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ABERYSTWYTH

WELSH SOILS DISCUSSION GROUP

Report No. 1
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'FOREST SOILS IN WALES'

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WELSH SOILS DISCUSSION GROUP

REPORT NO. I.

(1959 - 60)

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'FOREST SOILS, WITH SPECIAL REFERENCE TO WALES'

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W E L S H S O I L S D I S C U S S I O N G R O U P

R E P O R T N O . I .

(1959 - 60)

'Forest Soils, with Special Reference to Wales'

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The combined presence in Aberystwyth in 1958 of several specialists with widely varied training but with a common enthusiasm for soil study prompted the spontaneous creation of The Welsh Soils Discussion Group in co-operation with other colleagues traditionally devoted to soil science at the University College of North Wales, Bangor. Wales offered an almost unique opportunity for the regional study of soils for three reasons:-

1. The geographical individuality of the Principality derived from distinctive local events in its geological and human history.
2. The relatively early and extensive progress of soil surveys, especially in North Wales.
3. The re-inforcement of a traditional interest in academic pedology and applied soil science by a contemporary enthusiasm for the study of the soil in Wales, which crystallised in the formation of the Discussion Group.

It has never been the intention of the Group to duplicate in any way the functions of the British Society of Soil Science to which the majority of our founder-members belong. The aim was to intensify soils interests within a relatively small and accessible area and concentrate on local soil problems. Thus a meeting ground was created for those marginally concerned with the soil in addition to those professionally involved with it. Geologists, geographers, biologists, foresters, plant-breeders and agriculturists have become members of the Group as naturally as pedologists, chemists and soil-surveyors. Topics selected for discussion have been deliberately wide by implication to cater for such a potentially wide range of viewpoints, and the treasured informality of our meetings has promoted free and spontaneous interchange of ideas and arguments.

Three successful sessions have been held to date. The practice is to hold two paper-reading meetings, and one field-meeting per year. The meetings have been held either at Aberystwyth or at Bangor. All were well attended. The inaugural session (1958/59) centred on two addresses given by Aberystwyth colleagues on popular aspects of geochemistry and micro-climatology as related to the soil; the field-meeting, held at Trawscod, unearthed fresh problems in local soils classifications. The themes adopted for the second and third sessions were (1959/60) 'Forest Soils with special reference to Wales' and (1960/61) 'Glaciation in Wales as related to soil profile development'. To cover the cost of preparing Reports (including original papers and edited discussions) for the second and third sessions, an annual subscription of 10/- has had to be established. Reports will be on sale to non-members at circa 7/6d. plus postage; applications should be made to James A. Taylor, Esq., M.A., Geography Department, U.C.W., Alexandra Road, Aberystwyth, Cardiganshire.

(Signed) GORONWY AP GRIFFITH.

SOIL STUDIES AT ABERYSTWYTHby James A. Taylor

'ABERYSTWYTH' is a famous name in agricultural circles in many different parts of the world. The grasses, clovers and cereals bred by Stapledon and his colleagues, and their successors, have been effectively introduced in many parts of the British Isles and abroad. At this same time, our sister College at Bangor achieved renown for specialisation in Soil Studies under the stimulating guidance of the late Professor Robinson. Pioneer soils mapping was conducted in North and South Wales in the inter-war period, and many contemporary research reports were published in the 'Welsh Journal of Agriculture' during the years 1925 to 1945. The latter dates represent the life span of a very useful journal which coincided with a period of vigorous pioneer research into Welsh soils. In the post-war period, however, the journal has not been revived and since the untimely death of Robinson himself in 1950, we have witnessed almost a full decade in which soil studies in Wales have lost something of the impetus given to them in the inter-war period. This is not to underestimate or devalue the recent work of Robinson's colleagues at Bangor, the post-war work of the N.A.A.S. in Wales and the present work of the Soil Survey of England and Wales. The latter has made great progress in North-West and North-East Wales, due in no small measure, however, to the pioneer mapping of the Robinsonian team. Reaction to this decade of relative neglect of soil studies led to the recent proposal at Aberystwyth to form an organisation to promote pedological research in Wales and to encourage regular liaison amongst the many academic departments and government services which are concerned in one way or another with the soil. Thus was created the Welsh Soils Discussion Group which has prompted the British Society of Soil Science to support the idea of forming regional study groups to introduce and collate local soil research projects and stimulate an active and co-operative interest in soils by all parties concerned.

