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William G. Smith B.Sc., Ph.D. ^a

^a Yorkshire College, Leeds

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for all. The geographer is a student of the world of peace as well as of the theatre of war—the exponent of the environment to be dealt with in any venture, commercial or military, political or missionary. He must have time to study and to travel, and in return, the fruits of his observations and his thoughts should be given to his pupils and to the world. It seems to the writer that one of the most important duties of geographer is to show forth sympathetically the conditions of other countries to the younger generation in the university, and on occasion to the public, and thus help to remove prejudice and foster good feeling, which is so essential for the rapid harmonious development of this complex world in the twentieth century.

A BOTANICAL SURVEY OF SCOTLAND.

By WILLIAM G. SMITH, B.SC., PH.D., Yorkshire College, Leeds.

(*A Paper read before Section E at the British Association, Glasgow, 1901.*)

AN observer, after some experience of travel in Britain and abroad, acquires the impression that landscapes differ, the hill-region from the plain, the northern from the southern, a cold region from a warm or temperate. Differences in the vegetation assist largely in fixing this impression; thus a region of cornfields and woodlands contrasts strongly with the grassy or heathery moorland. Geological features give character to hill and dale, while the nature of the underlying rocks or other deposits, and the presence or absence of stratification, dip, and jointing have an effect on the surface vegetation. Geographical and climatic features, altitude and latitude, degree of exposure to sun, cold, wind, and rain, together play an important part in determining the distribution of plants, and in modifying the soil for plant-life. The influence of man in a country like Britain is also no minor factor in making a landscape.

In the records of travellers, description is assisted by reference to dominant features of vegetation; thus Humboldt (1806) distinguishes nineteen plant-forms as characteristic,—palm, cactus, bamboo, grass, etc. In Britain to mention cultivated fields, pine woods, or heather moors is to recall scenes once visited. The use of maps to demonstrate the features of a country is evident. The orographical map with heights and depths coloured according to a scheme of tints is a great advance on a black and white map, however well supplied with contour-lines and other information. Geological maps with the various formations indicated by distinctive colours are now prepared for many countries. Facts regarding rainfall and other climatic features are also conveyed by maps rather than by statistics. But the distribution of plants is as yet recorded on maps only in the most superficial way. The existing vegetation charts, found in recent atlases of physical geography or in works devoted to plant-geography, are based on the assumption that the relations between

vegetation and the factors regulating the distribution of plants, are so broad and general that they can only be represented on maps which include some large portion of the earth's surface drawn to a small scale. In the first decade of the nineteenth century, A. Pyr. de Candolle planned a map to show the main features of plant-distribution in France, but it remained in the initial stages because reliable maps of the country did not exist, and information which might be of use to an invader was suppressed. The actual publication of vegetation maps was an event of the last decade of that century whose beginning saw the suggestion. It is not our intention to trace in detail the development of plant-geography which led to the present position, but a few stepping-stones will give a clearer understanding.

In Britain, the principal method of recording the distribution of plants has hitherto been that laid down by H. C. Watson (5, 6, 7).¹ According to Watson's scheme, Britain is divided into eighteen provinces, thirty-eight sub-provinces, and one hundred and twelve counties and vice-counties, the limits of which are partly natural, partly political. Since vegetation changes according to altitude, a lower or agrarian region is distinguished from a higher or Arctic region, and each of the two regions is sub-divided into three zones designated infer, mid, and super respectively. The zones are characterised by the occurrence of certain plants; for example, the super-agrarian zone extends upwards to the limits of cultivation or to the altitude where the Bracken Fern (*Pteris aquilina*) ceases, above this the infer-arctic zone begins. The northern limits of the agrarian zones are defined by certain lines of latitude, thus the infer-agrarian plants occur south of a line across England from the Dee to the Humber, while the mid-agrarian extends northwards to a line from Clyde to Tay. The Arctic zones are only represented where vegetation occurs above 1500 feet. In the *Cybele Britannica* and its *Compendium*, each species of plant is examined as to its distribution in counties and zones in Britain, its occurrence beyond Britain, and other details. Watson had distinct ideas of the use of maps in his work, but we only know of those which represent the vice-counties and those where each species is shown on separate maps. The method of Watson has been followed by other workers in topographical botany; the map which accompanies the Handbook of Natural History issued at the British Association Meeting at Glasgow is an example.

