mangham

- b Heath association invaded by subspontaneous *Pinus sylvestris*, same locality.

Heath Formation.

places, several other species are found, but the Callunetum is always poor floristically as compared, for instance, with the grass-heath association.

The following is a general representative list for the southern heaths.

Dominant species.

Calluna vulgaris		<i>E. vagans</i> (Cornwall only)	
<i>Erica cinerea</i>		<i>Vaccinium Myrtillus</i>	
<i>Erica Tetralix</i> (damper peaty heaths)		<i>Campanula rotundifolia</i>	f
<i>Viola Riviniana</i>	f	<i>Gentiana Pneumonanthe</i>	r
<i>V. canina</i> (= <i>V. ericeto-</i> <i>rum</i>)	o	<i>Cuscuta Epithymum</i> (on <i>Ulex</i> and <i>Calluna</i>)	la
<i>V. lactea</i>	r	<i>Veronica officinalis</i>	a
<i>Polygala serpyllacea</i>	f	<i>Pedicularis sylvatica</i>	la
<i>Hypericum pulchrum</i>	f	<i>Euphrasia officinalis</i> (agg.)	a
<i>Linum catharticum</i>	f	<i>Melampyrum pratense</i>	f
<i>Genista anglica</i>	l	<i>Teucrium Scorodonia</i>	la
<i>G. pilosa</i>	r	<i>Salix aurita</i>	o
<i>Ulex europæus</i>	la	<i>Juniperus communis</i>	la
<i>U. minor</i> (mainly S. Eng- land)	la	<i>Orchis ericetorum</i>	la
<i>U. Gallii</i> (W. and N. Eng- land, Wales, Ireland)	la	<i>Schœnus nigricans</i>	l
<i>Cytisus scoparius</i>	f	<i>Carex pilulifera</i>	o
<i>Lotus corniculatus</i> (agg.)	f	<i>C. binervis</i>	l
<i>Rubus spp.</i>	a	<i>C. flava</i>	o
<i>Potentilla erecta</i>	a	<i>C. verna</i>	o
<i>Galium saxatile</i>	f	<i>Agrostis canina</i>	la
<i>Senecio sylvaticus</i>	o	<i>A. setacea</i> (S. W. England)	a
<i>Cnicus pratensis</i> (= <i>Cir-</i> <i>sium anglicum</i>)	o	<i>Deschampsia flexuosa</i>	a
<i>Serratula tinctoria</i>	o	<i>Nardus stricta</i>	l
<i>Wahlenbergia hederacea</i>	o	<i>Molinia cœrulea</i>	f
		<i>Pteris aquilina</i>	la
		<i>Blechnum Spicant</i>	f
		<i>Lastrea montana</i>	r
		<i>Lycopodium clavatum</i>	r

The distribution of the common gorse (*Ulex europæus*) on heaths is of some interest. It does not appear to be a typical member of the Callunetum but rather belongs to neutral pasture and grass heath. It is very often locally dominant along roadsides and by villages and cottages and from such situations it invades typical

heathland, mainly along the sides of tracks and paths. Professor Weiss' observations¹ have shown that ants carry away the seeds for the sake of the bright orange oily caruncle (*elaiosome*), which they bite and tear as they push the seed along. It is probable in fact that *Ulex europæus*, and also the broom (*Cytisus scoparius*), are typical myrmecochorous plants. Ants often make use of human tracks, and it is likely that the invasion of heaths by the gorse (and less commonly by the broom) is brought about through their agency.

Wet heath sub-association. In constantly wet places, for instance, where owing to local hollows the ground-water reaches the surface and a bog is formed, a characteristic sub-association is found (Plate VI a). In such situations peat is frequently accumulated to a greater depth than on the dry heaths, and owing to its acid character the association contains many species of the moor formation (Chapter XI), though in very different proportions.

<i>Viola palustris</i>	o	<i>J. supinus</i>	la
<i>Hypericum Elodes</i>	o	<i>J. acutiflorus</i>	f
<i>Drosera rotundifolia</i>	la	<i>Eleocharis multicaulis</i>	r
<i>D. intermedia</i>	l	<i>Scirpus cæspitosus</i>	r
<i>D. anglica</i>	r	<i>S. setaceus</i>	r
<i>Oxycoccus quadripetala</i> (=		<i>Schœnus nigricans</i>	r
<i>Vaccinium Oxycoccus</i>)	r	<i>Eriophorum vaginatum</i>	r
<i>Calluna vulgaris</i>	f	<i>E. angustifolium</i>	o
<i>Erica Tetralix</i>	a	<i>Rhynchospora alba</i>	r
<i>E. ciliaris</i> (Dorset and Corn-		<i>Carex pulicaris</i>	r
wall)	l	<i>C. ovalis</i>	f
<i>Pinguicula vulgaris</i>	o	<i>C. elata</i> (= <i>C. stricta</i> Good.)	l
<i>Scutellaria minor</i>	o	<i>C. Oederi</i>	r
<i>Gentiana Pneumonanthe</i>	l	<i>Molinia cærulea</i>	a
<i>Salix repens</i>	a	<i>Nardus stricta</i>	l
<i>Myrica Gale</i>	la	<i>Osmunda regalis</i>	r
<i>Malaxis paludosa</i>	■	<i>Lycopodium inundatum</i>	r
<i>Juncus squarrosus</i>	o	<i>Sphagnum spp.</i>	a

¹ *New Phytologist*, Vol. VII. (1908), p. 27, and Vol. VIII. (1909), p. 81.

The following are the most noteworthy regions of English heathland.

1. *East Anglian heaths*. These occupy considerable stretches of flat sandy country in north-east Norfolk and south-east Suffolk on the Pliocene "crag," and again in west Norfolk and north-west Suffolk on Quaternary deposits overlying the chalk. On the latter grass heath alternates with Callunetum and this is probably due to the varying proportions of lime in the soil. Some of the grass heaths approach chalk pasture in the character of their vegetation. It is quite possible that the East Anglian heaths represent primitive heathland which has never been colonised by trees.

2. *South-eastern heaths*. The heaths of the south-eastern counties are developed partly on the sandy beds of the Lower London Tertiaries, partly on the Lower Greensand to the north and west of the Weald, and partly on the Ashdown sand in the centre of the Weald. They are, for the most part at any rate, derived from oak-birch woodland, which still exists in considerable quantity. The heaths of Ashdown Forest are the most extensive in this region (Plates IV—VII).

3. *Heaths of the London basin*. The Bagshot sand and the overlying plateau gravels to the south-west of London bear extensive heaths. In this region *Pinus sylvestris* has very extensively colonised the heathland by sowing itself from neighbouring plantations. Little semi-natural woodland exists in the district, and it is impossible to decide, at any rate at present, whether the heaths are primitive or derived from woodland.

4. *Heaths of the Hampshire basin*¹. The Hampshire basin is a broad syncline of Tertiary rocks, consisting of alternating sands and clays, occupying south Hampshire and extending eastwards into Sussex, westwards into

¹ Mr W. M. Rankin has contributed the substance of these paragraphs.

Dorsetshire and southwards into the Isle of Wight. The plateau formed by these beds was covered in late Tertiary times by extensive sheets of river and estuarine gravels, which have since been dissected by river systems forming shallow valleys. The plateau gravels and the Tertiary sands now bear wide stretches of heath, mainly to the west of Southampton water. The New Forest alone has 30,000 acres (c. 12,140 hectares) of heathland, and further to the west, in Dorsetshire, are even greater areas, of which the "Egdon heath" of Thomas Hardy's novels forms part. These Dorsetshire heaths are broken only by occasional plantations of conifers, but in the New Forest region heaths alternate with considerable areas of dry oakwood. On the edges or even throughout some of these woods degeneration through the stage of oak-birch heath to the heath association can be observed, while some of the heaths still bear isolated trees of holly, yew, more rarely of whitebeam (*Pyrus Aria*) and bushes of hawthorn (*Crataegus monogyna*). But much of this heath area is certainly very old. Domesday Book and Leland mention the great "bruaria" of Dorsetshire and the Southampton district.

The general level of the heaths of this region hardly reaches 100 feet (c. 30 m.) of altitude, though in places a height of 400 feet and more (c. 120 m.) is attained.

All the heath-bearing soils (Bagshot, Bracklesham and Barton sands, valley and plateau gravels, dunes and shingle banks of coastal origin) of the Hampshire basin are poor in soluble minerals. The typical heath soil is covered by a thin layer of dry peat generally but a fraction of an inch in thickness, though in constantly damp places it may attain sufficient thickness to allow of its being flaked off in "turves" for fuel. Below the layer of dry peat are a few inches of dark peaty soil through which the root systems of the heath plants ramify horizontally. The Bagshot and Bracklesham

Soils.

sands contain appreciable quantities of iron silicate. The water from springs in these beds is frequently red-brown in colour. In places the limit between the six inches of surface soil and the subsoil is marked by a layer of ferruginous "pan."

The grass-heath association occupies but a small fraction of the area, and is often in close
Grass heath. relation with scrub and woodland of the dry oak type, from which it has probably degenerated; in other places grass heath is being invaded by *Callunetum*. The area of grass heath has been much reduced of recent years by the extensive strawberry cultivation in the neighbourhood of Southampton. Grass heath also occurs as a late stage of the sand dune succession. The composition of the association presents no remarkable features.

The heath association proper is characterised by an overwhelming dominance of *Calluna*. The
Heath association. ling gives fairly close but rather stunted growth, not attaining the luxuriant knee-deep growth of the Pennine and Scottish moors. On the driest spots *Erica cinerea* is freely mixed with the dominant; in moister places *Erica Tetralix* takes its place. In the west of the region, from the borders of Dorset to near Bournemouth, the pretty ciliate heath (*Erica ciliaris*) occurs, mainly in association with *E. Tetralix* in the damper places. This species is a feature of Wareham heath, and occurs again in Cornwall. The general floristic composition is not remarkable. A feature of the Hampshire heaths is the abundance of *Ulex minor*, which creeps on the surface of the soil. *Ulex europæus* is rarely common beyond the immediate vicinity of cottages. *Ulex Gallii*, which is practically absent from the Wealden area to the east, shows a steady increase from east to west of the region, corresponding with its western distribution in the country generally.

The bracken fern (*Pteris aquilina*) is rarely common away from the stream-sides, where it is generally associated with trees, and very likely marks the relics of degenerated woodland.

Pinus sylvestris apparently owes its prevalence on some of the New Forest heaths to its introduction into Ocknell Clump in 1776, though there is some evidence of its much earlier occurrence in the district. It flourishes exceedingly on the poor soils, and sows itself freely on the unenclosed heaths. The natural afforestation of the heathland by the pine is however often checked, just as it is on the Bagshot sand and plateau gravels of the London basin, by the frequent forest fires set alight by careless or mischievous passers (see p. 117).

5. *Western heaths.* On the Devonian sandstones and grits of Exmoor and on the granite of Dartmoor extensive heaths are developed, but in both regions local patches of the true moor formation occur on deep peat.

Of the Cornish heaths those of the Lizard peninsula are interesting because of the occurrence of *Erica vagans*, the so-called "Cornish heath," a plant of south-west Europe which occurs nowhere else in the British Isles. It is dominant over large areas of the Lizard heaths in association with the common species—*Calluna vulgaris*, *Erica cinerea* and occasionally *E. Tetralix*. The vegetation of these heaths is not otherwise remarkable. *Ulex Gallii* is abundant and forms a beautiful feature, as on most of the western heaths. The abundance of *Schœnus nigricans*, which is very local further east, is also striking. Most of the species of south-west European plants for which the Lizard district is famous occur on the grassland of the sea cliffs or in their clefts, and not on the heaths.

Erica ciliaris is also found in several localities in Cornwall, though not in the Lizard peninsula. As in Dorsetshire it generally occurs as a member of the wet-heath association.

6. *Midland heaths.* The heaths occurring on light soils in the Midlands have not been investigated. The natural vegetation of the Lower Greensand of the eastern Midlands appears to be essentially similar to that of the Weald. Dry oakwood, degenerating into heath, and extensive sub-spontaneous pinewoods are present. Some of this country is however properly forested—notably the Duke of Bedford's estate at Woburn.

The vegetation of the Bunter sandstone of Sherwood Forest in Nottinghamshire and Delamere Forest in Cheshire also consists of oak-birch heath, grass heath and Callunetum.

7. *The heaths of north-east Yorkshire.* These have been studied by W. G. Smith, whose results are still unpublished. The following account is based on material supplied by him.

The heaths of this area are situated on the plateau of the Oolite *massif* and have an average elevation of about 1250 feet (c. 380 m.) descending to 800 feet (c. 244 m.) on the North Sea coast. They are developed on a few inches of humous sand, covered by 2 or 3 inches of sandy peat, and passing down into sand, derived mainly from the Estuarine sandstones, but partly from the "Calcareous grit" and other sandstones of the Oolite series. The greater part of this upland heath is free from glacial deposits.

These heaths, like all the upland areas dominated by *Calluna* in the north of England and Scotland, are called "moors" and are used for the preservation and shooting of grouse (*Lagopus scoticus*), but over the warmer sandy soils which cover most of the area there is rarely any great extent of deep peat, so that the substratum is that of the heath formation.

The mean annual rainfall of these uplands is about 35 inches (c. 90 mm.). The climate is fairly dry during the growing season but decidedly damper than that of

grown high, woody and thinly leaved. They approach in character the true *Calluna* moors (p. 275) of the Pennines, in that they occur on a greater depth of surface peat than the English heaths and contain more species characteristic of the moor formation, especially where drainage becomes impeded in hollows or on the flatter terraces. Nevertheless they are always developed, like the southern heaths, over sand or gravel, and are not so damp (except locally) as typical *Calluna* moor. We may consider that there are two edaphic factors which control the heath formation, the sandy or gravelly soil and the accumulation of acid peaty humus, whereas the moor formation is controlled by the acid peat alone.

The thickness of the superficial peaty layer is commonly 4 to 8 inches (c. 10 to 20 cm.), though in extreme cases, according to Hardy¹, it may reach a depth of 12 inches (30 cm.). Below, the peat passes into sand or gravel, and at a depth of 12 to 24 inches (30 to 60 cm.) from the surface a layer of "moor-pan" frequently occurs.

The topography of the *Calluna* heath varies to a considerable extent, as it has a vertical range from the valleys upward of 1500 feet (c. 450 m.), and its terrain includes steep slopes, stream valleys, and undulating summits. It is therefore natural to expect variation of facies, and while *Calluna* is the dominant species, the other associates vary considerably. Several of these owe their outstanding position in the association to their quick recovery after the moor-burning, so that they precede *Calluna* during the first year or two of regeneration. So far as records are available, the following are species which thus temporarily occupy the ground. *Cladonia rangiferina*, and other species, often form almost the only covering; *Erica cinerea* recovers quickly on dry soils, *Vaccinium Myrtillus* and *V. Vitis-Idæa* on steep slopes, *Arctostaphylos Uva-ursi* at higher altitudes (towards

¹ Hardy, 1905, p. 106.

2000 feet); heath-grasses (*Festuca ovina*, *Agrostis* spp., *Deschampsia flexuosa*, *Anthoxanthum odoratum*) come quickly on sandy humus, *Nardus stricta* on moister humous soils; while *Juncus squarrosus*, *Scirpus cæspitosus* and *Eriophorum vaginatum* follow the wetter peaty soils, generally accompanied by *Erica Tetralix*.

Several associates of the Highland *Calluna* heath are characteristic, although their occurrence is generally rather sparse; they include *Genista anglica*, *Lycopodium clavatum*, *Tridentalis europæa*, *Antennaria dioica*, *Melampyrum pratense* var. *montanum*, *Listera cordata*, and *Pyrola media*. *Juniperus communis* occurs abundantly in some districts, generally along stream valleys, but in other localities it is quite rare. Seedlings of birch and mountain ash (*Pyrus Aucuparia*) have been observed all over the heaths in many districts (R. Smith). The bracken (*Pteris aquilina*) occurs to some extent on steeper slopes, but it rarely assumes the dominance it has on many English heaths. *Ulex europæus* and *Cytisus scoparius* are sometimes plentiful near roads, but they belong more to the grassland type. Various other plants may occur on the Scottish as on the English heaths, but they are neither so characteristic nor so generally distributed as the species mentioned, and are generally to be regarded as relicts of or invaders from some other association.

The following is a generalised list of the more characteristic species from four stations near Blair Atholl in the Tay valley, Perthshire (R. Smith).

Dominant.

Calluna vulgaris

Locally sub-dominant.

Vaccinium Myrtillus

V. Vitis-Idæa

Empetrum nigrum

Arctostaphylos Uva-ursi

Erica Tetralix

Locally abundant.

Erica cinerea

Nardus stricta

Hypnum spp.

Frequent.

Polygala vulgaris (agg.)	Deschampsia flexuosa
Potentilla erecta	Agrostis vulgaris
Galium saxatile	Anthoxanthum odoratum
Antennaria dioica	Festuca ovina
Luzula multiflora	Blechnum Spicant
Carex Goodenowii	Lycopodium clavatum
C. dioica	Cladonia spp.

Sparse or local.

Genista anglica	Trientalis europæa
Melampyrum pratense var. montanum	Juniperus communis

A typical list given by Hardy¹ from the Dee valley (Aberdeenshire) is very similar.

Pinewood association (*Pinetum sylvestris*).

It is generally held that within the limits of these islands *Pinus sylvestris* is native only in Scotland. Certainly it was formerly native in many parts of England and Ireland, where its remains are found buried in peat. Clement Reid writes: "*Pinus sylvestris* seems to have been abundant throughout Britain during part of the Neolithic Period, for its cones are abundant at the base of peat-mosses and in 'submerged forests.' It afterwards disappeared from the South of England and only recently has been re-introduced²." It is just possible that it may have survived in small numbers in the South of England till the extensive clearing of the lighter soils gave it a fresh opportunity of asserting itself. But it was certainly re-introduced into the south in the eighteenth century, and perhaps earlier, and it quickly spread very rapidly over some of the sandy soils, where it now forms extensive sub-spontaneous woods.