In the inaugural session 1958/9 three highly successful meetings have been held. On October 29th, 1958, Dr. Nicholas Rast (then Lecturer in Geology, U.C.W.), delivered a lecture entitled "Geochemistry in the Service of the Soil". Some 30 people attended including Dr. Alex Muir, Director of the Soil Survey of England and Wales. The enthusiasm of at least one local geologist for 'drift' as well as 'solid' geology showed admirably how soil studies impinge almost unexpectedly on a host of adjacent specialisms. The pattern of behaviour of geochemical elements demands the attention of geologists and biologists alike, in addition to all the specialists primarily concerned with the environmental relations of life forms - ecologist, biogeographer, botanist, zoologist and, above all, pedologist.

At the second meeting on February 4th, 1959, Mr. James A. Taylor (Lecturer in Geography, U.C.W.) demonstrated the geographical approach

to soil study in a lecture entitled "Slope, Climate and Soil". Some 60 people attended. The intimate relations between land geometry, topoclimates and soil properties including soil climate, were revealed in the light of local experimental work. The discussion provoked by the lecture was lively and profitable. The new technique of land form mapping may enable the geographer to contribute, for example, to reconnaissance soil survey. Mr. Taylor's research into the relation of land aspect and soil texture to soil climate and to variations in periods and amounts of growth, suggests that these factors have more ecological significance in Britain than has hitherto been appreciated. Discussion also touched on British Soil Survey methods, maps and memoirs and the problems of reconciling 'Soil Series' with agricultural and forestry requirements.

Finally, on April 19th, a highly successful Field Meeting was organised at the N.A.A.S. Headquarters at Trawscoed by Dr. Rice Williams and his colleagues. Some 40 members were present. Dr. Rice Williams gave an introductory talk on local soils with special reference to the Trawscoed Estate, and indicated some of the problems of classification. On a subsequent tour of the Estate several sequences of soil pits fired off many arguments concerning the mode of origin and evolution of certain local soil profiles. It is evident that much more research into glacial and periglacial evidence in Wales is needed, in addition to complete geochemical analyses, before confident and final genetical soils classifications can be achieved.

The Group has had an enthusiastic and effective launching. The most encouraging sign is the wide range of academic and professional disciplines represented amongst its members. In addition to members of the staff of the colleges at Aberystwyth and Bangor, representatives of the Welsh Plant Breeding Station, the N.A.A.S., The Soil Survey of England and Wales, the Nature Conservancy and the Forestry Commission have attended meetings.

The programme for next year will focus on Forest Soils, including the effects of planted trees on soil characteristics. Full details will be announced later, but it is probable that two of the meetings will be held in Bangor in October and May and one in Aberystwyth in February.

(Reprinted from the Journal of the Agricultural Society, 1959, Vol. XXXX).

WELSH SOILS DISCUSSION GROUP
ANNUAL REPORT (1959/60)

The programme for 1959/60 was devoted to "Forest soils with special reference to Wales", a subject which attracted speakers from universities and research institutions outside the Principality. More than 50 members attended a meeting held in Bangor in October when the subject "Methods of examining soil minerals" was discussed. Dr. Smithson (U.C.N.W.) gave an account of his microscopic investigations of the sand and silt fractions of soils, with special reference to the use of polarising and phase-contrast equipment for the identification of minerals. Mr. Ball (Nature Conservancy) suggested that the powder method of X-ray diffraction was a useful technique and he showed some examples of his results. Mr. Archer (N.A.A.S.) described the use in analysis of direct arc spectroscopy and explained how substitution in minerals could account for the presence of trace elements.

In February, over 70 members attended a meeting in Aberystwyth when Mr. Thom (Forestry Commission) introduced a discussion on "Forest soils". Mr. Brown (Forestry Commission) described the present methods of soil reconnaissance for afforestation and expressed the view that more refined techniques are required. Mr. Davies (U.C.N.W.) examined soil profile development in the New Forest and gave examples of permanent soil degradation induced by certain conifers. Dr. Stewart (U.C.W.) presented a morphological study of the inter-relationships of some of the soils in Central Wales based primarily on a representative transect on the College farm at Aberystwyth. In the afternoon, Dr. Loyton (Oxford) presented a paper on "Mineral nutrient relations of trees on some Welsh soils", and Dr. Benizian (Rothamsted) discussed "Nutrition Problems in Forest Nurseries".

The final meeting of the session was held in North Wales in April under the joint auspices of the Nature Conservancy and the Forestry Commission. At this field meeting the aim was to examine soil-vegetation relationships under both deciduous and coniferous woodland. In the morning, Dr. Hughes (Nature Conservancy) described the Nature Reserve of Coed Gorswen, Ro Wen, a lowland oakwood at the northern end of the Conway Valley. He was followed by Mr. Ball (Nature Conservancy), who outlined the geology, glaciology and soils of the area. In the afternoon, Mr. Smith (Forestry Commission) described a part of the Gwydyr Forest and again Mr. Ball indicated the pedology of the area. The Group is indebted to Mr. Ball not only for the preparation and management of a full day's "soils" programme, but also for producing a comprehensive booklet on the profiles observed.