The subject now under consideration, the botanical survey of Scotland projected by the late Robert Smith, is based on a different conception of vegetation, though the earlier method has aided in its development. The impetus towards the present method has been given chiefly by an increased interest in the study of plants in relation to their environment, or, as it is called, ecological botany. Under this influence field botany is no longer merely the seeking, collecting, and preservation of species in herbaria and their names in a flora; it is still a primary essential to recognise accurately common species at least, but investigation of structure

¹ Numbers after authors' names refer to papers in the list given at the end of this paper.

and interpretation of these as adaptations to conditions of life cannot be ignored. This distinction may be better expressed in R. Smith's own words (2): "The floristic method of study, on the one hand, is more directly concerned with the historical development of the flora. It attempts to answer the questions: How have these species originated? or whence have they come? It studies phylogeny and migration; and the botanical characters to which it directs attention are those on which we chiefly rely for indications of racial affinity, namely, those of the floral organs. In considering the vegetation, on the other hand, the essential characters of the species are those indicating adaptation to the environment, and are to be found mainly in the vegetative organs. Hence groups of similar adaptational form need by no means coincide with natural families or groups of species." The text-book by Warming (4) explains the application of œcological botany to plant-geography; it is a crystallisation of his own numerous observations and of the work of earlier observers; it may be taken as the standard work on this particular aspect of botany. Ecological plant-geography considers the plant-species less for itself and more as a unit in a community or association of plants. The plant-association may be defined as a community or society of plants living together and adapted to certain conditions of environment. In each association there are—(1) one or more dominant social forms, (2) secondary or sub-dominant forms struggling for dominance, (3) dependent species. For example, a natural wood consisting entirely of oak-trees has one dominant form—the oak—whose presence is determined by the prevalent climatic, soil, and other conditions, while its size and gregarious nature give it dominance; in this wood there may be other trees or shrubs (*e.g.* birch, mountain-ash, or hazel), more or less isolated, but which, given the opportunity by removal of the oak, will become dominant forms; the motley carpet of the oak wood is made up of many species dependent on the larger forms for shelter and shade, or living as epiphytes, parasites, and humus-saprophytes, and including not only flowering plants, but ferns, mosses, lichens, and fungi. The association is thus a mixed community with complex relationships, its members struggling for existence and dominance, but it is a coherent whole, and may be studied as a unit. The association may be considered broadly, or it may be limited to a few species; the recent tendency is to make the term comprehensive and wide. The vegetation of a country or other area may thus be regarded as composed of *either* so many species of plant, *or* so many associations. The species as a unit is something which is fairly definite, and lends itself to an estimation of so many hundreds per square mile. The plant-association has the disadvantage that it is a more arbitrary unit—at least in our present state of knowledge; it has the distinct advantage that the bewildering number of species of an area are gathered into a few groups, which may be recorded on maps and read with moderate ease by one who is no specialist.

Progress in the making of maps has prepared the way in no small degree for a botanical survey. The ordnance survey maps are sufficiently detailed to enable the geographer-botanist to ascertain his

position and the limits of an association without resorting to the surveyor's instruments. Recent advances of cartography in other directions, including the colouring of maps, render it possible to reproduce a working field-map with a moderate number of distinctive colours in a form convenient for publication. In the case of my brother's survey of Scotland, the scientific spirit and personal interest of Mr. J. G. Bartholomew was no small factor in the production of the maps.

A brief biography will explain the earlier development of the Scottish survey. The late Robert Smith had acquired at an early age a good knowledge of the flora of the Scottish east coast and the Grampians, and excursions to Ireland and Norway furnished new material and wider views on distribution. After the days of academic student-life and a short busy period as teacher, came the opportunity of a winter (1896-97) at the University of Montpellier with Professor Ch. Flahault, who is carrying out De Candolle's ideal of a botanical survey of France. During numerous excursions and in the intervening study in laboratory and herbarium, an enthusiastic master inspired a willing pupil and sent him home prepared to begin the work in Scotland. The earlier attempts were made in 1897 on the Pentlands near Edinburgh, and together we traversed these many times till the basis of the present method was developed.

The botanical survey of France as carried on by Professor Flahault (1) is based on the distribution of trees. From a geographical point of view, forests of a particular tree indicate certain conditions of climate and soil; from a botanical aspect, the presence of certain associated subordinate species; and from an economic point of view, regions suitable for the growth of certain cultivated plants. Flahault has selected characteristic trees, whose areas of distribution are ascertained by personal observation and recorded by colours on maps. In introducing the botanical survey to the Royal Scottish Geographical Society (3), R. Smith thus explains why this method was not quite applicable in Scotland: "To base the survey of the vegetation of Scotland on the distribution of the chief trees, as Professor Flahault has done for France, would give a very inadequate, if not erroneous, impression of the plant-covering of the country. Deforesting has proceeded so far in Britain that little primitive forest remains, and artificial planting has only begun the reconstruction of the former woodlands. The general plant carpet is formed by a type of vegetation lower than the arboreal, such as the cultivated plants, the grasses, the heaths, etc.; the woods occur only here and there. The main divisions of the present map, which seeks to show the outstanding features of existing plant life, have accordingly been determined by this lower vegetation, whilst the trees have only been indicated over areas which they actually inhabit." The information collected is, however, suitable for a comparison of the Scottish with the French survey.