In Scotland *Pinus sylvestris* exists as an apparently endemic variety (var. *scotica* E. and H.) with short grey needles. This tree at one time covered large areas in the

¹ l.c. p. 109.

² *The Origin of the British Flora*, 1899, p. 100.

Phot. A. G. Tansley

- a. Subspontaneous pinewood and chert diggings. *Pinus sylvestris*, *Calluna vulgaris*, *Erica cinerea*, *Pteris aquilina*. Crockham Hill Common, Kent, on Hythe Beds of Lower Greensand.

Phot. A. G. Tansley

- b. Side of chert diggings. *Pteris aquilina*, *Vaccinium Myrtillus*, *Calluna vulgaris*. Same locality.

Heath Formation.

Highland straths (broad valleys) and glens, extending for considerable distances up the mountain slopes. The former area is now very greatly restricted, but considerable tracts of forest, largely open owing to heavy exploitation of the timber, still remain in some places.

It is of interest to note that both native and subspontaneous pine is in this country apparently always associated with heathland. The sub-spontaneous pinewoods of southern England occur mainly on the heaths of the Bagshot Sand and of the Lower Greensand, though the pine sows itself fairly freely on some of the East Anglian heaths and also on those of north-east Yorkshire. In the Highlands of Scotland the native pine woods seem to be developed on the same habitats as the heath association, to which they give place when heavily cleared. The pinewood association is therefore naturally included in the heath-formation.

The sub-spontaneous pinewoods of the southern sands may be very briefly dealt with. In the neighbourhood of mature plantations or of mature self-sown woods thousands of pine seedlings in all stages of growth may frequently be found colonising adjoining heathland, often in company with the birch. The pine seedlings sometimes push up from among fairly thick heather (Plate VI a and b). In this way many of these heaths are being rapidly converted into pinewoods, the pine easily beating the birch in the later stages of competition by reason of the much deeper shade which it casts. The process is only checked by the frequent heath and forest fires which occur in dry summers and autumns.

The close pinewood association is very poor floristically, partly on account of the deep shade and partly because of the thick layer of pine needles which carpets the floor of the wood. The shade forms of *Pteris aquilina* and *Vaccinium Myrtillus* often occur, and the silvery tussocks

English sub-spontaneous pinewoods.

of the moss *Leucobryum glaucum* are also frequent. Occasionally young beeches form a sparse shrubby undergrowth. In the more open spots various members of the heath association occur, and if the wood is felled, this association quickly colonises the ground.

Good examples of native Scottish pinewoods are to be found in the Black Wood of Rannoch (on the southern shores of Loch Rannoch in Perthshire (Plate VIII a)), and in Rothiemurchus Forest in Strathspey (Inverness-shire)¹ The latter occupies a great basin enclosed by the Cairngorm mountains and formed part of a much larger forest which stretched on both sides of the Spey valley for a considerable distance. Much of this has been replanted, but in Rothiemurchus itself no planting appears to have been done.

Rothiemurchus Forest is situated on gravelly sands of glacial origin forming a gently undulating tract several square miles in extent, having an average elevation of about 1000 feet (c. 300 m.), and extending up the lower slopes of the neighbouring mountains. In some places the pines stop short with the lines of moraine on the hill slopes, but in others they extend far up the hill sides, reaching an altitude of 2000 feet (600 m.) or more, probably the highest existing limit of woodland in the British Isles.

The pinewood association of Rothiemurchus Forest is for the most part very open in character, seldom forming a close wood; it is in fact practically a "pine heath," with a very uniform vegetation, poor in species (Plate VIII b).

The peaty character of the surface soil extends to a depth of some inches. Under the pines, below the surface covering of needles, there are about 4 inches

¹ Ballochbuie Forest at the foot of Lochnagar in Aberdeenshire, and Locheil Old Forest on Loch Arkaig in Inverness-shire are also recorded as native pinewoods.

Phot. A. G. Tansley

- a. Pine-heath. *Pinus sylvestris*, *Calluna vulgaris*, *Molinia cærulea*.
Black Wood of Rannoch, Perthshire.

Phot. A. G. Tansley

- b. Pine-heath. *Pinus sylvestris*, *Calluna vulgaris*, *Juniperus communis*.
Rothiemurchus Forest, Inverness, on glacial sand and gravel.

Heath Formation.

(10 cm.) of brown humus with interlacing pine-roots and stems and roots of *Vaccinium*, and this is succeeded by about 5 inches (12 to 13 cm.) of black peaty humus with numerous fine rootlets. This layer passes down into peaty sand with numerous stones. On the open heath there is a surface layer of nearly pure peat about 3 inches (7—8 cm.) thick, apparently formed mainly by *Cladonia* and this is succeeded again by several inches of black peaty sand passing down into grey or yellow sand. In places a hard layer of yellow-brown "pan" is met with at the depth of a foot (30 cm.).

The following species occur :

<i>Pinus sylvestris</i>		<i>Vaccinium Myrtillus</i>	a ¹
var. <i>scotica</i>	a (ld)	V. <i>Vitis-Idæa</i>	a ¹
<i>Calluna vulgaris</i>	d		
<i>Hypericum pulchrum</i>	o	<i>Erica Tetralix</i>	o
<i>Oxalis Acetosella</i>	o	<i>Erica cinerea</i>	o
<i>Potentilla erecta</i>	a	<i>Arctostaphylos Uva-ursi</i>	f ²
<i>Pyrola minor</i>	f	<i>Betula tomentosa</i>	o
<i>P. media</i>	o	<i>Empetrum nigrum</i>	f ²
<i>P. secunda</i>	o	<i>Deschampsia flexuosa</i>	a
<i>Moneses grandiflora</i>	v.r	<i>Siegingia decumbens</i>	o
<i>Trientalis europæa</i>	f	<i>Juniperus communis</i>	a
<i>Melampyrum pratense</i>		<i>Blechnum Spicant</i>	o
var. <i>montanum</i>	f	<i>Phegopteris Dryopteris</i>	o

¹ Locally co-dominant with *Calluna*.

² Towards the upper limits of the pine heath.

Along the paths, even deep in the forest, are many species which apparently do not occur on the heath itself. Among these are *Anemone nemorosa*, *Viola Riviniana*, *Juncus squarrosus*, *Agrostis tenuis*, *Anthoxanthum odoratum*.

When the pinewood is close and casts a deep shade *Calluna* is absent, and the ground vegetation is mainly made up of *Vaccinium Myrtillus*, and *Deschampsia flexuosa*.

The pinewood rejuvenates itself by the self-sowing of seed, freely but not abundantly. One factor which militates against abundant rejuvenation appears to be the thickness and height of the heather, which often reaches 3 feet (c. 1 m.) or more, for numerous seedlings occur along the path sides, but none were found in the thick heather.

The juniper (*Juniperus communis*) is abundant and very luxuriant. It sometimes forms tall conical shrubs reaching a height of 10 or 12 feet (c. 3 to 3·5 m.) (Plate VIII b).

Diagram showing the probable genetic relations of the plant-communities of the Formation of Sandy Soils and of the Heath Formation.

CHAPTER V

THE PLANT-FORMATION OF THE OLDER SILICEOUS SOILS

A. THE PENNINE REGION

By C. E. Moss

THE older siliceous soils, alluded to in this chapter for the sake of brevity and convenience simply as siliceous soils, include the soils of the metamorphic and Palæozoic non-calcareous rocks, such as schists, slates, sandstones, and shales, but not the sandy soils derived from the more recent rocks, such as the Triassic sandstones, the Upper and Lower Greensand, the Eocene sands, and the glacial sands. The plant-formation of the latter sandy soils is treated in Chapter III.

Siliceous soils are usually much shallower than sandy soils: they contain less silica: they are frequently more finely grained in texture: when wet they are much more greasy or slippery; and, at the surface, they often degenerate into a kind of false clay. Siliceous soils, when well aerated, are characterised by the presence of "mild humus": when badly aerated, damp or wet, acid peat tends to accumulate on them. Sandy soils, on the other hand, often give rise to the drier, though still acid, peat or humus which is characteristic of typical heaths (see Chapter IV).

These differences, perhaps along with others not yet fully understood or appreciated, between siliceous and

sandy soils are related to conspicuous differences in the plant-communities which characterise the two kinds of soil respectively. On clayey soils, the characteristic woodland association is dominated by *Quercus Robur*, or a mixture of this and *Carpinus Betulus*; and such woods on degeneration give rise to neutral grassland. On sandy soils, the woodland associations are more varied in character. *Quercus Robur*, *Q. sessiliflora*, *Fagus sylvatica*, *Betula tomentosa*, and *Pinus sylvestris* may all form more or less definite plant-communities, with many intermediate stages; and these on degeneration give rise to typical heaths often intermingled with grassy patches containing many arenicolous species. On siliceous soils, the typical woodland association is dominated by *Quercus sessiliflora* or, at higher altitudes, by *Betula tomentosa*; and these on degeneration give rise to a type of grassland which we may call siliceous pasture, whose characteristic, widespread, and dominant species are *Nardus stricta* and *Deschampsia flexuosa*.

Association of the sessile oak (*Quercetum sessilifloræ*). Over non-calcareous rocks of the Pennine hills in the north of England, oakwoods whose dominant tree is *Quercus sessiliflora* are typically and characteristically developed. The rocks of these hill slopes consist of alternating beds of sandstones and shales belonging to the Pendleside (Yoredale) series, Millstone Grit, and Coal-measures. In all cases, these soils have a very low lime-content. In several analyses, the percentage of lime (calculated as calcium oxide) was so low as 0·02 per cent.; and in no case was it higher than 0·05 per cent. The total soluble mineral-content of all these soils is also very low. The soils often show a marked tendency to allow of the accumulation of acidic¹ humus; and the amount of such

¹ This word is used by Dr Moss for soil of any kind whose waters give an acid reaction [Editor].

humus present in the soil may be roughly gauged by the abundance of such plants as the heather (*Calluna vulgaris*), the bilberry (*Vaccinium Myrtillus*), and the silver hair-grass (*Deschampsia flexuosa*) in the ground flora. The soils are shallow, sometimes very shallow; and on the whole, therefore, the trees are of small dimensions.

The Quercetum sessilifloræ ascends, in general, to about 1000 feet (305 m.); and, above this

**Altitudinal
range.**

level, the influence of altitude is seen in the absence of well-developed oakwoods.

Derivative scrub occurs, however, as well as small patches of woods of *Betula tomentosa*, above this height. Birch-woods are more extensively and typically developed in the Lake District, and especially in Scotland, than on the southern Pennines.

The woods of *Quercus sessiliflora* have been described by several writers¹, and variously subdivided

**General
character.**

into upland and lowland oakwoods, dry oakwoods, and mixed deciduous woods, etc. In

the present account, the woods described by these writers are regarded as particular cases of the association of *Quercus sessiliflora*.

In all these woods, this species (*Q. sessiliflora*) is indisputably the dominant tree. On the lower, non-calcareous Pennine slopes, this species grows well and forms fairly large trees on the damper soils up to about 800 feet (244 m.), especially on the shales: above this altitude, especially on soils over the sandstones, the trees are usually of short stature and small girth; and near their upper altitudinal limit, they are little taller than shrubs.

The pedunculate oak (*Q. Robur*) is totally absent from the great majority of the oakwoods of the

Planted trees.

Pennine slopes, although it occurs here and

¹ Smith and Moss, 1903; Smith and Rankin, 1903; Crump, *Flora of Halifax*, 1904; Woodhead, 1906; and Moss, 1911.

there in situations where it has obviously been planted; and it sometimes, no doubt, spreads from the plains for some distance up the lower valleys. As a planted tree, mixed with such undisputed aliens as the sycamore (*Acer Pseudo-platanus*) and the larch (*Larix decidua*), it has been observed so high as 1100 feet (c. 336 m.).

No conifers are indigenous in these woods; but the larch and the Scots pine (*Pinus sylvestris*) are frequently planted. Other conifers which are occasionally or rarely planted are the black or Austrian pine (*P. austriaca*), the Douglas fir (*Pseudotsuga Douglasii*), and the Redwood (*Sequoia sempervirens*). As sub-fossil timber, the Scots pine is occasionally found buried under the peat of the southern Pennines; and it is rather remarkable therefore that the tree is not indigenous in the Pennine woods at the present time. Even where planted, the Scots pine does not here seem to be very prosperous, as seedling pines are never abundant. It is clear that this species does not thrive on the damp soils of the Pennines nearly so well as on the drier heaths of the south of England.

The beech (*Fagus sylvatica*), although an almost invariable constituent of the larger woods, has little claim to rank as indigenous. In favourable seasons, ripe fruits are formed even at an altitude of 1500 feet (457 m.); and first-year seedlings are frequently seen. Older seedlings, however, have not been observed; and there is no evidence to show that the beech rejuvenates itself in these upland woods.

The common birch (*Betula tomentosa*) is, on the whole, the most common and the most constant associate of the sessile oak in these woods.

**Associated
native trees.**

Forms or varieties with glabrous twigs are not uncommon; and the variety *parvifolia* (? = *B. carpatica*) has been observed. Not infrequently the birch becomes locally dominant in places where extensive felling of the oak and no subsequent replanting has

taken place. The white birch (*B. alba* = *B. verrucosa*) is probably not indigenous in these woods; and the pendulous form (*B. alba* forma *pendula* = *B. pendula* Roth.) is extremely rare even as a planted tree.

The wych elm (*Ulmus glabra* Huds. non Mill.; *U. montana*) is indigenous, and occurs up to about 1000 feet (305 m.). Above this altitude, it occurs in plantations up to 1500 feet (457 m.). It is a constant and sometimes an abundant constituent of the damper woods, but is rare in the drier ones. In favourable localities, seedlings are very common.

The rowan or mountain ash (*Pyrus Aucuparia*) occurs in most of the woods; and, in rocky, upland, and heathery situations, it is often very abundant.

The holly (*Ilex Aquifolium*) also is found in almost every oakwood on the Pennines; but, although it sometimes produces flowers, it rarely fruits.

The ash (*Fraxinus excelsior*) and the alder (*Alnus rotundifolia*) are almost limited to stream sides and marshy places, where, however, they are often very abundant.

Of rarer trees, the aspen (*Populus tremula*) and the small-leaved lime (*Tilia cordata*; *T. ulmifolia*; *T. parvifolia*) are very rarely met with; and possibly they are not indigenous on the siliceous soils of the Pennines. The cherry (*Prunus Cerasus* and *P. Avium*) also occurs in the woods, and is locally not uncommon.

A number of shrubby species are fairly abundant and characteristic on the damper soils, but there

Shrubs.

is no species which is generally dominant. Brambles are exceedingly abundant and very many species are recorded by batologists. *Rubus Selmeri* and *R. dasyphyllus* ascend higher than any of the other forms. *R. cæsius* is rather rare and confined to the lower levels. Of the roses, *R. canina* is fairly abundant and *R. arvensis* locally so at the lower altitudes; among the less common

Phot. W. B. Crump

- a. *Quercus sessiliflora*, *Holcus mollis*, *Pteris aquilina*.
Heath Moor of Pennine (August).

Phot. W. B. Crump

- b. *Quercus sessiliflora*, *Vaccinium Myrtillus*, *Deschampsia flexuosa*.
Hardcastle Crag, Hebden Bridge, Yorkshire, on Millstone Grit.

Sessile oakwood association.

species *Rosa mollis* and *R. tomentosa* occur, but are rather rare.

In the drier parts of the woods the sloe or blackthorn (*Prunus spinosa*) and the hawthorn (*Crataegus monogyna* = *C. Oxyacantha*) are characteristic, and on the outskirts and in open places the broom (*Cytisus scoparius*) and gorse (*Ulex europæus* at lower levels and *U. Gallii* at higher) are locally abundant.

The ground vegetation, as in most types of wood, is very variable from place to place. Three ground sub-associations may, however, be recognised, though transitions between them are numerous.

1. The sub-association of damp situations with well-aerated soil and mild humus. This possesses a fairly rich flora containing many species with more or less conspicuous flowers.

2. The sub-association of drier situations with less humus, characterised by a poorer and more uniform flora (Plate IX a).

3. The sub-association of acid peaty humus characterised by a heathy flora (Plate IX b).

It will be seen that the habitats of these three sub-associations correspond fairly closely with those of the woodland associations of the formation of clays and loams, the formation of sandy soils and the heath formation, i.e. to the damp oakwood, the dry oakwood and the oak-birch heath respectively, and the lists of species (pp. 81, 93, 101, 128) emphasise this correspondence. Nevertheless it is held that the common characters of the habitat, which presumably determine the general dominance of *Quercus sessiliflora* throughout the three types of sub-association, are sufficiently marked to consider the whole of this vegetation and the related type of pasture or grassland as belonging to a single formation.

The following is a list of the more characteristic

species occurring in the *Quercetum sessilifloræ* of the Pennines :—

Trees.

<i>Prunus Cerasus</i>	l	<i>Ulmus glabra</i> (<i>U. mon-</i>	
<i>Pyrus Aucuparia</i>	f to la	<i>tana</i>)	f
<i>Ilex Aquifolium</i>	o	<i>Betula tomentosa</i>	la
<i>Fraxinus excelsior</i>	la ²	<i>Quercus sessiliflora</i>	d
<i>Alnus glutinosa</i>	la ²	<i>Salix fragilis</i>	l ^{1,2}

Shrubs.

<i>Ulex Gallii</i>	l	<i>Cratægus monogyna</i>	
<i>U. europæus</i>	f	(<i>C. Oxyacantha</i>)	a
<i>Prunus spinosa</i>	o	<i>Acer campestre</i>	f
<i>P. Padus</i>	la	<i>Sambucus nigra</i>	f
<i>Rubus spp.</i>	a	<i>Viburnum Opulus</i>	f
<i>R. cæsius</i>	r ¹	<i>Corylus Avellana</i>	f
<i>Rosa canina</i>	o	<i>Salix caprea</i>	f
<i>R. arvensis</i>	la ¹	<i>S. cinerea</i>	f
<i>Pyrus Malus</i>	o	<i>S. aurita</i>	l ³

Climbers.