A memorandum based on the sessions' lectures and discussions is in the course of preparation. The theme proposed for next session is "The glaciology of Wales in relation to soil profile development" and meetings will be held in October, February and April.

J. A. TAYLOR,
Secretary

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Introduction

by J. R. Thom

I am very glad that such a large turn-out of interested people has come to this meeting this afternoon. I see, not only Soil Scientists, but also Agriculturalists and Foresters. One of the penalties of being Chairman of a Group such as this is that one quickly realises one's own imperfections with regard to the subject under discussion. In an effort to remedy this, I have referred to various books on Soils, and in perusing Pearsall's "Mountains and Moorlands" again, I was very pleased to find that he lists quite simply five types of what he calls environmental factors controlling the development of the over-lying soil. These are:-

1. Nature of the rock from which soil is formed by physical and chemical weathering.
2. Climate which affects weathering and also affects the percolation of moisture through the soil and thus leaching in the lower layers of the soil.
3. Relief which influences the lateral movement of water down a slope.
4. Time factor during which all the above take place. Obviously this must occur over a period of time and that period of time is dependant upon these factors.
5. Finally, vegetation which derives its sustenance from the soil and as such is an indicator of the soil and moreover returns itself to the soil in the form of decayed matter.

To Foresters, in particular, all these factors are of the greatest importance and anything that can be done affecting these factors, especially in the way of drainage, so that the soil may be improved, may make all the difference between what is considered to be plantable land or unplantable land.

My own experience as a Forester has been largely confined to the more acid peat soils found in the higher rainfall zones in the upland areas of Scotland and Wales. In particular, there are the soils found in the Border Counties with a shallow layer of peat below which is a most difficult mountain clay soil. This soil is difficult to drain initially and brings with it many difficulties in the establishment of satisfactory tree-growth. I am sure that on these soils the Soil Scientist can do much to help the Forester in discovering the answer to these problems of faulty drainage and poor aeration. I am certain that control of the water-table is all-important in tree-growth and where this is in jeopardy then possibly poor growth or even death of the trees may result. I would hope that when the second rotation of trees comes along, it may be possible to improve drainage problems and to ensure a better return from the second rotation of trees.

Mr. Brown is going to touch on the necessity of accurate soil surveys as a prelude to successful afforestation. This matter is having very urgent attention by the Forestry Commission, in particular at the present time, as it is a very necessary pre-requisite to the compilation of efficient management plans for the State Forests. Too often plans have been made from a very superficial survey of ground vegetation, and while this is extremely important, and in many cases is still the only possible method of surveying an area quickly and reasonably accurately, there is a lot to be said for having an accurate soil survey made of a forest area.

I believe that Dr. Stewart is going to deal with the question of soil profiles and relate his experience in agriculture to that of the Forester. I am quite sure that with increasing co-operation between the Forester and the Farmer, not only in rural land-use but also in the field of advisory work, much can be learnt from each other for the ultimate good of the countryside.

Mr. Taylor has undertaken to speak on Soil Profile development and forest history in Wales. It is relevant to consider the nature of past vegetation patterns to establish certain ecological principles of present day afforestation policy.

Mr. Davies is going to show us some of the work he has been doing with regard to both hardwoods and conifers in the New Forest and although the soils there may be not comparable to Welsh soils, I am sure he will have much of interest to communicate to the Foresters at this meeting.

Dr. Leyton, who has been doing a lot of work on the physiology of tree species, is going to speak to us about the mineral nutrients of the various tree species, particularly the conifers grown in Wales. In this instance, Dr. Leyton has also been doing some very important work on the water conservation aspect of afforestation, and it may be that he will be saying something about this as well.

Finally we are going to hear something about nutrition problems in relation to nursery soils. This is in the capable hands of Miss Benzian and certainly the Forestry Commission has probably suffered more losses through faulty understanding of our nursery problems than in any other part of our work. The necessity of providing a sturdy, well-balanced, rooted seedling is certainly understood, but the means of achieving this is not always efficiently practiced. Here again the Soil Scientist can come into his own with definite help and advice to the Forester.

I am sure that it is the wish of Mr. Taylor, who has so kindly organised this meeting, that all of you present will take part in any subsequent discussion, whether you be a Soil Scientist, a Geographer, a Geologist, a Meteorologist, Agriculturalist or Forester.