In selecting the associations to be recorded, it is necessary that they be representative and numerous enough to include the whole vegetation of the area, leaving no blanks. At the same time it has to be kept in view that, on maps of one-inch or half-inch scale, a number of tints would

bewilder and only obscure the chief features of the vegetation. After preliminary trials, it was decided to represent the vegetation of the great natural areas as follows:—

I. *Littoral or Maritime*.—This area includes that belt of uncultivated land which fringes our coasts, as well as the submerged vegetation. Owing to the narrowness of this zone on the one-inch maps, it is coloured uniformly, although five associations were recognised by R. Smith, namely, submerged vegetation, salt-marshes, seaside rocks, sandy shores and dunes, and seaside “links” or fixed dunes. The area could only be adequately recorded on the six-inch-to-a-mile maps.

II. *Temperate*.—The area of vegetation agreeing with that of temperate Europe includes all land up to the limits of cultivation, an altitude on the average of 1000 feet (304 metres), but rising in places to 1250 feet. The area thus agrees nearly with H. C. Watson’s “Agrarian region.” In a country with a less artificial and more abundant tree vegetation than Britain, this area would be subdivided according to the distribution of characteristic trees, but, as already explained, that is unworkable here. The existing woods are generally a medley of introduced European and North American trees planted for effect rather than for any economic value. Two distinct types of woods of deciduous trees are however recognisable: Those in which Beech and Oak are together dominant, and those in which Oak alone dominates. These are indicated on the maps by two shades of green. The Oak wood is the more natural and better defined type; it occurs towards the upper limits of the agrarian region, generally in valleys along the streams, and as one passes downwards it gradually merges into the lowland type of Beech wood. The Beech rarely occurs as a pure association, it is indicative of the artificial plantation. The land under farm-cultivation presents several distinct types, of which two are represented by shades of yellow, viz., a lower zone where Wheat can be included in the farm-rotation, and an upper zone where Wheat cannot be grown. The influence of man is particularly evident in this agrarian area, and adds to the difficulty of recording. The maker of plantations has too often in view the embellishment of some domain, or the providing of coverts; the farmer follows the markets, and at present his land serves his purposes better under grass than in growing wheat. These economic factors mean much in the preparation of a botanical survey; they multiply time and labour, and the results are unsatisfactory. Yet it must be obvious to any botanist that the flora of the woods, hedges, and stream sides of the lowland Wheat area is distinct from that of corresponding places near the upper limits of cultivation; the difficulty is in fixing a line of boundary. Patches of moor may occur in the agrarian area; these are indicated in the same way as the moors in the sub-alpine. The colours used in representing the vegetation of the agrarian are indicative of wide associations, which in a map on a larger scale would be subdivided into communities of closer associates. In the Scottish survey this is suggested, and in a forthcoming survey of Yorkshire we hope to give it fuller consideration.

III. *Sub-alpine, extending from about 1000 feet to 2000 feet*.—The

moorlands of the parts of Scotland already visited fall into two great groups, the grassy moor and the heather moor; on the maps these are clearly shown by the use of a shade of green for the grass, and a brown for the heaths. The distribution of these two types, their associate plants, and their relation to environment, has received a full discussion in the papers already published, whilst valuable material for further work has been left in manuscript. A third type of moor also occurs, the peat-bog with either Heather (*Calluna*) or Cotton Grass (*Eriophorum*) dominant; on R. Smith's unpublished field-maps this becomes an important feature of the vegetation, and in surveying the Yorkshire moorlands it occurred over great stretches of country. The woods of the sub-alpine area consist chiefly of Scots Pine, Larch, and other coniferæ; two shades of blue indicate these, one being used where Scots Pine dominates with other coniferæ interplanted, the other for plantations of Larch, a conspicuous feature of the Scottish moorland woods. The upper limits of tree vegetation (about 2000 feet) are indicated by thickets of Birch with associates; a special colour is used to show these.

IV. *Alpine*.—Above an altitude of 2000 feet trees are rare, many species of plants disappear, and the vegetation becomes Alpine or Arctic in character. The Bilberry (*Vaccinium myrtillus*), a plant common enough at lower elevations as a sub-dominant form in the Heather area, becomes here a conspicuous dominant species covering extensive areas. The Heather and Grass types may also occur in the Alpine. The bare vegetation of many summits, consisting of little more than Mosses and Lichens, has a distinctive colour allotted; it corresponds to a large area of this character on the mountain-masses of Europe. Alpine crags with their interesting flora are also shown. Many of the richer stations of the Grampian and Breadalbane Alpine flora are thus recorded on the North Perthshire sheet.