<i>Hedera Helix</i>	a	<i>Lonicera Periclymenum</i>	ll
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Ground vegetation.(1) *Sub-association of damp situations.*

<i>Anemone nemorosa</i>	f	<i>V. sylvatica</i>	r
<i>Ranunculus auricomus</i>	l	<i>Geum rivale</i>	la ³
<i>R. Ficaria</i>	la	<i>G. urbanum</i>	l
<i>Trollius europæus</i>	r ³	<i>Fragaria vesca</i>	f
<i>Aquilegia vulgaris</i>	r	<i>Spiræa Ulmaria</i>	la ³
<i>Caltha palustris</i>	f ³	<i>Chrysosplenium oppositi-</i>	
<i>Cardamine amara</i>	l ³	<i>folium</i>	la ³
<i>C. pratensis</i>	o ³	<i>C. alternifolium</i>	l ³
<i>C. sylvatica</i> (<i>C. flexuosa</i>)	f	<i>Epilobium montanum</i>	f
<i>Viola Riviniana</i>	f	<i>E. palustre</i>	l ³
<i>Lychnis dioica</i> (<i>Melan-</i>		<i>Circæa lutetiana</i>	la
<i>drium rubrum</i>)	f	<i>Sanicula europæa</i>	la
<i>Stellaria Holostea</i>	a	<i>Heracleum Sphondylium</i>	f
<i>S. nemorum</i>	la ³	<i>Angelica sylvestris</i>	l ³
<i>Oxalis Acetosella</i>	a	<i>Asperula odorata</i>	l
<i>Vicia sepium</i>	a	<i>Valeriana dioica</i>	r ³

¹ Chiefly at lower altitudes.² Chiefly near streams.³ Chiefly in marshy places.

<i>V. sambucifolia</i>	la ³	<i>L. maxima</i>	a
<i>Petasites ovatus</i>	la ³	<i>Arum maculatum</i>	la
<i>Cnicus palustris</i>	la ³	<i>Carex pendula</i>	o ¹
<i>C. heterophyllus</i>	r ³	<i>C. helodes</i> (<i>C. lævigata</i>)	o ¹
<i>Crepis paludosa</i>	l ³	<i>Carex remota</i>	l
<i>Lactuca muralis</i>	l	<i>C. sylvatica</i>	v ²
<i>Campanula latifolia</i>	r	<i>C. strigosa</i>	v ²
<i>Primula vulgaris</i>	r	<i>Milium effusum</i>	la
<i>Lysimachia nemorum</i>	la ³	<i>Deschampsia cæspitosa</i>	o ¹
<i>Myosotis sylvatica</i>	l	<i>Holcus lanatus</i>	o ¹
<i>M. scorpioides</i> (<i>palustris</i>)	la ³	<i>Melica uniflora</i>	o
<i>Scrophularia nodosa</i>	a ³	<i>Festuca gigantea</i>	o
<i>Veronica montana</i>	la	<i>F. sylvatica</i>	r
<i>Lathræa Squamaria</i>	r	<i>Bromus ramosus</i>	
<i>Lamium Galeobdolon</i>	a	(= <i>B. asper</i>)	o
<i>Ajuga reptans</i>	a	<i>B. sterilis</i>	la
<i>Mercurialis perennis</i>	a	<i>Athyrium Filix-fœmina</i>	a
<i>Neottia Nidus-avis</i>	r	<i>Lastrea Filix-mas</i>	a
<i>Listera ovata</i>	r	<i>L. aristata</i> (= <i>L. dilatata</i>)	a
<i>Helleborine latifolia</i>	r	<i>L. montana</i>	la ¹
<i>Orchis mascula</i>	r	<i>Polystichum aculeatum</i>	r
<i>Habenaria virescens</i>		<i>Phegopteris Dryopteris</i>	r ¹
(= <i>H. chloroleuca</i>)	r	<i>P. polypodioides</i>	r ¹
<i>Iris Pseudacorus</i>	la ¹	<i>Osmunda regalis</i>	extinct
<i>Scilla non-scripta</i>	a	<i>Equisetum sylvaticum</i>	la ¹
<i>Allium ursinum</i>	la		
<i>Juncus effusus</i>	la ¹	<i>Bryophyta</i> : numerous	
<i>Luzula pilosa</i>	a	and abundant	

(2) *Sub-association of drier situations*⁴.

<i>Viola Riviniana</i>	f	<i>Lamium Galeobdolon</i>	o
<i>Polygala serpyllacea</i>	f	<i>Teucrium Scorodonia</i>	f
<i>Arenaria trinervia</i>	f	<i>Rumex Acetosella</i>	o
<i>Potentilla erecta</i>	f	<i>Scilla non-scripta</i>	ls
<i>P. procumbens</i>	l	<i>Luzula pilosa</i>	o
<i>Conopodium majus</i>	o	<i>Carex binervis</i>	o
<i>Galium saxatile</i>	a	<i>Anthoxanthum odoratum</i>	o
<i>Hieracium boreale</i>	o	<i>Holcus mollis</i>	s
<i>Campanula rotundifolia</i>	o	<i>Pteris aquilina</i>	ls
<i>Digitalis purpurea</i>	o	<i>Lastrea aristata</i>	o

¹ Chiefly at lower altitudes.

² Chiefly near streams.

³ Chiefly in marshy places.

⁴ The "mesopteridetum" of Woodhead, 1906.

(3) *Sub-association of more open situations with much acid humus.*

<i>Corydalis claviculata</i>	o	<i>Pyrola media</i>	r
<i>Lathyrus montanus</i>	o	<i>P. minor</i>	r
<i>Ulex Gallii</i>	la	<i>Teucrium Scorodonia</i>	f
<i>Potentilla erecta</i>	f	<i>Luzula multiflora</i>	f
<i>Galium saxatile</i>	a	<i>Carex pilulifera</i>	o
<i>Solidago Virgaurea</i>	o to f	<i>Deschampsia flexuosa</i>	s
<i>Calluna vulgaris</i>	la	<i>Molinia cærulea</i>	l
<i>Vaccinium Myrtillus</i>	ls	<i>Pteris aquilina</i>	ls
<i>V. Vitis-Idæa</i>	l	<i>Blechnum Spicant</i>	o to f
<i>Melampyrum montanum</i>	la	<i>Lastrea aristata</i>	o

SUBORDINATE (RETROGRESSIVE) ASSOCIATIONS

Scrub associations. Every stage can be traced from typical woodland to open scrub; and there can be little or no doubt that, so far as the Pennines are concerned, the great majority of examples of open scrub are simply retrogressive woodland. In ancient times, when the woods ascended to their climatic limits, there was doubtless a natural region of climatic scrub at a higher level than the woods; but the woodland limit has been depressed some hundreds of feet since that particular period.

There can be no doubt that a great deal of the degeneration of the woodland has been brought about by the indiscriminate felling of trees, the absence of any definite system of re-planting, and the grazing of quadrupeds. It is doubtful, however, if these causes are quite sufficient to account for all the facts. It has to be remembered that the population of the remoter valleys, many of which are now almost or wholly treeless, is very small. A matter which is perhaps not sufficiently emphasised is that, in a closed plant association, seedlings, especially of plants with large seeds like the oak, are

rarely found. Now, as time goes on, the ground vegetation of a wood tends to become quite closed; and this simple fact, in itself, is probably one of great importance in the question of the rejuvenation or degeneration of forests. Some foresters make use of their knowledge of the fact, and go to great trouble in keeping the ground vegetation open by removing the woodland "weeds."

On many open hillsides, trees are more or less thinly scattered. In some such cases, the ground vegetation is of a grassy type; in others, heathy undershrubs prevail. It is believed that such examples of scrub are derived from woodland, because every transition occurs between woodland and scrub and because scrub frequently occurs within the woodland limits of altitude. Further, some of these scrubby places still retain the place-name "wood"; and, in one or two cases, it is stated by the local inhabitants that certain examples of scrub were woodland in comparatively recent times.

Whilst the majority of the examples of scrub that one meets in the British Isles are apparently of this retrogressive nature, scrub of a progressive nature, that is, scrub which is developing towards woodland, is sometimes met with, particularly in deserted quarries. Progressive scrub also occurs on fens and moors (see pp. 236, 250).

Siliceous grassland associations. Grassland occurs on the uncultivated slopes of the hills, where every transition can be traced from woodland, through scrub, to a clean turf of *Nardus stricta* and *Deschampsia flexuosa*. So far as one can judge, there are no soil changes corresponding to these different associations.

At the present time, grassland and scrub ascend to higher altitudes than the woods; but it seems probable that almost the whole of the land now occupied by grassland and scrub was once wooded. On some of the highest summits, however, grassland now occurs on ground which

has probably never been tree-clad—at least, not in post-Tertiary times.

A certain amount of grazing of sheep and cattle takes place on these uncultivated hill-slopes, but the amount is, on the whole, rather small. The land is not artificially manured or drained.

Two types of siliceous grassland have been described¹ as occurring on the Pennines, and have been distinguished as wet and dry. The most abundant and characteristic grass of the drier siliceous grassland is the mat-grass (*Nardus stricta*) and that of the wetter siliceous grassland is the purple moor-grass (*Molinia cærulea*). The former may be termed *Nardus* grassland and the latter *Molinia* grassland. The two species are respectively dominant in the two associations, since they nearly monopolise the ground and form the great bulk of the turf in which the other plants are rooted; and the associated species are therefore more or less controlled by the dominant plants. To a limited extent, the associations are layered plant-communities; and the smaller plants receive a certain amount of shade and shelter from the dominant ones. As is usual in plant-associations, one or other of the dependent species occasionally becomes social; and thus plant-societies arise.

(i) *Nardetum strictæ*. The typical *Nardetum* of the Pennines occurs on steep shaley slopes. In summer, this association is characterised by a grassy turf, grey-green in colour, dry and slippery. In late autumn, winter and early spring, the ground is damp and sodden; and the bleached haulms of the mat-grass (*Nardus stricta*) give tone to the landscape, and may be recognised at a considerable distance. The silver hair-grass (*Deschampsia flexuosa*) is, on the southern Pennines, a constant associate;

¹ Smith and Moss (1903); Smith and Rankin (1903); Lewis (1904, a and b).

and, in early summer, the tall, purple scapes of this grass are very conspicuous. There seems little doubt, however, that the Nardetum of the southern Pennines is ecologically identical with that of the Wicklow Hills¹ and with that of the northern Pennines², even though the silver hair-grass is not included in the lists of the association by the authors mentioned.

The two grasses (*Nardus stricta* and *Deschampsia flexuosa*) of the association remain abundant or even dominant up to about 1500 feet (457 m.). Below about 1250 feet (381 m.), the common bent grass (*Agrostis tenuis* = *A. vulgaris*) is often very abundant; and, in the late summer months, its delicate and purple panicles may colour a whole hillside. As lower altitudes are approached, this species becomes increasingly abundant at the expense of the mat-grass, and associated species become more and more abundant. The sheep's fescue-grass (*Festuca ovina*) is also often associated, and this species sometimes forms plant-societies or facies.

The shady hill-slopes which encircle the upper Edale valley afford an extensive and continuous expanse of the typical Nardetum. On the north of this upland valley are the slopes of the Peak, on the south the slopes of the Mam Tor range, and on the west the slopes of the Colborne moors. In the sheltered Grindsbrook clough, the bracken (*Pteris aquilina*) asserts itself very strongly: the small furze (*Ulex Gallii*) occurs in small patches here and there, and the springs of water on the hillsides are marked by clumps of the common rush (*Juncus effusus*).

The last three species give to the association very different aspects or facies. The bracken, where the soil is dry and the locality sheltered, sometimes occurs in extensive sheets, masking the otherwise dominant grasses.

¹ Pethybridge and Praeger, 1905.

² Lewis, 1904.

The small gorse (*Ulex Gallii*) is never so prominent on the southern Pennines as, for example, on the Malvern Hills, in Devonshire and Cornwall, on the Wicklow Hills (Plate X), or in the west of Ireland; but it occurs in patches in dry and fairly exposed localities. Rushes (*Juncus effusus*, and sometimes *J. conglomeratus*), in damp places, and independently of conditions of shelter or exposure, are abundant and characteristic associates. The bracken and the rush, in fact, are in many places harvested by the upland farmers.

The relationships of the various facies of the *Nardus* association may be indicated diagrammatically as follows:—

Just as there are many localities which are difficult to describe as wood or scrub, so there are many localities which are difficult to describe as scrub or grassland; and the transitions between these physiographical types are complete. Doubtless, the great bulk of the area now occupied by scrub or grassland was formerly woodland; and, in fact, several localities now occupied by scrub or grassland retain the place-name "wood." Several species of plants which are characteristic of woodland occur here and there; and, whilst some of these are no doubt recent migrants, they may, on the whole, be fairly regarded as relics of pre-existing woodland (see also Moss, 1911).

The following is a list of the more typical and abundant

Siliceous grassland. Facies of *Ulex Gallii*, Wicklow mountains.

Phot. R. Welch

plants which occur in the *Nardus* pasture: full lists are given by Moss (*op. cit.*).

<i>Dominant species.</i>	<i>Nardus stricta</i>
<i>Sub-dominant species.</i>	<i>Deschampsia flexuosa</i>
<i>Locally sub-dominant species.</i>	<i>Pteris aquilina</i>
<i>Locally abundant species.</i>	
<i>Ulex Gallii</i>	<i>Agrostis vulgaris</i>
<i>Juncus effusus</i>	<i>Festuca ovina</i>
<i>Less abundant and rare species.</i>	
<i>Ranunculus acris</i>	<i>Erica cinerea</i>
<i>R. bulbosus</i>	<i>Calluna vulgaris</i>
<i>Polygala serpyllacea</i>	<i>Chrysanthemum Leucanthemum</i>
<i>Viola lutea</i>	<i>Centaurea nigra</i>
<i>V. Riviniana</i>	<i>Crepis virens</i>
<i>Hypericum pulchrum</i>	<i>Leontodon hispidus</i>
<i>Cytisus scoparius</i>	<i>Hieracium Pilosella</i>
<i>Ulex Gallii</i>	<i>Gentiana Amarella</i>
<i>Lotus uliginosus</i>	<i>Veronica officinalis</i>
<i>Vicia sepium</i>	<i>Euphrasia officinalis</i> (agg.)
<i>Lathyrus montanus</i>	<i>Plantago lanceolata</i>
<i>Potentilla erecta</i>	<i>Rumex Acetosella</i>
<i>P. procumbens</i>	<i>Empetrum nigrum</i>
<i>Linum catharticum</i>	<i>Anthoxanthum odoratum</i>
<i>Pimpinella Saxifraga</i>	<i>Briza media</i>
<i>Conopodium majus</i>	<i>Carex binervis</i>
<i>Galium saxatile</i>	<i>C. pilulifera</i>
<i>Scabiosa Succisa</i>	<i>Juncus squarrosus</i>
<i>Campanula rotundifolia</i>	<i>Blechnum Spicant</i>
<i>Jasione montana</i>	<i>Ophioglossum vulgatum</i>

In many places, such dwarf shrubs as *Erica cinerea*, *Calluna vulgaris*, and *Empetrum nigrum* become very abundant; and thus a type of vegetation is produced which is transitional from *Nardus* grassland to moorland (see diagram on p. 137).

(ii) *Molinietum cæruleæ*. The wetter type of siliceous grassland (see p. 132), dominated by purple moor-grass (*Molinia cærulea*), is of far less extent on the southern Pennines than the *Nardus* grassland, and much more local in its occurrence.

The *Molinia* pasture occurs in the more badly drained places. In a general way, the *Molinia* grassland affects the ground overlying the sandstone rocks, whilst the *Molinia* pasture is more characteristic of the steep slopes of the shales. The soil of the *Molinia* grassland is wet, often very wet, and more or less peaty and acidic. However, as shown in Chapter X, the purple moor-grass is by no means confined to acidic soils. On such soils, the *Molinia* association frequently forms a transition from grassland to moorland. The moorland relations of the habitat are seen in the peaty soil (always acidic on siliceous soils), often supersaturated with moisture, and in the abundance of associated species which characterise certain parts of the moorland.

Molinia is often very abundant in the degenerating oak and birch woods of siliceous soils; and there can be little, if any, doubt that some parts of the *Molinia* grassland have resulted from the degeneration of such woods. Transitional areas occur, for example, near Crowden railway station in north Derbyshire. The following is a list of the species which characterise many of the Molinieta of the Pennines:—

Ranunculus Flammula	la	J. acutiflorus	la
Viola palustris	r to o	Scirpus cæspitosus	r to o
Drosera rotundifolia	r	Eriophorum vaginatum	r to o
Hydrocotyle vulgaris	la	E. angustifolium	la
Erica Tetralix	la	Carex curta	r
Calluna vulgaris	la	C. echinata	la
Oxycoccus quadripetala	l	C. Goodenowii	o to a
Pinguicula vulgaris	r	C. flacca	o
Taraxacum palustre	r	C. panicea	o to a
Empetrum nigrum	la	C. flava (agg.)	la
Orchis ericetorum	r to o	Agrostis canina	l
Narthecium ossifragum	r to la	Deschampsia flexuosa	r to a
Juncus effusus	la	Molinia cærulea	a to d
J. conglomeratus	la	var. depauperata	r to d
J. squarrosus	la	Nardus stricta	la

Diagram showing the relationships of the plant-communities of the Formation of Siliceous Soils.

B. OTHER REGIONS

The formation of siliceous soils above described appears to be developed on all the siliceous rocks of the Pennine chain; its extension in the British Isles is however far wider than that. So far as they have been investigated the formation appears to be almost co-extensive with the siliceous rocks of Palæozoic age below a certain altitude; these, as was pointed out in Part I, occupy a large part of western England, Wales, Scotland and Ireland. Similar woods also occur on some of the harder secondary rocks, *e.g.* the non-calcareous oolites of north-east Yorkshire.