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PRELIMINARY SOIL RECONNAISSANCE FOR AFFORESTATIONby J. M. B. Brown.

An estimate of the productive capacity of the site is no less important in forestry than in other branches of husbandry. To a large extent productivity is determined by climatic factors and the forester's first task is to ascertain, with due regard to the marked influence of altitude on the general climate of the district, what trees are likely to be suited by the locality. In a country which relies to a considerable degree on exotics, such knowledge can often be gained only by trial and error, but study of the climate of the place of origin will guard against grave misfits.

Having satisfied himself what species indigenous and alien, will make healthy and vigorous growth in the locality, the forester next decides how they shall be allocated to the available sites. A knowledge of the range of soil variation and of the distribution of the main soil classes is essential if the most effective use is to be made of the land. In Britain, as indeed in many other countries, forest scientists are still very much occupied in collecting the fundamental data which should form the basis of efficient use of forest land and it will be many years before we are in a position to forecast, for a given site, the yields which may be expected from such species as appear climatically suited. Meanwhile, however, as forestry is a long-term business and mistakes cannot quickly be rectified, it is necessary that we should make full use of all the information we now have.

Forestry is for the most part conducted on hill-lands and, unless the lithological variations are very important, it will often be the case that the significant changes in soil depth, drainage, stoniness and fertility are fairly closely related to geometrical features of the land surface. Where there are several different geological outcrops within a forest, this relationship will not be so obvious, but the surface changes will still be of great importance in soil classification and mapping. In most cases, whether of wasteland or forest land, the variations in the natural vegetation give valuable indications of variations in water or nutrient supply, but differences in past treatment are apt to mask these indications.

Reconnaissance of the soil and other locality features is principally directed towards the optimum distribution of species, for it is thus that the forester can have the greatest influence on the yield of his forests. At the same time the need for such soil amendments as drainage, manuring or cultivation may be brought to light. But the tree itself is the most important agent in moulding the soil. Accordingly the long-term maintenance of the soil's productive capacity, as well as the proximate yield, is bound up with the assessment of site and the choice of tree or mixture of trees, based on it. The forester's ultimate objective is not simply the production, with or without appropriate amelioration of the soil, of a profitable stand of timber trees, but the creation, or recreation, of forests in harmony with their environments, and effective in maintaining, or, if possible, improving, the site. In this context soil reconnaissance for afforestation covers a wide field and it is essential on the one hand to understand the direction of soil development and the factors determining it, and on the other hand to assess the attributes of the trees in relation to soil properties and profile development.

"Soil profile development under individual tree species.
Examples from New Forest, Hampshire and from North Wales".

By
Mr. R.I. Davies

Trees are influenced by the soil on which they grow and also themselves influence the development of the soil profile. In natural woodland a delicate balance of species and soil is established; introduction of exotic species may upset this balance, sometimes with rather spectacular effects on the soil profile. Changes of this kind are more likely to be observed in sites where the soil parent material is relatively poor in readily weatherable minerals as e.g. in quartzose sands like the Barton sand of the New Forest. Microscopic examination by Dr. F. Smithson showed that the main source of weatherable inorganic material in the Barton sand was glauconite. This releases potassium, iron, magnesium and other elements on weathering.

Colour slides taken where Oak and Scots Pine were planted (1861) in immediately neighbouring positions in Knightwood Inclosure on Barton Sand, showed under oak a low base status brown forest soil with a somewhat raw humus layer but with no bleached horizon; whereas under Scots Pine a deep podzol had developed with 15 - 18" of bleached sand (A₂). Grains of glauconite were visible throughout the soil profile under oak, none were present in the bleached sand under Scots Pine and those in the zone of redeposition in this profile were corroded. This destruction of weatherable mineral grains was common in all the bleached sand layers even where, occasionally, podzols were found under larch and beech.

Podzol formation occurred only on freely drained sites, never in the slightly wet hollows. Where, however, the exotic species had produced a drying of the profile then some podzolisation followed. The fact that on very poor soil, even larch and beech may produce a podzol while on a soil richer in nutrient no podzolisation occurred, has prompted an investigation into differences in leaves and litter of individual tree species, comparing rich and poor sites. (Coulson, Davies & Lewis, 1960 (a) (b))

The following tentative suggestions are based on preliminary experiments at Bangor:-

- (1) Green leaves produce water-soluble polyphenols which may be washed from the leaves by rain. They are capable of reducing ferric iron to the ferrous condition and then forming stable non-ionic complexes with the ferrous iron. The polyphenols are more stable and therefore remain active under more acid conditions. The quantity of polyphenol in rain washing is greater from coniferous than deciduous species. It is greater in leaves

of trees on nutrient-deficient soils than in nutrient-rich soils and acid conditions in the soil humus tend to preserve it from change.