The method of survey is to traverse the selected area till its prominent associations are recognised. The extent of country observed in a single excursion is variable and depends on whether the vegetation is uniform and easily accessible, or the contrary. It may be necessary to traverse a difficult area at distances of a few hundred yards, but in parts where the vegetation seen from a distance is found to be uniform the routes may be farther apart. Opportunities of checking previous observations occur when a place already visited is seen from another vantage, or when two routes cross, as they frequently do. In preparing the maps, the limits of prominent associations are ascertained and recorded on the field-map on the spot. A less apparent but more important work is to collect information regarding associations. When an association is recognised, the plants found there are recorded in a field notebook with the order of their occurrence as dominant, secondary, or dependent species, also their state of flowering. Other observations are made regarding subjacent rocks or deposits, conditions of drainage, the altitude, exposure, and environment generally. The records thus obtained are important not only as information about the vegetation and its local conditions, but also as standards for comparison. One type of

vegetation has to be compared with another quite distinct in character; or, it frequently happens that an association as developed in one place has to be compared with another somewhat similar but in a different locality. It is only by careful notes that one overcomes the difficulty of carrying on the survey during a series of excursions extending through two or three years, as was the case in the maps already published. The field-notes are also invaluable when one observer wishes to compare results with another. The maps used for outdoor work are generally the "one-inch" sheets of the Ordnance Survey, although in some cases the "six-inch to mile" sheets are preferable. The published maps are on the scale of one-inch to two miles, and this is a convenient size for publication with the small number of types of vegetation used. The number of types on the published maps does not, however, represent all those recognised in field-work, but they are taken as sufficient to effect a primary analysis of the vegetation.

A botanical survey of Britain carried out as suggested provides material not only for the botanist but for other scientific workers. The relation of vegetation to altitude is rendered evident in a way which admits of rapid comparison. The influence of climate may be traced from the maps by the meteorologist or geographer who has some knowledge of common plants. A distinction between the vegetation of the eastern side of Britain and the western is already evident, especially when one refers to my brother's unfinished field-maps of parts of western Scotland and to the Yorkshire maps. The method renders the maps of use to the geologist, and a relationship between the geological—especially soil maps—and the vegetation maps has already been shown in a way more convincing than hitherto. As the study of associations proceeds, it becomes more evident how many plants of our flora are bound up into definite communities, although all do not thus fall into distinct groups. Detailed studies of the morphology and anatomy of selected species are suggested as a profitable field for observations likely to throw more light on the relationships of plants to their environment. From an economic point of view the maps are useful guides. They show the dominant woods of an area and indicate what trees are likely to be profitably grown there. The distinction of grass moor from heather is a guide to its value as grazing or shooting grounds respectively, and an approximation of the area available for each purpose may be attained. The division of the agrarian region into Wheat and "No Wheat" has a value for the farmer, but a more detailed survey of cultivated lands with a record of the underlying soils would give better results.

The present survey was never intended to be final; it is a stepping-stone from our present maps of vegetation to detailed surveys of small areas thoroughly investigated in all respects. In such detailed surveys the associations selected would be small, and would include all the species of the British flora, and some light might be thrown on the question of varieties as produced by environment; the existing topographical floras would here come into service and their present value be further enhanced. On the other hand, the present survey in conjunction with similar investigations in other countries furnishes more accurate

records than exist for the preparation of vegetation maps of the earth generally; it is only by some method such as this that we can eliminate many of the rough approximations and errors which are evident on existing maps of plant distribution.

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THE MAKING OF AUSTRALIA.

By Rev. J. BRYANT.

THE story of exploration in the island-continent of Australia has not received hitherto the interest it deserves. There have been lacking in the story those elements of excitement which go with the discovery of new tribes and conflict with warlike races. The vast loneliness and the far-stretching waterless areas of Australia have made the journals of its explorers monotonous and lacking in incident in comparison. But for grim, unyielding battle with Nature in her most repellent and pitiless forms these journals are a wonderful record. If to-day Australian exploration is on its broader lines complete, it is because men measured themselves like heroes and demigods against the forbidding and almost impossible conditions of the Australian interior. Such names as Oxley, Eyre, Mitchell, Hume, Sturt, Gregory, Stuart, Kennedy, Leichhardt, Burke, Wills, Grey, Forrest, Giles, Lindsay, Wells, Landsborough, not to mention others, make a brave galaxy.

It has to be noted that Australian exploration only dates from 1813. It was in that year that the passage of the Blue Mountains was forced by Blaxland, Lawson, and Wentworth. During the first quarter of a century of the existence of the colony of New South Wales, it was not possible to journey from Sydney by land for more than forty miles in any direction. The first great expedition into the interior was under Oxley in 1817. It was not, however, until 1862 that M'Dowall Stewart on his third attempt succeeded in crossing the continent from south to north. In 1873 Warburton achieved his perilous and all but disastrous