Woods of *Quercus sessiliflora* have been recognised in the Lake District and in North and Central Wales on Ordovician rocks, in west-central England on siliceous Silurians, in Devonshire and Cornwall on Upper Greensand and on various Palæozoic strata, in Co. Wicklow on Ordovicians, in Co. Kerry on Old Red Sandstone, and in Co. Galway on metamorphic rocks. In Scotland such woods have also been recognised, but their extension has not been studied. In some of the cases mentioned the woods of

**Distribution
of *Quercetum
sessilifloræ*.**

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<i>Viola palustris</i>	r to o	<i>Scirpus cæspitosus</i>	r to o
<i>Drosera rotundifolia</i>	r	<i>Eriophorum vaginatum</i>	r to o
<i>Hydrocotyle vulgaris</i>	la	<i>E. angustifolium</i>	la
<i>Erica Tetralix</i>	la	<i>Carex curta</i>	r
<i>Calluna vulgaris</i>	la	<i>C. echinata</i>	la
<i>Oxycoccus quadripetala</i>	l	<i>C. Goodenowii</i>	o to a
<i>Pinguicula vulgaris</i>	r	<i>C. flacca</i>	o
<i>Taraxacum palustre</i>	r	<i>C. panicea</i>	o to a
<i>Empetrum nigrum</i>	la	<i>C. flava</i> (agg.)	la
<i>Orchis ericetorum</i>	r to o	<i>Agrostis canina</i>	l
<i>Narthecium ossifragum</i>	r to la	<i>Deschampsia flexuosa</i>	r to a
<i>Juncus effusus</i>	la	<i>Molinia cærulea</i>	a to d
<i>J. conglomeratus</i>	la	<i>var. depauperata</i>	r to d
<i>J. squarrosus</i>	la	<i>Nardus stricta</i>	la

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**Distribution
of *Quercetum
sessilifloræ*.**

Quercus sessiliflora are strikingly pure; in others the pedunculate oak (*Q. Robur*) is more or less mixed with the sessile-fruited species, but whether this is always due to planting, as is apparently the case in the Pennine woods, or whether it is sometimes a natural mixture, as it certainly is in many of the oakwoods of sandy soils previously described (p. 92), is not yet clear.

The associated trees and shrubs in these various woods are, for the most part, and so far as they have been studied, much the same as on the Pennines, but some interesting variations occur. Thus on some of the Lake

**Oak-ash
woods.**

District hills which receive a very heavy rainfall the oakwoods contain a great deal of ash, which is by no means confined to streamsides as on the Pennines, but spreads through the woods in all directions, largely replacing the oak, which has probably been extensively removed. The ground vegetation, however, is that of a typical oakwood of siliceous soil. Some of the Devonshire woods of *Quercus sessiliflora* also contain much generally distributed ash.

The ground vegetation of most of these woods closely corresponds with the three types recognised in the Pennine woods or with transitions between them, but, as in the case of the associated trees, variations occur.

**Bryophyte
ground
vegetation.**

Thus in the oakwoods of Co. Wicklow at Glendalough the ground vegetation is largely dominated by mosses, species of *Dicranum*, *Hypnum* and *Polytrichum*, with local patches of *Sphagnum* and also many Liverworts; a similar type of ground vegetation occurs in the woods of *Q. sessiliflora* on the sides of the valleys near Aberystwyth in Central Wales.

The woods of *Quercus sessiliflora* at Killarney in Co. Kerry, south-west Ireland, are specially interesting as being the chief station in the British Isles of the strawberry tree (*Arbutus*

**Killarney
woods.**

Society of Arbutus luedo in Quercetum sessiliflorae. Quercus sessiliflora, Pteris aquilina, Calluna vulgaris.
Upper lake shore, Killarney, on Old Red Sandstone.

Unedo) which is found besides only in a few isolated stations nearer the Kerry and Cork coasts, to the south and south-west of Killarney¹. The nearest continental station of the arbutus is in south-western France, about 400 miles (c. 640 km.) from its Irish stations.

These woods occur both on Old Red Sandstone and on Carboniferous Limestone, and the arbutus is freely scattered through them; in one small portion of the area it is locally dominant (Plate XI).

The composition of the vegetation is shown in the following lists of the more abundant and the more characteristic but less frequent species.

<i>Quercus sessiliflora</i>	d	<i>Hedera Helix</i>	f
<i>Taxus baccata</i>	a	<i>Scutellaria Nicholsoni</i>	l
<i>Ilex Aquifolium</i>	a	<i>Euphorbia hiberna</i>	f
<i>Arbutus Unedo</i>	a	<i>Allium Scorodoprasum</i>	vl
<i>Fraxinus excelsior</i>	o	<i>Neottia Nidus-Avis</i>	r
<i>Pyrus Aucuparia</i>	o	<i>Cephalanthera longifolia</i>	vr
<i>Old Red Sandstone.</i>		<i>Carboniferous Limestone.</i>	
<i>Betula tomentosa</i>	a	<i>Betula tomentosa</i>	o
—		<i>Pyrus rupicola</i>	l
<i>Juniperus sibirica</i>	l	—	
<i>Vaccinium Myrtillus</i>	a	<i>Corylus Avellana</i>	f
<i>Calluna vulgaris</i>	a	<i>Cratægus monogyna</i>	o
<i>Erica cinerea</i>	a	<i>Euonymus europæus</i>	o
<i>Myrica Gale</i>	f	<i>Rhamnus catharticus</i>	l
—		<i>R. Frangula</i>	r
<i>Saxifraga Geum</i>	l	<i>Rubus saxatilis</i>	l
<i>S. umbrosa</i>	f	—	
<i>Pinguicula grandiflora</i>	f	<i>Vicia sylvatica</i>	vr
<i>Melampyrum hians</i>	f	<i>Rubia peregrina</i>	f
<i>Listera cordata</i>	vr	<i>Galium asperum</i>	r
<i>Luzula sylvatica</i>	a	<i>Orobanchæ Hedera</i>	l
<i>Molinia cærulea</i>	a	<i>Calamintha montana</i>	
<i>Hymenophyllum tun-</i>		(= <i>C. officinalis</i>)	l
<i>bridgense</i>	f	<i>Helleborine atroviridis</i>	l
<i>H. peltatum</i>	l	<i>Lastrea Thelypteris</i>	vl

¹ The editor is indebted to Dr R. W. Scully for very kindly contributing the substance of this account.

Old Red Sandstone (cont.) :

<i>Trichomanes radicans</i>	vr	<i>Lastrea aristata</i>	f
<i>Asplenium acutum</i>	vr	<i>L. æmula</i>	f
		<i>Osmunda regalis</i>	f

Arbutus Unedo appears to show no special soil proclivities at Killarney, occurring not only on both sandstone and limestone, but also both in the shallow soil of dry rocky woods and in the deeper soil of damp almost marshy hollows. It grows considerably more luxuriantly than in the Mediterranean "maquis," the finest trees reaching a girth of 8 feet (2·4 m.) or in extreme cases 14 feet (4·2 m.). This is probably owing to the fact that its growth is not checked by the hot dry Mediterranean summers. The common character of the two habitats is of course the mild winter, the mean January temperature of Killarney being nearly the same as that of the Riviera.

The present range of the species in the Killarney region extends over an area roughly 6 miles (c. 9·7 km.) north and south by about 3 miles (c. 4·8 km.) east and west, excluding outlying stations where a few trees still exist as remnants, probably, of woods long since disappeared. There can be no doubt that the *arbutus* has much decreased both in abundance and in the extent of its Irish area, even in comparatively modern times. Thus Dr Smith, whose *History of Kerry* was published in 1756, makes constant references in that work to the recent destruction of this tree in large quantities for smelting purposes, as well as by a disastrous fire which caused great havoc among them; while if place-names can be relied on as a clue to its former distribution, the *arbutus* appears to have extended to Co. Clare and even as far north as Co. Mayo, where an island in Clew bay derives its name from the tree.

Of the other plants occurring in the same woods *Saxifraga Geum* and *Pinguicula grandiflora* are confined, within the British Isles, to the south-west of Ireland, *Saxifraga umbrosa* is confined to Ireland and is mainly

found in the west and south, *Euphorbia hiberna* is mainly though not quite exclusively Irish. All these belong, outside the British Isles, mainly or exclusively to the Iberian peninsula.

Birchwood association (*Betuletum tomentosæ*).

(Plate XII.)

It has already been shown that on the siliceous rocks of the Pennines a fringe of birchwood frequently occurs immediately above the oakwoods at an altitude of 1000—1500 feet (c. 300—450 m.), but the association is, on the whole, poorly developed. In Scotland, however, birchwoods are the characteristic woods of the sides of the Highland valleys, where they are often extensively developed above the upper limit of the oakwoods (c. 1000 feet = 300 m.) and sometimes, though rarely, attain a height of about 2000 feet (c. 600 m.) on the slopes of the higher mountains (Plate XII a). This increase of altitude is of course in accord with the general rule that the greater the height of a hill-mass the higher any given altitudinal zone of vegetation will ascend.

W. G. Smith writes of the Scottish birchwoods¹ that their occurrence may indicate:—

(1) “An oakwood from which the oak, originally dominant, has been removed, while the less valuable birches have been left, and along with naturally sown seedlings have in time formed a wood.

(2) A wood-clearing or a piece of moorland preserved from excessive grazing by sheep, deer, and rabbits. Under these conditions, birch seedlings and mountain ash frequently develop in such numbers that a thicket or wood results....

(3) The sub-alpine deciduous wood, the highest zone of woodland in the Highland valleys.”

The first two cases we have already seen constantly

¹ W. G. Smith, 1905, p. 5.

occur in connexion with the oak-birch heath association in southern England, and are to be regarded merely as stages in the multiform succession exhibited by the heath formation. There is little or no distinction of habitat between such birchwoods and the associations which precede or follow them in succession.

The third kind of birchwood, however, has a different status, for it occupies a distinct climatic zone, above that of the oakwood, but the edaphic factors of its habitat appear to be the same. It might perhaps be regarded as a separate climatic formation, but its characters are too negative, and it is better considered simply as a separate, climatically differentiated, association of the formation of siliceous soils.

Robert Smith, who first described the Highland birchwoods from the ecological standpoint, treated them along with the pinewoods of the same region, and wrote¹: "The subordinate vegetation in the sub-alpine woods is of a less marked character than that in the temperate woods [e.g. the oakwoods], hardly differing, except in the proportion of the individuals present, from the adjoining moorland or hill-pasture....In the pinewoods heather and its associates usually constitute the plant carpet, whilst in...birchwoods the ground is more often covered by grasses and bracken, although this rule is by no means invariable."

The sub-alpine Scottish birchwoods possess, in fact, a ground vegetation made up of the oakwood species which can endure the higher altitude together with any species of siliceous grassland. They appear to have no species peculiar to them. Thus these birchwoods take their place just like those of the Pennines as a climatic zonal association of the formation of siliceous soils; while the pinewoods, as we have already seen (p. 117), appear to be naturally included in the heath formation. The

¹ R. Smith, 1900, p. 451.

Phot. A. G. Tansley

- a. *Betula tomentosa*; *Myrica Gale* on the right: 900-1250 feet (c. 270-380 m.) alt., near Kinloch Rannoch, Perthshire. Slopes of Schiehallion behind.

Phot. A. G. Tansley

- b. *Betula alba* with *Myrica Gale* (wet heath sub-association) in foreground. Wood of *Betula tomentosa* behind. Near Lochan Eilein, Inverness-shire.

Highland birchwoods.

birch, as in the south, may also colonise, and even form woods on, heathland, but it is almost certainly unable to withstand the competition of pine on such soils, because of the deep shade cast by the latter, if the two species meet under equal conditions.

Pteris aquilina is an abundant constituent of the more

**The Bracken
Fern in
Siliceous
grassland.**

open woods on siliceous soils except in the dampest places, and it very frequently persists after the woodland has disappeared. An enormous extent of siliceous grassland in the north and west of England, and in Scotland, is covered with this fern, which rapidly spreads and covers the ground as soon as the shade of the trees is removed. Under its shelter several woodland species often maintain themselves, *e.g.* *Scilla non-scripta*, *Anemone nemorosa*, *Oxalis Acetosella*. The bracken does not fully expand its fronds till early June in the south and late June in the north of Great Britain, so that during the spring the grasses and other low-growing constituents of the turf can vegetate. In the late summer and autumn however the light is cut off from them by the dense foliage of the bracken. Thus the area occupied by *Pteris* is withdrawn from pasturage during a considerable part of the year and it thus becomes quite a pestilent weed of the semi-natural siliceous pastures. Enormous tracts of land are greatly lowered in value from this cause. Deep ploughing is the only method of eradicating the deeply situated rhizomes of the fern, though repeated mowing at the beginning of the growing season will in time starve the plants. The bracken is often cut in the autumn for use as litter.

CHAPTER VI

THE VEGETATION OF CALCAREOUS SOILS

Calcicole and Calcifuge species. SOILS containing a comparatively large proportion of lime are always marked by the presence and usually by the abundance of certain species of plants—the so-called “calcicole” species. That this feature is not determined by inability of the species in question to flourish in the absence of a large amount of calcium carbonate is sufficiently shown by the fact that practically all of them occur and flourish on soils poor in lime—if not in the same at least in other regions.

Contrasting with the “calcicole” species there are others, called “calcifuge,” which appear to be really intolerant of much lime in the soil. Examples of pronounced calcifuge species usually quoted are the maritime pine (*Pinus Pinaster*), the sweet chestnut (*Castanea sativa*), and among native plants, the broom (*Sarothamnus scoparius*), and the foxglove (*Digitalis purpurea*).

Causes of the distinction. One explanation which has been given of the occurrence or abundance of calcicole species on calcareous soils is that on such soils they are free from the competition of the calcifuge species, and are thus able to hold their own. The same explanation has been given of the occurrence of halophytes on salt-containing soils, and in that case with considerable

plausibility, since the great majority of plants are highly intolerant of salt soils. But in the case of calcicole and calcifuge species it is highly doubtful whether competition has much to do with the matter. In the first place the number of calcifuge species is not so great as to make the absence of their competition a consideration of much importance. And further, this theory does not explain but rather conflicts with the abundance and luxuriance of vegetation, other than that made up of distinctively calcicole species, on suitable calcareous soils.

It seems probable, in fact, that there is some positive feature of calcareous soils favourable to vegetation at large and to calcicole species in particular. Whether it is the chemical characters, as such, of these soils, or correlated physical characters, we do not know. This is one of the problems of plant-ecology, which we may hope will shortly find a satisfactory solution.

Meanwhile we have to recognise that the calcareous soils bear a characteristic vegetation, marked by a number of species which are rarely found away from them, at least in the same region (or if found away from them, occurring only on special types of non-calcareous soil), but generally containing also numerous "indifferent" species which are abundant alike on calcareous and on non-calcareous soils. The correlation of calcareous soils with characteristic plant-communities makes it necessary to recognise in these soils a distinct type of habitat bearing distinct plant-formations.

The distinctive calcareous soils of this country are in the first place the limestones in the wide sense, including the chalk, which is a relatively pure and very soft limestone, and secondly the calcareous sandstones and the marls, which are mixtures of lime and sand and of lime and clay respectively.

In England and Wales the most extensively developed

limestones are the chalk (southern, eastern and north-eastern England), the Oolitic limestones of the Jurassic series (west midlands), the Magnesian Limestone of Permian age (northern England), the Carboniferous or Mountain Limestone (Pennines, Wales and Somerset), and various Devonian limestones in Devonshire. Limestone strata of minor importance occur in rocks of all ages. In Ireland the Carboniferous Limestone has a very wide extension, and though it is frequently covered with non-calcareous deposits, it is exposed over considerable areas in the west; but in Scotland there are no extensively developed rocks of this class, though minor limestone bands occur. Some of the soils derived from igneous rocks rich in lime-containing minerals, such as some of the felspars, are also calcareous.

Though there are more or less important floristic and ecological differences between the vegetation of the chalk, which is mainly developed in the drier regions of the east and south, and that of the older limestones, which are mainly developed in the wetter regions of the west and north, yet these do not seem of sufficient importance to override the essential unity of the limestone vegetation as a whole. We shall therefore consider the whole of this vegetation as constituting a single formation, regarding the vegetation of the older limestones as one sub-formation, that of the chalk as a second and that of the other calcareous soils as a third.

THE SUB-FORMATION OF THE OLDER LIMESTONES

By C. E. MOSS

By far the most extensive of the older limestones is the so-called Mountain Limestone of carboniferous age, which forms the centre of the Pennine Range, occurs in

Phot. W. B. Crump

- a. Ash scrub. *Fraxinus excelsior*, *Crataegus monogyna*, etc. Ebbor Gorge, Somerset.

Phot. W. B. Crump

- b. *Fraxinus excelsior* (coppiced). Damp ground sub-association. *Allium ursinum*, *Lamium Galeobdolon*. Long Wood, Cheddar, Somerset.

Ashwood and scrub on Mountain Limestone.

Wales and in the Mendip Hills in Somerset, and is exposed over considerable areas in Ireland. The vegetation of this rock has been principally studied in the Pennine area and on the Mendips, and the following account is mainly based on these regions.

As in most other cases, the characteristic vegetation of the older limestones is naturally considered as falling into three associations corresponding to woodland, scrub and grassland.

Ashwood association (*Fraxinetum excelsioris*)
(Plates XIII and XIV).

Ashwoods are characteristic of the limestone hills of the north and west of England. Woods of this type occur on the limestone hills of Yorkshire¹ and Derbyshire², Westmorland³ and Somerset⁴.

Those described by Smith and Rankin are in many cases of the nature of scrub (see p. 153), and
Distribution. those described by Lewis are of the ash-birch type (see p. 149). In Somerset, ashwoods are well developed on the slopes of hills of the Carboniferous or Mountain Limestone, of the Dolomitic Conglomerate, and of the Jurassic limestones.

In Derbyshire, they are well developed on the slopes of hills of the Mountain Limestone. The summits of the limestone hills of north Derbyshire attain a height of about 1550 feet (c. 470 m.), and their average height is about 1200 feet (c. 370 m.). The plateau is dissected by numerous valleys or "dales," most of which are streamless. The dales descend from the plateaux, and the ash woods begin to appear at an altitude of about 1000 feet (305 m.), above which scrub occurs but no genuine woods, and continue to the bottoms of the dales.

¹ Smith and Rankin, 1903.

² Moss, 1911.

³ Lewis, 1904 a.

⁴ Moss, 1907.

It is probable that at some past time, the whole of the limestone areas of England below about 1000 feet (c. 300 m.), or perhaps even 1250 feet (c. 380 m.), were covered by a primæval ash forest, just as similar places on the older siliceous hills were once covered by forests of oak (*Quercus sessiliflora*) and birch (*Betula tomentosa*). The numerous place-names including the word "ash" indicate that the abundance of *Fraxinus excelsior* is of long standing. In north Derbyshire, for example, there are Ashwood dale, Ashford, Money Ash (= "many ash"), and, on the edge of the plateau at the upper limit of woodland, One Ash.

On the Chalk of the south and east of England, the ash is a very abundant and characteristic plant, though its dominance in woods is apparently confined to the south-western region of the chalk outcrop.

In the limestone districts above indicated, the ash (*Fraxinus excelsior*) is the dominant tree of the natural and semi-natural woods, whether the soil be damp or dry¹. In non-calcareous areas, the ash only becomes dominant or abundant where the soil is wet or decidedly damp; and it seems clear that, in any given natural station, the abundance of the ash is due to one of two causes, either to a high lime-content of the soil or to a high water-content. Some of the local foresters are of opinion that the timber of the ash grown on the limestone soils is harder and more durable than that grown on the wet, non-calcareous soils.

The two most frequent woody associates of the ash are the wych elm (*Ulmus glabra* Huds. = *U. montana*) and the hawthorn (*Cratægus monogyna*), both of which are more abundant in the ashwoods than in typical oak

Relation to
water and
to lime.

Associated
trees and
shrubs.

¹ These ashwoods cannot be separated from oakwoods on the basis of a difference in the water-content of the soil, for in each case there is a range from very wet to very dry soils.

and birchwoods. The elm is more abundant at the lower altitudes and in the damper situations, the hawthorn in the drier situations and at the higher altitudes. When the ash is removed or dies out naturally, the elm or the hawthorn becomes locally sub-dominant, and societies of elm and hawthorn are as characteristic of ashwoods as societies of birch and alder are of oakwoods.

Two conifers are native in the ashwoods, namely, the juniper (*Juniperus communis*) and the yew (*Taxus baccata*); but they are somewhat local in their distribution. In Derbyshire, for example, the yew is rather rare, whilst in north Lancashire it is abundant.

The aspen (*Populus tremula*) is the only indigenous species of the genus *Populus*; but sometimes *P. serotina* is planted at the edges of the woods. An interesting society of *P. tremula* occurs in upper Cressbrook Dale.

Of willows which are certainly indigenous, the crack willow (*S. fragilis*) and the osier willow (*S. viminalis*) occur by stream sides, and the salallows (*S. caprea* and *S. cinerea*) occur in the woods themselves. *S. aurita* appears to be absent from the ashwoods of limestone soils.

In Derbyshire, oaks appear to be absent from the ashwoods, except locally as introduced trees; but in other localities *Quercus Robur* and *Q. sessiliflora* may occur.

The beech (*Fagus sylvatica*) is frequently planted on all kinds of soil in this country, but is probably not indigenous in the north of England.

The hazel (*Corylus Avellana*) is a very abundant and characteristic shrub of the ashwoods, where dense thickets of this plant frequently occur.

The alder (*Alnus rotundifolia*) is much less abundant than in the oakwoods.

In the ashwoods of Somerset and Derbyshire, birches (*Betula* spp.) are very rare and local; but on the limestone hills of the northern Pennines, particularly at the higher

150 *Sub-formation of the Older Limestones*

altitudes, the birch locally becomes subdominant or dominant (Moss, Rankin and Tansley, 1910, p. 142).

One of the most noticeable features of the English ashwoods of calcareous soils is the large number of associated species of trees and shrubs. For example, the following plants are characteristic of ashwoods but are absent or nearly absent from oak and birchwoods on the older siliceous soils.

<i>Tilia cordata</i>	la	<i>Cornus sanguinea</i>	a
<i>T. platyphyllos</i>	r	<i>Viburnum Lantana</i>	la
<i>Rhamnus catharticus</i>	la	<i>Ligustrum vulgare</i>	a
<i>Euonymus europæus</i>	la	<i>Daphne Mezereum</i>	r
<i>Rosa spinosissima</i>	l	<i>D. Laureola</i>	o
<i>R. micrantha</i>	o	<i>Juniperus communis</i>	l
<i>Pyrus Aria</i>	lf	<i>Taxus baccata</i>	l

Ericaceous undershrubs are totally absent from the ashwoods.

Two species which characterise sub-associations of the oakwoods, namely *Deschampsia flexuosa* and *Holcus mollis*, do not occur in the ashwoods. The following divisions (sub-associations) of the ground vegetation will illustrate the range in habitat and in floristic composition which occurs within the ashwoods.

(1) In marshy places, which occur in ashwoods by stream sides, at the bottoms of the streamless dales, and on slopes where springs arise, such moisture-loving plants as the following occur:

<i>Trollius europæus</i>	l	<i>Polemonium cæruleum</i>	l
<i>Caltha palustris</i>	a	<i>Myosotis Scorpioides</i>	
<i>Spiræa Ulmaria</i>	u	(palustris)	lf
<i>Geum rivale</i>	l	<i>Mentha aquatica</i>	a
<i>G. rivale</i> × <i>urbanum</i>	r	<i>Sparganium ramosum</i>	l
<i>Epilobium hirsutum</i>	a	<i>Scirpus compressus</i>	
<i>Valeriana officinalis</i>		(= <i>Blysinus Carici</i>)	l
(<i>Mikanii</i>)	u	<i>Phalaris arundinacea</i>	l
<i>Petasites ovatus</i>	va	<i>Phragmites vulgaris</i>	
<i>Cirsium heterophyllum</i>	l	(= <i>P. communis</i>)	l

Phot. W. M. Rankin

a. Wooded hill. Anstwick, Yorkshire.

Phot. W. M. Rankin

b. Ashwood on limestone pavement. *Fraxinus excelsior*.
Chapel-le-Dale, Ingleton, Yorkshire.

Ashwood on Mountain Limestone.

(2) Other parts of the woods, which, though not marshy, are nearly always very moist, have a rich and varied ground flora. Sheets of wood-garlic (*Allium ursinum*) (Plate XIII b) and of the lesser celandine (*Ranunculus Ficaria*) are characteristic. The following is a selected list of the species of such damp parts of the ashwoods:

<i>Anemone nemorosa</i>	a	<i>Campanula latifolia</i>	o
<i>Ranunculus Ficaria</i>	a	<i>Myosotis sylvatica</i>	lf
<i>Trollius europæus</i>	l	<i>Lamium Galeobdolon</i>	a
<i>Aquilegia vulgaris</i>	l	<i>Orchis mascula</i>	f
<i>Lychnis dioica</i>	a	<i>Habenaria virescens</i>	
<i>Fragaria vesca</i>	u	(chloroleuca)	o
<i>Oxalis Acetosella</i>	f	<i>Allium ursinum</i>	la
<i>Asperula odorata</i>	la	<i>Arum maculatum</i>	f
<i>Valeriana officinalis</i>		<i>Carex sylvatica</i>	f
(<i>Mikanii</i>)	a	<i>Bromus ramosus</i>	f
<i>V. dioica</i>	l	<i>Triticum caninum</i>	l
<i>Cnicus palustris</i>	a	<i>Hordeum sylvaticum</i>	l
<i>C. heterophyllus</i>	l		

(3) On soils which are drier than the preceding, and which, during the summer months, may become temporarily very dry, sheets of dog's mercury (*Mercurialis perennis*) often occur; and this plant is in Derbyshire very frequently associated with the moschatel (*Adoxa Moschatellina*). At the beginning of April, in the Derbyshire dales, the dog's mercury is about three inches high, its leaves are beginning to unfold, and a few stamens are ripe. At this time of the year, the moschatel is here flowering abundantly, and is almost hidden by the young shoots of the dog's mercury. In the fairly dry portions of the ashwoods of the Peak district, this plant society of dog's mercury and moschatel is a characteristic feature. The society is an excellent example of what Woodhead (1906, p. 345) terms a "complementary" society, as the roots of the dog's mercury reach down to lower layers of soil than the roots of the moschatel, whilst the small

and delicate shoots of the *Adoxa* receive their necessary shade from the larger and more vigorous shoots of *Mercurialis*. Before the end of June, *Adoxa* has entered on its long period of dormancy; and the dull green leaves of the dog's mercury, hiding its ripening berries, occur in extensive and monotonous stretches. It may, therefore, be said that the roots of the two species are edaphically complementary and the shoots seasonally complementary. In the oak and birchwoods, the dog's mercury occurs in more or less local patches, and *Adoxa* is extremely rare; whilst the *Mercurialis-Adoxa* society does not occur.

The dog's mercury is much more abundant in English woods on calcareous soils than in those on non-calcareous soils; and this is a partial confirmation of an observation made by Thurmann¹, who mentions the plant as one of fifty "xerophilous" plants typical of "dysgeogenous" or calcareous soils.

(4) The dry parts of the ashwoods are characterised by stretches of ground ivy (*Nepeta hederacea*), which remains green throughout the whole year and flowers from early spring to late summer. If the ground is stony and composed of old screes, taller herbs occur, such as the hairy St John's wort (*Hypericum hirsutum*), the nettle (*Urtica dioica*), and the wood sage (*Teucrium Scorodonia*). These plants form close herbaceous thickets in summer; and their dead stalks remain upright and rigid throughout the succeeding winter and spring. Locally, the lily-of-the-valley (*Convallaria majalis*) and the stone-bramble (*Rubus saxatilis*) form fairly extensive plant societies, and in these the nodding melic-grass (*Melica nutans*) sometimes occurs.

(5) The very driest parts of the ashwoods occur on the rocky knolls. Here the soil is extremely shallow, and in places the bare rock protrudes. Trees and shrubs are absent, and the absence of shade allows of the growth of

¹ Thurmann, 1849.

saxicolous lichens and bryophytes, of ephemeral species as *Arenaria serpyllifolia*, *Draba verna*, and *Saxifraga tridactylites*, and of dwarf perennials like *Sedum acre* and *Thymus Serpyllum*. Such a community does not, except in a topographical sense, belong to a woodland association at all, and is to be regarded as an outlier of another association.

Limestone screes and cliffs also occur in the midst of the ashwoods. These, if damp, become in time clothed with the vegetation of the ashwoods; and, by comparing several such localities, it is possible to gain some idea of a progressive succession from bare screes and cliffs to a closed ashwood association. Such a succession supplies the reason, an historical one, why plants like the mossy saxifrage (*Saxifraga hypnoides*) and the limestone polypody (*Phegopteris Robertiana*) are sometimes found on old screes in the midst of existing ashwoods.

Limestone scrub association. The ashwoods merge imperceptibly into calcareous scrub, and many areas occur which it is difficult to classify either as woodland or scrub. An excellent series of such transitional areas may be seen in Monsal Dale and Cressbrook Dale in Derbyshire. As on the siliceous soils, the scrub assumes many different facies. In some cases, the taller woody plants are more or less isolated, and the ground vegetation quite grassy. In other cases, dense thickets of shrubs occur, and the ground flora contains many shade-loving species. In the great majority of cases, however, the scrub appears to be of a retrogressive nature, though progressive scrub communities occur here and there, as at the foot of cliffs and on screes. As the scrub contains many woodland species as well as many grassland species, it is often extremely rich floristically, as in the case of the calcareous scrub in upper Cressbrook Dale above mentioned; but very nearly all the plants of scrub occur in the related woodland or grassland (Plate XIII a).

The species of shrubs of the limestone scrub association are as follows:

<i>Prunus spinosa</i>	o	<i>Rhamnus catharticus</i>	r
<i>Rubus spp.</i>	o	<i>Hedera Helix</i>	f
<i>Rosa canina</i>	o	<i>Cornus sanguinea</i>	r
<i>R. mollis</i>	r	<i>Lonicera Periclymenum</i>	o
<i>R. spinosissima</i>	la	<i>Fraxinus excelsior</i>	o
<i>Cratægus monogyna</i>	la	<i>Corylus Avellana</i>	la
<i>Euonymus europæus</i>	r	<i>Salix spp.</i>	r

The following are some of the more characteristic species of the ground vegetation:

<i>Thalictrum minus</i>	r	<i>Chrysanthemum Leucan-</i>	
<i>Anemone nemorosa</i>	o	themum	f
<i>Cardamine impatiens</i>	l	<i>Cnicus palustris</i>	o
<i>Helianthemum Chamæ-</i>		<i>C. eriophorus</i>	o
cistus	a	<i>Picris hieracioides</i>	r
<i>Stellaria Holostea</i>	r to o	<i>Primula veris</i>	f
<i>Geranium sanguineum</i>	l	<i>Teucrium Scorodonia</i>	r
<i>Rubus saxatilis</i>	l	<i>Nepeta hederacea</i>	la
<i>Fragaria vesca</i>	o	<i>Origanum vulgare</i>	f
<i>Poterium Sanguisorba</i>	a	<i>Cypripedium Calceolus</i>	vr
<i>Saxifraga hypnoides</i>	l	<i>Listera ovata</i>	o
<i>Hypericum hirsutum</i>	la	<i>Convallaria majalis</i>	l
<i>H. montanum</i>	l	<i>Luzula pilosa</i>	o
<i>Galium Cruciata</i>	r to o	<i>Avena spp.</i>	o
<i>Solidago Virgaurea</i>	o	<i>Koeleria gracilis</i>	o
<i>Inula squarrosa</i>	r	<i>Melica nutans</i>	r
		<i>Brachypodium gracile</i>	f

Limestone grassland association (*Festucetum ovinæ*).

From calcareous scrub, every transition may be traced to pure grassland. Typical calcareous grassland consists of short, grassy turf, largely composed of the sub-aërial parts of the sheep's fescue-grass (*Festuca ovina*). Such grassland is characteristic and widespread on the slopes of the limestone hills of the west and north of England and equally so on the chalk downs of the south (see p. 173).

FIG. 5. Chart of associations of the Limestone Formation of Cressbrook Dale and Monsal Dale, Derbyshire. The natural and semi-natural associations are mainly confined to the valley sides. The lower half of the figure is occupied by Monsal Dale which has a winding course and a mainly southerly direction; the upper half by the dry tributary valley of Cressbrook Dale, which runs southwards and joins Monsal Dale about the middle of the figure.

I. Cultivation: (1) of valley bottom alluvium, (2) intakes from limestone slopes, (3) of plateau.

II. Limestone grassland on valley sides and extending on to plateau.

III. Limestone scrub; on valley sides and extending slightly on to plateau.

IV. Ashwood: on valley slopes.

The soil of limestone grassland is shallow, often being only a few inches deep. In colour, it varies from a whitish grey, where the lime-content is very high, to a brownish or even reddish-brown where the lime-content is lower and the iron-content high. The more newly-formed soils have the higher lime-content, and the older soils have the lower lime-content. The newer soils are also dry and porous: the older ones have often a comparatively high water-content. Marshes occur here and there on the limestone hill-slopes, so that the range of water-content on the calcareous grassland is similar to that which occurs on the siliceous grassland. However, in a general way, it is correct to say that the soils of the calcareous grasslands are drier than those of the siliceous grasslands. The water-content of non-calcareous soils varies directly as the humus-content, a result doubtless due to the water-absorbing properties of humus. The water-content of calcareous soils, on the other hand, is greater the less lime they contain.

The two principal grasses (*Nardus stricta* and *Deschampsia flexuosa*) of the drier type of siliceous grassland are quite absent from calcareous grassland, and so is the principal grass (*Molinia cærulea*) of the wetter type of siliceous grassland (cf. pp. 132-6). The bracken (*Pteris aquilina*), gorse (*Ulex* spp.), and the common rushes (*Juncus effusus* and *J. conglomeratus*) which bring about such characteristic facies of the siliceous grassland, are only of local occurrence on calcareous grassland, and perhaps mainly confined in Derbyshire to leached soils or soils mixed with non-calcareous material. Many other plants characteristic of the siliceous grasslands are also absent from the calcareous grasslands, and the following list is a selection of the more widespread of these:

**Differences
from siliceous
grassland.**

Spergularia rubra
Polygala serpyllacea

Cytisus scoparius
Genista anglica

Potentilla procumbens	Melampyrum pratense var.
Galium saxatile	montanum
Gnaphalium sylvaticum	Empetrum nigrum
Jasione montana	Salix repens
Erica cinerea	Orchis ericetorum
Calluna vulgaris	Luzula multiflora
Vaccinium Myrtillus	Carex binervis
Digitalis purpurea	Holcus mollis
	Blechnum Spicant

On the other hand, the following widespread plants are a few selected from those which are characteristic of calcareous grassland but absent from or rare in siliceous grassland:

Thalictrum minus	Campanula glomerata
Viola hirta	Origanum vulgare
Polygala calcarea	Plantago media
Anthyllus Vulneraria	Ophrys apifera
Hippocrepis comosa	O. muscifera
Poterium Sanguisorba	Orchis ustulata
Potentilla verna	O. pyramidalis
Helianthemum Chamæcistus	Avena pubescens
Galium asperum	A. pratensis
Asperula cynanchica	Koeleria gracilis (cristata)
Scabiosa Columbaria	Bromus erectus
Leontodon nudicaule	Brachypodium pinnatum

Local variations in floristic composition. Interesting local differences are seen in the floristic character of calcareous pasture in different parts of the country. For instance, in the north of England, *Sesleria cærulea* is a very abundant and characteristic member of calcareous grassland. This grass appears to reach its southern British limit on the Pennines of mid-Yorkshire, and is absent from the limestone of Derbyshire. *Actæa spicata* and *Primula farinosa* also seem to have found the siliceous soils of the Leeds and Halifax district an effectual barrier against a southern extension of their range. *Carex ornithopoda* is a very local plant in England,

occurring on the calcareous pasture, and also on limestone cliffs in Derbyshire.

In the west of England *Helianthemum polifolium*, *Trinia glauca*, and *Koeleria vallesiana* occur locally on the calcareous pasture of the limestone hills.

A larger number of species characterise the chalk of south-eastern England and have failed to reach the limestones of the west and north.

Although swamps are less characteristic of calcareous than of siliceous pasture, they do occur here and there on the slopes of the fissured limestones, and they are characterised by different plant communities from the swamps of siliceous soils. On the Pennines, for example, the following plants occur on the swamps of the limestone hills :

**Limestone
swamps.**

<i>Thalictrum flavum</i>	r	<i>Petasites ovatus</i>	la
<i>Trollius europæus</i>	la	<i>Carduus heterophyllus</i>	la
<i>Caltha palustris</i>	a	<i>Cnicus palustris</i>	a
<i>Spiræa Ulmaria</i>	a	<i>Primula farinosa</i>	la
<i>Potentilla palustris</i>	l	<i>Polemonium cæruleum</i>	la
<i>Geum rivale</i>	la	<i>Myosotis palustris</i>	la
<i>G. rivale</i> × <i>urbanum</i>	o	<i>Mentha spp.</i>	a
<i>Chrysosplenium oppositifolium</i>	la	<i>Pedicularis palustris</i>	l
<i>C. alternifolium</i>	la	<i>Orchis latifolia</i>	l
<i>Parnassia palustris</i>	la	<i>Epipactis palustris</i>	r
<i>Epilobium hirsutum</i>	a	<i>Juncus glaucus</i>	la
<i>Valeriana officinalis</i> (V. Mikanii)	a	<i>Scirpus compressus</i>	l
<i>V. dioica</i>	la	<i>Carex disticha</i>	l
<i>Eupatorium cannabinum</i>	la	<i>Festuca elatior</i>	l
		<i>Selaginella selaginoides</i>	l

In exposed situations, especially on plateaux and the higher hill-slopes, the soil of the calcareous pasture tends to lose its high lime-content owing to the leaching action of rain. As this process continues, some of the plants of siliceous grassland may invade the leached area, and in time, a *limestone*

The "lime-
stone heath."

heath may be produced. A limestone or calcareous heath is characterised by the occurrence side by side, on soils unmixed with non-calcareous débris, of calcicole plants and calcifuge plants. The former are, in the majority of cases, deep tap-rooted plants; and the roots reach down to the lower layers of soil where the lime-content is high. The latter are nearly always plants with a superficial root-system whose activities are confined to the leached upper layers where the lime-content is low. Thus, such calcifuge plants as *Calluna vulgaris* may be found growing side by side and completely mixed up with such lime-loving plants as *Poterium Sanguisorba*¹.

The following is a list of plants occurring in the limestone grassland association of the Pennines.

<i>Thalictrum minus</i>	l	<i>Pimpinella Saxifraga</i>	o
<i>Ranunculus bulbosus</i>	a	<i>P. magna</i>	r
<i>Cochlearia alpina</i>	l	<i>Conopodium majus</i>	o
<i>Erophila verna</i>	la	<i>Asperula cynanchica</i>	la
<i>E. præcox</i>	la	<i>Galium verum</i>	a
<i>Arenaria verna</i>	l	<i>G. Cruciata</i>	la
<i>Geranium lucidum</i>	la	<i>G. asperum</i>	la
<i>G. sanguineum</i>	r	<i>Scabiosa Columbaria</i>	o
<i>Polygala vulgaris</i>	a	<i>Bellis perennis</i>	o
<i>Viola hirta</i>	o	<i>Antennaria dioica</i>	la
<i>V. lutea</i>	la	<i>Achillea Millefolium</i>	a
<i>Anthyllis Vulneraria</i>	o	<i>Chrysanthemum Leucan-</i>	
<i>Lotus uliginosus</i>	a	<i>themum</i>	a
<i>Hippocrepis comosa</i>	l	<i>Carlina vulgaris</i>	o
<i>Potentilla verna</i>	l	<i>Carduus nutans</i>	o
<i>P. Crantzii</i>	l	<i>Cnicus eriophorus</i>	l
<i>Alchemilla vulgaris var.</i>		<i>C. palustris</i>	l
<i>filicaulis</i>	o	<i>Centaurea nigra</i>	a
<i>Poterium Sanguisorba</i>	a	<i>C. Scabiosa</i>	o
<i>Saxifraga hypnoides</i>	l-	<i>Picris hieracioides</i>	o
<i>S. tridactylites</i>	la	<i>Crepis virens</i>	a
<i>Sedum acre</i>	a	<i>Leontodon hispidus</i>	a
<i>Hypericum hirsutum</i>	la	<i>L. nudicaule</i>	l
<i>Helianthemum Chamæ-</i>		<i>L. autumnalis</i>	la
<i>cistus</i>	a	<i>Hieracium Pilosella</i>	a

¹ Moss, 1907 and 1911.

<i>Hieracium spp.</i>	la	<i>H. conopsea</i>	l
<i>Campanula glomerata</i>	o	<i>Listera ovata</i>	lo
<i>C. rotundifolia</i>	o	<i>Spiranthes autumnalis</i>	r
<i>Primula veris</i>	a	<i>Allium vineale</i>	r
<i>Centaureum umbellatum</i>	r	<i>A. oleraceum</i>	r
<i>Gentiana Amarella</i>	a	<i>Luzula campestris</i>	a
<i>G. baltica</i>	r	<i>L. pilosa</i>	l
<i>Stachys Betonica</i>	o	<i>Carex caryophyllea</i>	la
<i>Origanum vulgare</i>	la	<i>C. flacca</i>	o
<i>Thymus Serpyllum</i>	a	<i>C. ornithopoda</i>	r
<i>Veronica Chamædrys</i>	o	<i>C. pilulifera</i>	l
<i>Euphrasia officinalis</i>		<i>Anthoxanthum odoratum</i>	o
(agg.)	a	<i>Trisetum flavescens</i>	l
<i>Plantago media</i>	la	<i>Avena pratensis</i>	o
<i>P. lanceolata</i>	a	<i>A. pubescens</i>	l
<i>Ophrys apifera</i>	r	<i>Arrhenatherum elatius</i>	la
<i>O. muscifera</i>	r	<i>Koeleria gracilis (cristata)</i>	o
<i>Orchis Morio</i>	la	<i>Briza media</i>	o
<i>O. mascula</i>	la	<i>Festuca ovina</i>	d
<i>O. maculata</i>	l	<i>Bromus erectus</i>	l
<i>O. ustulata</i>	r	<i>Brachypodium gracile</i>	a
<i>O. pyramidalis</i>	r	<i>B. pinnatum</i>	r
<i>Habenaria viridis</i>	la	<i>Asplenium spp.</i>	l

Associations of limestone pavements.

A very striking feature of some of the summits of the Carboniferous Limestone, as in the mid-Pennines¹ and the north Pennines, is the intricate maze of deep and narrow clefts of the limestone rocks. Limestone rocks weathered in this way are spoken of as "pavements." They are also of great extent at low altitudes on the limestone plain of Co. Clare, in west Ireland² (Plate XV).

The exposed surface of the rock is very bare, and, although rather rich in lichens and mosses, is extremely poor as regards its Phanerogamic flora. Within the clefts, however, ferns and flowering plants are abundant. The clefts are sheltered from wind and sun; and, there

¹ Smith and Rankin, 1903, p. 19 of separate.

² R. Lloyd Praeger, 1909, p. 50 et seq.

PLATE XV

Phot. W. Welch

Mountain Limestone pavement. Black Head, Co. Clare, West Ireland.

being little evaporation, the soil is almost always moist. Many of the plants found are those of the ash-woods, such as the dog's mercury (*Mercurialis perennis*), the wood garlic (*Allium ursinum*), and the hartstongue fern (*Phyllitis Scolopendrium* = *Scolopendrium vulgare*); but in addition to the woodland species, there are *Ribes petraeum* Sm., the green spleenwort (*Asplenium viride*), *Lastrea rigida*, and the holly fern (*Polystichum Lonchitis*). The following is a more complete list:

<i>Thalictrum minus</i>	f	<i>Hedera Helix</i>	la
<i>Anemone nemorosa</i>	f	<i>Lactuca muralis</i>	o
<i>Actæa spicata</i>	l	<i>Mercurialis perennis</i>	f
<i>Viola Riviniana</i>	o	<i>Corylus Avellana</i> , dwarfed	la
<i>Geranium Robertianum</i>	o	<i>Listera ovata</i>	o
<i>Oxalis Acetosella</i>	a	<i>Allium ursinum</i>	f
<i>Rubus Idæus</i>	la	<i>Asplenium viride</i>	la
<i>Cratægus monogyna</i> (=		<i>A. Trichomanes</i>	a
<i>Oxyacantha</i>), dwarfed	la	<i>Phyllitis Scolopendrium</i>	f
<i>Ribes petraeum</i>	la	<i>Polystichum lobatum</i>	r
<i>Heracleum Spondylium</i>	o	<i>Lastrea rigida</i>	la

Sometimes, in more sheltered places, the limestone pavement becomes completely overgrown with vegetation and an ashwood may then take possession of the habitat (Plate XIV b).

THE SUB-FORMATION OF THE CHALK

By A. G. TANSLEY and W. M. RANKIN

The English chalk uplands, called "downs" in the south and "wolds" in the north, have a wide extension in the south and east of the country. Their well-known soft and rolling contours are very familiar to dwellers in and travellers through the country lying east and south-east of a line drawn from north Yorkshire southward to Buckinghamshire and thence south-westward to the Devonshire coast of the Channel.

The distribution of the chalk and some of its characteristic agricultural features have already been described in Part I (pp. 53-5). Stratigraphically and lithologically the rock is divisible into three, the Upper, Middle and Lower Chalk. The Upper Chalk is the thickest division and also the purest, frequently containing as much as 98% of calcium carbonate. The Lower Chalk is much less pure, containing considerable percentages of clay and siliceous material generally. The Lower and Middle Chalk are generally under cultivation, and it is mainly the Upper Chalk which bears the characteristic woodland, scrub and grassland to be here described. A large proportion of its surface is, however, covered by various later deposits of no great depth, such as clay-with-flints, plateau gravels, and in the regions near the North Sea, chalky boulder clay, together with rainwash from these accumulations. The typical chalk vegetation is thus generally confined to the escarpments and valley sides where the actual chalk comes to the surface.

The vegetation of the chalk proper, as in the case of other plant-formations, shows the obvious
Vegetation. division into woodland, scrub and grassland associations with which we have now become familiar. In many respects these associations are distinctive as compared with the corresponding associations of the older limestones. Thus the beechwoods of the escarpments and valley sides of the chalk contrast with the ashwoods of corresponding situations on the older limestones. To this generalisation there are indeed exceptions. The extreme limits of the chalk in Devon, Dorset and the Isle of Wight bear ashwoods in place of beechwoods, and on the northern wolds of Yorkshire and Lincolnshire natural beechwoods are also absent; while the oolitic limestones of the Cotswold Hills in Gloucestershire bear well-developed natural beechwoods.

Phot. S. Mangham

- a. Beechwood and chalk pasture on sides of dry valley in chalk escarpment. Chevening Park, Kent.

Phot. S. Mangham

- b. Interior of same beechwood. Communities of *Mercurialis perennis* in lighter spaces. [*Cephalanthera grandiflora* and *Neottia Nidus-Avis* occur in the darker shade.]

Beechwood association on Chalk.

The grasslands, as developed in the smooth down pastures, have a more varied flora than, for instance, the pastures of the mountain limestone, containing several species, notably certain orchids, which are confined in England to the south-east. Finally, the chalk scrub also possesses some distinctive features.

Beechwood association of the chalk (*Fagetum sylvaticæ calcareum*) Plates XVI—XVIII.

Distribution of beech-woods. Natural beechwoods occur on the escarpments and valley sides of the North and South Downs fringing the Weald; they are sparsely represented towards the eastern limits of both escarpments, but attain to very fine development at the western end of the Weald, especially between Arundel and Selborne. A second important beechwood area is that of the Chiltern Hills in Buckinghamshire and south Oxfordshire. From this centre beechwoods extend in one direction across the Thames valley, dying out in Wiltshire, and in the other, north-eastward along the main chalk escarpment into Hertfordshire and Cambridgeshire, where, however, they are very sparsely developed, while they are apparently quite absent from the chalk of Norfolk, Lincolnshire and Yorkshire. A third distinct area is that of the oolitic limestones of the Cotswolds. The western chalk escarpment of Salisbury Plain and the Jurassic limestones in the neighbourhood of Bath, which seem to offer suitable situations, and might serve to connect the Cotswold and Chiltern areas, are, however, apparently quite destitute of natural beechwoods.

“It seems likely that the beech is, speaking geologically, a comparatively recent migrant into this country from the Continent. Such a view is supported by its sub-fossil occurrence in Denmark in the recent, but not in the older peat. Whether the beech be a comparatively

recent immigrant or not, it seems that only in the south-east of England has it found climatic conditions enabling it to become dominant and to form woods, beating the ash, its light-demanding competitor on calcareous soils, by reason of the deep shade which it casts. While the beech has every appearance of being native so far west as Cornwall, and while it flourishes and ripens seed so far north as Scotland, where it is often successfully planted on very various soils, it appears quite unable to form natural woods outside the area indicated¹. It may, however, have had its distribution as a wood-former somewhat curtailed by clearance of forest on the outskirts of its present area, *i.e.* on the chalk escarpment on either side of the Chiltern region, for in Cambridgeshire and Wiltshire indications of natural beechwoods are not wanting²."

We may therefore conclude that the beechwoods on the chalk of southern England represent an extension of the continental beechwoods on calcareous soils³. In this country they occupy the drier chalk rather than the damper marls, a fact which may be connected with the damper climate of England. The factors which have arrested the further progress north-westward of the beech association are not at all clear, since the beech itself, as we have seen, flourishes and sets seed perfectly well far beyond its limits as a wood-former.

¹ "It is interesting to notice that the distribution of certain associations of land molluscs which show continental affinities, is limited in a similar way. *Helix obvolvata*, the most typical species of these associations, is found nowhere beyond the limits of the beech association."

² Moss, Rankin and Tansley, 1910, pp. 143 -4.

³ Graebner (*Die Pflanzenwelt Deutschlands*, 1909) describes the German beechwoods as occupying mostly marly soils. The English beechwoods on chalk must be carefully distinguished from the local beechwoods on sand which belong to the heath formation, and have already been mentioned (p. 102). Both types of beechwood are apparently confined to the south of England.

PLATE XVII

Phot. G. J. P. Cane

Beechwood in winter, with young trees. Ditcham Park, Hampshire.

Beechwood on Chalk.

The chalk beechwood association occurs typically on the steep slopes of the escarpments and valleys of the downs—a characteristic position that doubtless gave rise to the local name "hanger" for this type of wood. Sometimes beechwood is found on the more level ground of the chalk plateaux, but in these situations the chalk is generally covered by superficial non-calcareous deposits, and where such is the case the oak (*Q. Robur*) always occurs, either mixed with beech, or forming pure oakwoods of the damp or dry type according to the nature of the soil overlying the chalk. The summits of the downs, where they are bare of superficial deposits, are largely covered with calcareous pasture¹, which has from time immemorial been used as "sheep-walk"; from the constant occurrence of neolithic barrows and ancient camps and track-ways on the down summits it is very doubtful indeed if much of this grassland was ever covered with wood. It has been suggested that the ground water level is too far below the surface for the beech to flourish on these chalk summits and plateaux, and the general restriction of the beechwoods to the steeper slopes may be due to this cause. This restriction may also be partly due to the tendency to clear the gentler slopes first for agricultural or pastoral purposes.

The typical beech hangers are developed on very shallow soil, the rock being generally covered only by a few inches of mild humus; the roots of the trees are largely embedded in the chalk itself.

The beech is not only the dominant tree in the beechwood association; it typically forms a practically pure high forest in close canopy, and is very rarely coppiced (Plates XVI, XVII). Occasionally an ash is met with, occasionally a whitebeam (*Pyrus Aria*), but these trees cannot compete successfully with

¹ This is especially the case on the South Downs of Sussex and Hampshire, and on Salisbury Plain.

the beech if the latter is growing in close canopy, for their light demand is higher. The oak is extremely rare, and is entirely absent from many beechwoods. *Prunus Avium* is occasionally abundant. The yew (*Taxus baccata*) is abundant in many beechwoods, this species forming a distinct "layer" below the crowns of the dominant trees.

Shrubs are practically absent in a normal beechwood, for the light penetrating the canopy is insufficient to permit of their growth.

The ground vegetation is, for the same reason, very scanty—often indeed quite absent. However, in places where the foliage canopy is comparatively thin, *Mercurialis perennis* is the typical dominant, often covering the ground in continuous sheets (Plate XVI b), while *Sanicula europæa*, *Viola Riviniana*, *V. sylvestris*, *Fragaria vesca* and *Circæa lutetiana* are generally abundant and locally dominant (Plate XVIII a). *Viola hirta*, a pronounced calcicole, is also abundant and characteristic. The orchids *Cephalanthera grandiflora*, and the rarer *Helleborine violacea* and *H. atrorubens*, are also characteristic, and *Habenaria virescens* (*chloroleuca*) is frequent. In the humus the colourless saprophytes *Neottia Nidus-avis* and *Monotropa Hypopitys* are frequent. *Helleborus viridis*, *H. foetidus*, *Atropa Belladonna*, *Daphne Laureola*, and *Ruscus aculeatus* are characteristic species of the more open spots in or on the outskirts of beechwoods.

Ashwood association (*Fraxinetum excelsioris calcareum*).

The composition of this association does not differ essentially from that already described (p. 147) as the chief association of the formation of the older limestones, though minor floristic differences of course exist. The main interest of the association lies rather in its relation to beechwood—the more typical woodland association of the chalk.

Phot. A. G. Tansley

- a. Typical ground vegetation of beechwood in better lighted spots. *Mercurialis perennis*, *Fragaria vesca*, *Viola hirta*, *Viola Riviniana*.

Phot. W. M. Rankin

- b. Degenerating beechwood on chalk. *Fagus sylvatica*, *Pyrus Aria*, *Taxus baccata*, *Crataegus monogyna*. Chalk grassland and bases of foliage of trees and shrubs nibbled close by rabbits. Holt Down, near Butser Hill, Hampshire.

Beechwood on Chalk.

Ashwoods characterise the south-western extremities of the chalk outcrop, lying in the Isle of Wight, Dorset and East Devon. The line of contact between the ashwood and the beechwood regions occurs near Butser Hill north of Portsmouth, where the South Downs attain their greatest elevation (889 feet = c. 270 m.). Ashwoods are also developed on those portions of the Upper Greensand (which often forms a low terrace at the foot of the chalk scarp) that are highly calcareous, as in parts of the western Weald, in the Isle of Wight, Dorset and East Devon. Within the beechwood regions, ashwoods scarcely occur on the chalk.

The factors determining the distribution of beechwood and ashwood on the chalk are by no means clear. One factor may be atmospheric and soil moisture. The escarpments of the south-western chalk, such as the Isle of Wight and Purbeck ridges, as well as the heights of Butser Hill, receive a higher rainfall than any other part of the English chalk, while the more clayey and therefore moister nature of the Lower Chalk and somewhat similar Upper Greensand, which carry most of the ashwoods of the Isle of Wight, is another difference which may favour ashwoods rather than beechwoods.

The competition between beech and ash is an important factor in this question. Where the two trees are placed in direct competition on equally suitable soils the beech must eventually suppress the ash because of the deeper shade which it casts and its correlated lower demand for light. It may be that the beech, advancing westwards from the continent, across what are now the Straits of Dover, drove the ash, so to speak, before it and came to occupy those soils of south-eastern England previously in possession of the ash; and that this tide of invasion was checked, owing to climatic or other factors

**Competition
between
beech and
ash.**

somewhere about the line marking the present western and northern limits of the chalk beechwoods.

The equipment of the two trees for such a struggle is very different. The beech, like its relative the oak, is a heavy-seeded tree, and its wide dispersal must depend on the activity of birds and other animals. Many existing beechwoods show signs of failure to regenerate themselves, and this, as in the case of oakwoods, is often attributed to the disappearance from the woods of the herds of swine which used to feed on the mast and acorns, and incidentally keep the soil open and sow the seeds by trampling them into the ground. The greater production of seed by the ash and its dispersal by the wind clearly gives this species an advantage over the beech in colonisation, and *pro tanto* will favour the production of ashwood rather than beechwood on soils equally favourable for both species. On the other hand, given successful colonisation of an ashwood by the beech, the latter will inevitably beat the former in competition because of the deep shade cast by the beech foliage, so that eventually most of the ashes will be starved and the wood converted into a beechwood. On the borders of the beechwood region in East Hampshire this process may in places be observed. Beechwood has been extensively felled, but enough parent trees were left to furnish a supply of self-sown seedlings, and the ash which has sprung up since the beech was felled is here and there being overshadowed and killed by these self-sown beech seedlings as they grow up. In other places, however, in the same district, the beech is not coming back where it has been cleared, and the ground is occupied either by mixed chalk scrub or mainly by ash. The failure of the beech to regenerate and its replacement by the ash is a parallel phenomenon to the replacement of oak by birch (see pp. 102, 141); and it may be stated as a generalisation that extensive clearing tends to handicap the heavy-seeded trees and to lead to

their replacement by light-seeded ones which succeed on the same type of soil.

In many cases, also, the abundance of rabbits on the light chalk soil must tell more heavily against the species which produces fewer and less widely distributed seedlings of slower growth. The destructive effect of rabbits is sometimes extreme, as may be well observed on many chalk downs, where the trees and bushes are uniformly eaten close, up to a height that a rabbit can reach, while no tree seedling and scarcely a herbaceous plant can escape destruction, except the perennial constituents of the turf, which are nibbled close to the soil (Plate XVIII b). No woodland has the slightest chance of regenerating itself under such conditions, but where the incidence of this factor is rather less severe the chances will probably be in favour of the ash as opposed to the beech. The more abundant and lighter seeds of the ash will produce a more numerous and widespread crop of seedlings than those of the beech, which will largely germinate where they fall, under the edges of the tree canopy. In this position, where the ground is relatively bare owing to the deep shade of the parent tree, they will easily be seen by rabbits. The ash seedlings, on the other hand, are carried far and wide and frequently germinate in scrub or among tall grass, etc., where their earlier life is to some extent protected.

Thus with a disturbance of primitive conditions a number of factors are seen to tell against the heavy-seeded tree, in spite of its primary advantage of being able to bear shade, to which no doubt it owed its original success.

Yew-woods. The yew (*Taxus baccata*), as already mentioned, is often abundant in beechwoods, where it grows entirely shaded by the beech canopy; it is also found very commonly in the chalk scrub, and sometimes isolated yew shrubs occur in the chalk pasture, where

seedlings in various stages of growth are often met with. In places, notably on the borders of Sussex and Hampshire, considerable aggregations of yews are found forming small groves, or in some cases yew-woods of large extent (Plate XIX). These yew-woods are nearly pure, the whitebeam (*Pyrus Aria*) being the only tree at all commonly associated. The ground vegetation is extremely poor, much poorer even than that of the beech-woods, and the soil beneath the shade of the trees is typically bare.

The origin of these yew-woods is not clear. They occupy situations quite similar to those of the typical beechwoods, *i.e.* the fairly steep valley sides of the chalk downs, and in some cases the bottoms of dry chalk valleys. It is suggested that they may originate in the following way. If a beechwood possessing numerous yews is destroyed by total felling of the dominant trees, or if it degenerates owing to various causes, chalk scrub and chalk grassland in which yews are prominent will take its place. The yews can and do sow their seeds and produce seedlings freely under such conditions, and the young trees, probably owing to their poisonous foliage, are largely, if not wholly, immune from the attacks of rabbits and other animals. As soon as a locally closed community of yews is formed, competitors are almost entirely excluded, owing to the very deep shade cast by the trees. In this way local yew groves might be formed and an extension of the process might lead to the formation of extensive, nearly pure, yew-woods, since the intervening scrub and grass association would be gradually destroyed by the extension of the yew. The process would no doubt be slow, owing to the slow growth of the trees. On the other hand it would be very sure, because the equipment of the yew for this kind of competition is overwhelming. Nothing but the formation of a very dense scrub of other species or

Origin of yew-woods.

Phot. A. G. Tansley

- a. Yew wood on chalk escarpment. *Taxus baccata*, *Pyrus Aria*, *Crataegus monogyna* in foreground.

Phot. A. G. Tansley

- b. The same from above. *Juniperus communis* in foreground. Heath on "clay-with-flints" on left with *Calluna vulgaris* and *Ulex nanus*.

Yew wood on Chalk. Kingley Vale, Sussex.

Phot. W. M. Rankin

- a. *Taxus baccata*, *Cratægus monogyna*, *Cornus sanguinea*, *Prunus spinosa*, *Rhamnus catharticus*, etc. Chalk pasture with *Senecio Jacobæa* in the foreground. Butser Hill, Hampshire.

Phot. S. Mingham

- b. *Fagus sylvatica*, *Pyrus Aria*, *Taxus baccata*, *Cratægus monogyna*, etc. Chalk escarpment near Kemsing, Kent.

Chalk scrub association.

the felling of the yew trees would be likely to arrest it.

The explanation given is in accordance with the observed facts, but at present it lacks corroboration or direct verification. It is possible that other factors are operative, and it may be that the habitat of the yew-wood really differs from that of the beechwood, though we have no clue to such a difference.

Scrub association. On the outskirts of beechwoods and scattered on the chalk generally, but more especially occurring in old chalk pits, by the sides of trackways, and often left to form natural hedges, *e.g.* between the cultivated ground and the open chalk pasture, a very characteristic scrub occurs, consisting of a considerable number of species of shrubs, many of which are found chiefly or almost exclusively on calcareous soils (Plate XX).

It is noteworthy that some of the most abundant species of this scrub are also the dominant shrubs of the clays and loams and of the sands, sandstones and shales, *e.g.* *Cratægus monogyna* and *Prunus spinosa*. On calcareous soils, however, many other species, which are rare or almost absent on the non-calcareous soils, are abundantly associated.

A characteristic feature of the chalk is the abundance of species of *Rosa*. The fruticose Rubi, on the other hand, are neither so abundant nor so rich in species as on the sand. The Juniper (*J. communis*) is abundant in places and forms a most characteristic open scrub of stiff erect bushes almost black in colour and often several feet high.

The following shrubs and climbers occur:—

ca Clematis Vitalba	a	*Acer campestre	a
Ilex Aquifolium	la	Prunus spinosa	a
ca Euonymus europæus	la	P. insititia	o
ca Rhamnus catharticus	la	P. Cerasus	o

Rubus <i>spp.</i> (fruticosus)		Viburnum Opulus	f
R. cæsius	la	ca V. Lantana	a
* Rosa pimpinellifolia	l	* Bryonia dioica	la
* R. Eglantheria		Lonicera Periclymenum	f
(rubiginosa)	la	* Ligustrum vulgare	la
R. micrantha	f	Solanum Dulcamara	f
ca R. agrestis (sepium)	r	S. nigrum	o
R. stylosa <i>var.</i> systyla	o	ca Atropa Belladonna	la
R. canina	a	Daphne Mezereum	vr
R. arvensis	a	ca D. Laureola	la
ca Pyrus Aria	a	ca Buxus sempervirens	o
Cratægus monogyna	a to d	Corylus Avellana	la
Hedera Helix	f	Salix caprea	f
* Cornus sanguinea	a	* Ruscus aculeatus	f
* Sambucus nigra	a	* Juniperus communis	la

In the above list *ca* is prefixed to the species which may fairly be described as "calcicole," at any rate in the chalk districts, though none is absolutely confined to the chalk. An asterisk is prefixed to other species which are specially abundant on the chalk.

The chalk scrub often grows exceedingly thick and then excludes almost all ground species; commonly, however, it shelters many woodland species. Thus *Mercurialis perennis* often occurs in sheets under its shade. Among these woodland species are several of the characteristic chalk orchids, such as *Cephalanthera longifolia*, *C. grandiflora*, *Helleborine atrorubens*, *H. violacea*, *Ophrys muscifera*, *Orchis purpurea*, *O. militaris*, *O. Simia*, *O. hircina*, the last three of which are extremely rare. The orchids of chalk grassland are given on p. 178.

Trees of the beech, the whitebeam, the yew and the ash frequently occur in this scrub; the relation to beechwood is often clear, though it differs somewhat from the relation of scrub and woodland in the case of the formations of clays, loams and sands. This is owing to the fact that while the shrub flora of calcareous soils is richer than that of siliceous soils, the shade of the beechwood is so deep as to exclude almost all shrubby undergrowth. Hence while the scrub association of clay or sand is

commonly poorer in species than the shrub layer of the corresponding woodland, the scrub association of calcareous soils is much richer and develops largely on its own account in suitable situations. Sometimes this scrub can be clearly recognised as a progressive association which has colonised open chalky soil and in which such trees as the ash may spring up freely. In such cases an ashwood may develop, with its undergrowth consisting of the shrubs of the chalk scrub and a fairly rich ground vegetation. Whether in these cases the beech normally replaces the ash in succession is doubtful. It is probably generally prevented from doing so by the want of enough adult trees to furnish an adequate supply of seed.

Chalk grassland association [Chalk pasture] (*Festucetum ovinae calcareum*).

This association, which is the typical association of the South Downs¹, and has a very wide extension in the southern counties of England, is closely similar to the limestone grassland previously described. It has the same general dominant, the sheep's fescue (*Festuca ovina*), and a large proportion of the associated species are also the same, but a number of species confined to the south (and particularly the south-east) of England occur in the chalk pasture only. Swamps appear to be entirely absent.

There is good reason to suppose, as we have already pointed out, that much of the chalk pasture is extremely old, and much of its area has possibly never been occupied by a tree association—perhaps because of an inadequate supply of underground water. The chalk grassland, which forms a very excellent light crisp pasture, has from time immemorial supported considerable flocks of sheep. The smooth curves of the chalk downs are occasionally broken by ancient trackways, camps and

¹ Sussex, Hampshire, Dorset and Wiltshire. The North Downs of Surrey and Kent have much less.

**History of
chalk
pasture.**

other earthworks of many periods from the Neolithic onwards. It has been suggested¹ that the original purpose of many of these works was to shelter and defend the flocks from the attacks of predatory animals such as wolves, coming from the forests of the lower country. Be that as it may, it seems unlikely that primitive man was responsible for the disforestation of such great areas of the chalk upland as are marked by traces of his existence, and the conclusion is therefore indicated that much of this grassland is primitive, or at least has existed since the conditions of climate resembled at all closely those at present obtaining. There may well have been originally more scrub than there is now.

In addition to this possibly primeval grassland, occupying much of the rolling summits of the downs, there is much pasture on the slopes of the escarpments and valleys, and this has probably taken the place of beechwood and ashwood destroyed by man.

The chalk grassland is almost everywhere used for sheep pasture, and where the grazing is heavy the herbage is eaten very close. When rabbits are abundant the turf is even more closely nibbled, and scarcely a herbaceous plant is able to rise more than an inch or so above the surface of the soil (Plate XVIII b). In places freer from this constant grazing and nibbling the vegetation is able to develop much more vigorously, and a rich and varied flora occurs (Plate XX b).

The turf is springy, being formed of a close mat of wiry herbage, often easily separable from the substratum. It is made up of a multitude of species, among which *Festuca ovina* is typically, but by no means invariably, dominant. Besides the grasses and less abundant sedges there are many dicotyledonous species, and the association

**Characters
of chalk
pasture.**

¹ By the Messrs Hubbard.

varies from place to place, partly owing to minor variations of the depth and nature of the soil, partly to the incidence of exposure and of grazing.

On the North Downs of Surrey and Kent the grassland is more frequently mown, and in place of the sheep pasture dominated by *Festuca ovina*, a mixed grass association is present in which *Bromus erectus*, *Trisetum flavescens* or *Brachypodium gracile* (*sylvaticum*) are frequently dominant.

The soil of the chalk grassland is typically very shallow, often not exceeding an inch (2.5 cm.)

Soil.

in depth. If the whole depth of soil, down to the weathering rock, be taken together, estimations show a very high percentage of calcium carbonate; but the upper layers which accompany the greater part of the intricate network of roots and rhizomes of which the turf is composed, are typically extremely poor in lime. Corresponding with this very different nature of the surface layer from that of the underlying soil, two groups of plants, whose root systems are hardly competitive, may be distinguished¹.

The lower, calcareous, soil is tenanted only by roots of plants such as the rock-rose (*Helianthemum Chamæcistus*), the salad-burnet (*Poterium Sanguisorba*), the squinancy-wort (*Asperula cynanchica*), by the tubers of orchids, and generally by the underground systems of most of the plants which may be called calcicole. The upper non-calcareous layer, on the other hand, which is richer in humus but more exposed to drought, is occupied by the underground parts of shallow-rooted plants such as *Festuca ovina*, which occur in all dry grassland.

In the non-calcareous upper layer actual heath plants

**The "chalk
heath."**

such as *Calluna vulgaris* and *Potentilla erecta* sometimes occur. The mixture of these with deeper rooting calcicoles gives

¹ This is an example of a type of association which has been distinguished by Woodhead as *complementary* (Woodhead, 1905, p. 345).

rise to a curious sub-association which may be called *chalk-heath*, parallel with the limestone heath (p. 158).

Very characteristic of chalk pasture are numerous species of Orchidaceæ, some of which are extremely rare.

The exposure of the chalk pasture association to the atmosphere and to radiation is extreme.

Climatic conditions.

There is little or no shelter from the full effect of sunlight, wind, rain and radiation.

The very thin soil is able to retain very little water, such aerial water as is not quickly evaporated rapidly passing down into the chalk below. On some chalk summits and steep slopes the soil almost disappears owing to its "creep" to lower levels, and the vegetation becomes open. During protracted summer droughts much of the herbage commonly withers, but the deeper rooting plants are to some extent protected by thick underground organs and sometimes by xerophilous adaptations.

The following is a list of species occurring in chalk pasture. The species clearly belonging to the heath association, sometimes developed on the non-calcareous soil overlying the chalk, are excluded:—

Dominant—*Festuca ovina*.

Thalictrum minus	o	ca S. nutans	la
ca Anemone Pulsatilla	l	Cerastium arvense	lf
Ranunculus acris	f	C. triviale	a
R. bulbosus	f	Arenaria serpyllifolia	f
ca Reseda lutea	f	A. leptoclados	f
R. Luteola	f	Linum catharticum	a
ca Helianthemum		ca L. perenne	vl
Chamæcistus	f to a	L. angustifolium	o
ca Viola hirta	a	Ononis spinosa	o
ca V. calcarea	r	Medicago lupulina	f
Polygala vulgaris	a	Trifolium procumbens	f
P. oxyptera	l	T. minus	f
ca P. calcarea	la	T. filiforme	f
ca P. austriaca	vr	T. pratense	a
Dianthus deltoides	r	ca Anthyllis Vulneraria	a
ca Silene latifolia		Lotus corniculatus	a
(= Cucubalus)	f	ca Astragalus danicus	l

ca Hippocrepis comosa	■	L. autumnale	a
ca Onobrychis viciæfolia	f	Taraxacum officinale	a
Vicia Cracca	f	Tragopogon pratense	
ca Spiræa Filipendula	lf	(agg.)	f
Fragaria vesca	f	ca Phyteuma orbiculare	vl
ca Poterium Sanguisorba	■	ca Campanula glomerata	la
Sedum acre	f	C. rotundifolia	f
Pimpinella Saxifraga	a	Primula veris	la
ca Seseli Libanotis	r	ca Blackstonia perfoliata	a
Daucus Carota	■	Centaureum umbellatum	
Galium verum	f	(= Erythræa Centaureum)	a
ca Asperula cynanchica	f	C. capitatum	r
ca Scabiosa Columbaria	f	* Gentiana Amarella	f
S. arvensis	f	Myosotis arvensis	f
Bellis perennis	■	M. collina	f
Erigeron acre	l	* Echium vulgare	la
Filago germanica	f	* Verbascum Thapsus	f
ca Inula Conyza	a	* V. Lychnitis	o
Achillea millifolium	■	* V. nigrum	o
Chrysanthemum		Linaria vulgaris	f
Leucanthemum	f	Euphrasia officinalis	
ca Senecio integrifolius		(agg.)	■
(campestris)	r	Orobanche elatior (on	
S. erucifolius	f	Centaurea Scabiosa)	l
S. Jacobæa	■	O. Picridis	r
* Carlina vulgaris	a	ca Origanum vulgare	f
* Carduus nutans	la	* Thymus Serpyllum	a
* C. crispus	la	* T. Chamædrys	? f
Cnicus lanceolatus	a	* Clinopodium vulgare	f
ca C. acaulis	a	* Calamintha Acinos	f
Centaurea nigra	a	* C. montana (officinalis)	f
ca C. Scabiosa	a	Salvia Verbenaca	o
* Cichorium Intybus	o	Nepeta hederacea	f
Picris hieracioides	f	Prunella vulgaris	a
P. echinoides	f	ca Teucrium Botrys	vr
* Crepis taraxacifolia	f	T. Scorodonia	la
C. foetida	r	ca Ajuga Chamæpitys	r
C. capillaris (virens)	f	ca Plantago media	a
ca C. biennis	o	P. lanceolata	f
Hieracium Pilosella	a	ca Thesium humifusum	o
Hypochaeris radicata	a	Listera ovata	o
Leontodon hispidum	f	Spiranthes spiralis	
L. nudicaule	f	(autumnalis)	f

ca <i>Orchis pyramidalis</i>	la	ca <i>Trisetum flavescens</i>	lsd
ca <i>O. ustulata</i>	l	ca <i>Avena pubescens</i>	f
* <i>O. Morio</i>	f	<i>A. pratensis</i>	o
<i>O. maculata</i>	a	<i>Arrhenatherum elatius</i>	f
ca <i>Aceras anthropophora</i>	la	<i>Cynosurus cristatus</i>	f
ca <i>Ophrys apifera</i>	la	ca <i>Koeleria gracilis</i> (cristata)	f
ca <i>C. fuciflora</i> (arachnites)	vr	<i>Dactylis glomerata</i>	f
ca <i>O. sphegodes</i> (aranifera)	lf	* <i>Briza media</i>	la
ca <i>Herminium Monorchis</i>	o	* <i>Festuca rigida</i>	f
* <i>Habenaria conopsea</i>	la	<i>F. elatior</i>	f
<i>H. albida</i>	vr	ca <i>Bromus erectus</i>	la
* <i>H. viridis</i>	r	<i>B. mollis</i>	o
ca <i>Iris foetidissima</i>	l	<i>Brachypodium gracile</i>	
<i>Luzula campestris</i>	a	(<i>sylvaticum</i>)	ld
<i>Carex flacca</i> (glauca)	a	<i>B. pinnatum</i>	o
<i>C. verna</i> (præcox)	f	<i>Lolium perenne</i>	f
<i>C. humilis</i> (clandestina)	r	<i>Ophioglossum vulgatum</i>	o
<i>Phleum pratense</i>	f	<i>Phegopteris Robertiana</i>	
<i>Agrostis vulgaris</i>	o	(<i>calcareæ</i>)	vr

ca = calcicole

* specially abundant on chalk

The following is a hypothetical scheme of the relationships of the associations of the chalk sub-formation :—

It will be useful to add some results of a detailed study of the composition of a small area of the chalk grassland association on Fleam Dyke, Cambridgeshire¹.

Fleam Dyke is one of a series of very ancient military earthworks occurring in south-east Cambridgeshire and extending in a south-easterly direction from the Fenland to the chalk uplands, which are largely

¹ The results of this study, which was carried out by the Marshall Ward Society, of the University of Cambridge, were very kindly placed at the Editor's disposal by Mr R. H. Compton, late Secretary of the Society.

covered by chalky boulder clay. These earthworks cross, approximately at right angles, the line of the early pre-Roman road called Icknield Way, which follows the line of the chalk outcrop between the boulder clay country (which was no doubt once covered with thick forest) to the south-east, and the (originally) impassable Fenland to the north-west; and they are supposed to have been thrown up to facilitate the obstruction of the road to the passage of hostile forces.

Fleam Dyke, in its least altered portions, is a narrow and steep-sided bank of solid chalk, its summit lying about 12 feet above the general level of the surrounding country. On its south-west side is the ditch from which the chalk was dug. The surrounding country is almost entirely arable, but for a length of about two miles the dyke has been left almost untouched, though here and there pines and birches have been planted. The south-west side of the dyke bears a typical chalk grassland association; on the north-west side a good deal of bare chalk is exposed and the vegetation is taller though composed of few individual plants. At the bottom of the ditch are numerous rabbit burrows.

The following is a list of the species which occur in the chalk grassland association of the dyke.

Festuca ovina d.

<i>Thalictrum minus</i>	r	<i>Anthyllis Vulneraria</i>	a
[<i>Mahonia vulgaris</i>]	r	<i>Lotus corniculatus</i>	a
[<i>Papaver Rhæas</i>]	r	<i>Astragalus danicus</i>	la
[<i>P. hybridum</i>]	vr	<i>Hippocrepis comosa</i>	va
[<i>Fumaria officinalis</i>]	r	<i>Onobrychis viciæfolia</i>	o
[<i>Brassica nigra</i>]	r	<i>Vicia Cracca</i>	r
<i>Reseda lutea</i>	o	<i>Prunus spinosa</i>	vr
<i>Helianthemum Chamæ-</i>		* <i>Spiræa Filipendula</i>	la
<i>cistus</i>	va	<i>Poterium Sanguisorba</i>	ls
<i>Viola hirta</i>	o	<i>Rosa canina</i> (agg.)	o
<i>Polygala vulgaris</i>	a	<i>R. Eglanteria</i> (rubiginosa)	r
[<i>Lychnis alba</i>]	r	<i>Pyrus Malus</i>	vr
<i>Silene latifolia</i> (Cucubalus)	o	<i>Cratægus monogyna</i>	la
<i>Cerastium vulgatum</i>	o	<i>Pimpinella Saxifraga</i>	la
[<i>Stellaria media</i>]	o	<i>Peucedanum sativum</i>	la
<i>Linum catharticum</i>	la	<i>Daucus Carota</i>	la
<i>Rhamnus catharticus</i>	vr	<i>Viburnum Lantana</i>	vr
[<i>Acer Pseudoplatanus</i>]	vr	<i>Galium verum</i>	a
<i>Ulex europæus</i>	r	<i>Asperula cynanchica</i>	a
<i>Ononis spinosa</i>	r	<i>Scabiosa Columbaria</i>	o
<i>Medicago lupulina</i>	a	<i>S. arvensis</i>	l
<i>Trifolium procumbens</i>	o	<i>Erigeron acre</i>	r
<i>T. pratense</i>	o	<i>Achillea Millefolium</i>	o

*Chrysanthemum Leucan-		Thesium humifusum	vr
themum	o	[Urtica dioica]	l
Senecio Jacobæa	o	[Betula alba]	l
S.integrifolius (campestris)	o	[B. tomentosa]	l
Carlina vulgaris	l	Fagus sylvatica	vr
Cnicus acaulis	o	Orchis pyramidalis	r
[C. arvensis]	o	O. maculata	vr
Centaurea nigra	a	Carex caryophyllea (= C.	
C. Scabiosa	a	verna)	o
Picris hieracioides	r	C. flacca (glauca)	a
Crepis capillaris (virens)	o	Phleum pratense	o
Hieracium Pilosella	va	Agrostis tenuis (vulgaris)	l
Hypochæris radicata	l	Avena pratensis	ls
Leontodon hispidum	o	[A. fatua]	r
Sonchus arvensis	o	*Arrhenatherum elatius	
Tragopogon pratense	r	(avenaceum)	l
Campanula glomerata	o	Koeleria gracilis (cristata)	a
C. rotundifolia	o	*Dactylis glomerata	l
*Primula veris	o	Briza media	va
[Anagallis arvensis]	l	†Festuca elatior	l
Gentiana Amarella	r	Brachypodium pinnatum	l
Echium vulgare	l	[Picea vulgaris]	r
Linaria vulgaris	l	[Pinus sylvestris]	la
L. minor	r	Juniperus communis	r
Euphrasia officinalis (agg.)	o	Taxus baccata	vr
Thymus Serpyllum	a	{ Brachythecium purum	
Calamintha Acinos	r	* { Hypnum molluscum	
Prunella vulgaris	o	{ Thuidium abietinum	la
*Plantago media	l	{ Fissidens taxifolius	
*P. lanceolata	a	etc.	
[Fagopyrum sagittatum]	vr		

The species marked * occur mainly or exclusively in the ditch where the soil is deeper and not so dry. † under trees. The names enclosed in square brackets are those of species clearly alien to the vegetation of the dyke, whether native to the country or not.

The following species were present in one square metre of the association examined in detail. The order is that of decreasing frequency.

Festuca ovina: dominant, in considerable tufts, largely excluding other plants.

Poterium Sanguisorba: co-dominant with the last.

Hieracium Pilosella: very abundant, especially on patches of bare chalk, which it readily colonises.

Carex flacca: subdominant.

Helianthemum Chamæcistus: subdominant.

Briza media: in fair quantity.

Koeleria gracilis

Avena pratensis

Thymus Serpyllum

Hippocrepis comosa

Lotus corniculatus

Leontodon hispidum

Asperula cynanchica

Galium verum

Cnicus acaulis

Plantago media

Plantago lanceolata

Scabiosa Columbaria

Pimpinella Saxifraga

Centaurea nigra

Linum catharticum

Campanula rotundifolia

Euphrasia officinalis

Anthyllis Vulneraria

Carlina vulgaris

Pinus sylvestris (one seedling)

THE SUBFORMATION OF MARLS AND CALCAREOUS SANDSTONES

The vegetation to be described as belonging to this sub-formation occurs on calcareous soils derived from rocks containing a smaller proportion of lime than the limestones. It is therefore intermediate in character between limestone vegetation on the one hand and the vegetation of the non-calcareous rocks on the other. Owing to the presence of calcicole species by which this vegetation is characterised, it is treated as a sub-formation of the formation of calcareous soils, but naturally all transitions occur to the formations of non-calcareous soils.

Ash-Oakwood association.

The woodland association of this sub-formation is characterised by the constant presence of the ash in considerable quantity and is thus related to the typical ashwood association of limestone soils. On the other hand oaks are always present, not only as occasional constituents, as in ashwood, but typically co-dominant with the ash. On marls and calcareous clays the oak is always *Q. Robur*, but on some, though not all calcareous sandstones, *Q. sessiliflora* occurs, either alone or mixed with *Q. Robur*.

**General
characters.**

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The general ecological conditions are in many respects closely similar to those of the damp oakwood, but the floristic composition usually shows greater variety.

The shrubs of the ash-oakwood are as varied as those of the ashwood and consist of most of the same species. The hazel (*Corylus Avellana*) is commonly the dominant shrub, and the flora includes such characteristic calcicole plants as *Viburnum Lantana*, *Euonymus europæus* and often *Clematis Vitalba*. Such species as *Cornus sanguinea*, *Ligustrum vulgare* and *Acer campestre* are generally more abundant in individuals than in the damp oakwood.

Very much the same is true of the herbaceous ground flora. "The general list is mainly the same as that of the damp oakwood, but such plants as *Carex digitata*, *Paris quadrifolia*, *Colchicum autumnale*, *Iris foetidissima*, *Helleborine media*, *H. purpurata*, *Viola sylvestris*, *Primula elatior* (an East Anglian species), *Lithospermum purpureo-cæruleum* (a south-western form), and *Campanula Trachelium*, which are almost or quite absent from woods of the oak type, are characteristic of the ash-oak association. Dog's mercury (*Mercurialis perennis*) is much more generally dominant in the ground vegetation, and [various] other species, such as *Hypericum hirsutum*...are more generally abundant¹."

Some ash-oakwoods (e.g. many of those on the calcareous Upper Greensand of East Devon and of the Isle of Wight) have been left in an almost natural condition, and the close relationship of these to the ashwoods, into which they sometimes pass imperceptibly, is obvious enough. But the great majority of the ash-oakwoods of the southern half of England are treated as coppice with standards, the oaks being left as standard trees, while the ashes and

¹ Moss, Rankin and Tansley, 1910, p. 139.

practically all the other trees, as well as the various shrubs, are coppiced. Hazel is generally the dominant shrub in such coppice, and in many cases gaps are filled up with planted hazel. In this way the wood comes to resemble superficially the oak-hazel copse derived from damp oakwood. It is only by noting the abundance of ash in the coppice and the variety and abundance of shrubs other than the hazel, as well as the presence of calcicole species in the ground vegetation, that the wood can be assigned to its proper type (Figs. 6 and 7).

Another factor tending to the assimilation of the oak-hazel copses derived respectively from the ash-oakwood and from the damp oakwood is the frequent poverty in lime of the surface soil of the former to a depth of some inches, probably due to leaching. This, with the accumulation of humus, leads to the establishment on the floor of the wood of shallow-rooting plants not found on soils rich in lime. The more deeply-rooting plants, therefore, such as the shrubs, are often a better index than the herbaceous species of the essential character of these woods.

Oak-hazel woods of the type described are well developed on the Triassic and Jurassic marls of Somerset and on the chalky boulder-clay of Cambridgeshire. They have been described by Moss¹ and by Adamson² respectively, to whose memoirs the reader is referred for lists of species. Adamson has also studied in some detail the ecological conditions determining the occurrence of different sub-associations of the ground vegetation.

The ash-oakwoods on calcareous sandstones and sandy limestones have not been described, but so far as they have been investigated they show similar intermediate

¹ Moss, 1907, pp. 51—56. These woods are described by Moss simply as "oak-hazel woods"; they certainly belong to the ash-oakwood association, an association which has since been recognised. See Moss, Rankin and Tansley, 1910, p. 138.

² Adamson, 1911.

Scale $\frac{1}{8}$ mile

EXPLANATION OF SYMBOLS

○ <i>Quercus Robur</i>	♂ <i>Salix cinerea</i>
× <i>Fraxinus excelsior</i>	↓ <i>Viburnum Opulus</i>
— <i>Corylus Avellana</i>	⤴ <i>V. Lantana</i>
) <i>Acer campestre</i>	△ <i>Betula spp.</i>
↑ <i>Populus tremula var. villosa</i>	⊥ <i>Pyrus torminalis</i>

FIG. 6. Chart of the trees and shrubs of part of Gamlingay wood, Cambs., showing an island of the dry oakwood association (on sandy loam) enclosed within Ash-oak-hazel wood (on calcareous boulder-clay).

Scale $\frac{1}{8}$ mile

EXPLANATION OF SYMBOLS

==	<i>Spiræa Ulmaria</i> society	//	<i>Pteris aquilina</i> society
—	<i>Spiræa-Deschampsia-cæspitosa</i> society	///	<i>Holcus mollis</i> society
—	<i>Fragaria vesca</i> society	~	<i>Carex</i> spp.
—	<i>Mercurialis perennis</i> society	∧	<i>Juncus</i> spp.
—	<i>Polytrichum gracile</i>		

FIG. 7. Chart of the societies of the ground vegetation of part of Gamlingay wood, Cambs. (see Fig. 6).

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characters between ashwoods and oakwoods. *Quercus sessiliflora* is the oak characteristic of some of these woods, and the wych elm (*Ulmus montana*) and the white birch (*Betula alba*) may be conspicuous features.

Scrub and Grassland associations. The scrub association of this sub-formation has not been studied. Comparatively little semi-natural grassland belonging to this sub-formation appears to exist, because the type of soil is valuable for arable land or for permanent pasture. It has scarcely been studied, but appears, as might be expected, to contain a mixture of species belonging to neutral grassland and of those belonging to calcareous soils. Derelict pasture on the chalky boulder clay of Cambridgeshire appears to be very readily invaded by a loose scrub consisting largely of the hawthorn (*Cratægus monogyna*).

CHAPTER VII

AQUATIC VEGETATION¹

COMPREHENSIVE studies of aquatic vegetation, on the lines followed in this book, have not yet been carried out in this country; and consequently the material for a systematic treatment of the vegetation scarcely exists. For the sake of completeness the subject has not been omitted altogether, but the following pages must be regarded rather as suggestive of the lines along which future work may proceed, than as expressing a satisfactorily established scheme of classification².

The first and most obvious division of aquatic vegetation is into the vegetation of saltwater and the vegetation of freshwater, for the presence of dissolved salt in any proportion near that of seawater is well known to change completely the aquatic flora. The vegetation of the sea is entirely omitted from this book, though the "maritime" land communities inhabiting the coasts and coming within the zone of direct influence of the sea are dealt with in a later chapter.

In considering the vegetation of freshwaters we meet with very wide differences in habitat, but nevertheless it

¹ The aquatic vegetation of the Norfolk Broads is dealt with in Chapter X, on account of its close relation to the vegetation of the fen formation.

² For some of the ideas contained in this chapter the Editor is indebted to Dr C. E. Moss.