(2) At senescence the polyphenols are of a size and kind that can tan some of the protein within the leaf so hindering processes leading to normal breakdown. This has already been suggested by Handley (1954) in differentiating between mull and mor humus formation. A greater amount of tanning occurs on nutrient-deficient than on nutrient-rich sites.

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A morphological study of the inter-relationships of selected
soils in Mid-Wales

(based on a study of a Key Transect on the U.C.W. College Farm,
Aberystwyth).

by Dr. V. I. Stewart.

Throughout Mid-Wales the parent rock from which the soils have been derived is remarkably uniform: Ordovician and Silurian shales and grits. Despite this, however, there is quite a wide variety of soils, variation resulting mainly from differences in texture: e.g. some have virtually no stones, and others 70% stone; some have silt and clay contents of about 40% and others almost 80%. Such a wide range of variation in texture is of some significance to the forester as well as the agriculturalist, all the more so as the pattern of textural variations is similar to that for soil moisture effects due to relief; thus the heaviest soils tend also to be by far the wettest and the lighter soils the driest. The aim of this paper is to suggest that the wide range of variation in soil type in this part of Wales derives from the action of geomorphological, glacial and periglacial processes capable of effecting resorting of mineral residues on a massive scale.

According to the soil map of the College farm, U.C.W. Aberystwyth, produced by Evan Roberts and Edward Crompton, in the 1950's there are 6 soil series within the limits of the farm. Powis, Penrhyn, Sannan and Cegin all on the hard shales, and on the soft shales Corwen and Gvern. The series names used (Fig. 1) in this paper are those adopted by Roberts and Crompton. It would appear that some revision will be necessary in due course.

In order to get some idea of the inter-relationships of these soils, sites were chosen for special study where the transition from one to another could be most easily seen. This approach has been greatly facilitated of late (1959-60) by the activities of contractors putting in water-mains to supply the new college buildings. One trench, passing from top to bottom of the farm on Penglais Hill, behind the Institute, has been of particular interest as it cuts through all the soil types said to occur on the farm and places them in sequence according to their position on the slope (Fig. 2). This, in fact, is the "Key Transect" referred to in the title of this paper.

Relief.

The hill behind the Institute falls away from a flat, dome-like top in a succession of steep slopes and terraces, the broader

terraces tending to form shallow, basin-like depressions into which the drainage off the hill above would appear to be funnelled before overflowing into the next lower sequence of hill slope and terrace (Fig. 3).

Parent Material.

The parent material of the soils in the transect begins, on the broad, flat hill top, with a soil formed in deep drift. Rock outcrops would appear to form the shoulders of the hill-slopes below which the hill-side falls steeply away. These rock outcrops may at one time have formed small craggy bluffs beneath which scree may have accumulated to a small extent. Now the steep slopes beneath the rock outcrops have been filled in and, by a deep accumulation of erosion debris, to some extent smoothed out into gentle concave slopes. The erosion debris becomes increasingly gravelly with depth. As more foundation digging goes on it will be interesting to see how deep it is and what underlies it. Where basin-like depressions occur on the broader terraces beneath such slopes they are filled with a surface layer of heavy texture. It would appear that a certain amount of water-sorting has gone on within the mantle of erosion debris leaving lighter soils, loam in texture, on the middle and lower slopes and heavy textured, silty loams and clay loams in the basins.

That erosion has occurred is not only indicated by the nature of the mantle of mineral debris accumulated on the lower hill slopes and terraces but also by the presence of sand and gravel-sized, charcoal fragments throughout this mineral debris. From observations in the main trench and elsewhere it would appear that a discontinuous charcoal horizon may exist at about 3 - 4 ft. in places within the mantle of erosion debris. Just beneath the main rock outcrop in the trench transect an excellent example was found at about 3 ft. (Marked on Sketch Map, Fig. 2). This suggests that erosion on a massive scale must at one time have followed removal of the surface vegetation by fire.

The glacial drift, which occurs to a depth of at least 4 - 5 ft. on the flat hill-top, is characterised by a massive, strongly indurated, blue-grey horizon reaching to within a foot of the surface. On the crest of the hill this indurated horizon is smooth-topped and well-defined. On gently sloping sites its surface may be somewhat corrugated. This is interpreted as being the Welsh equivalent of the permafrost horizons found in Scotland and described by FitzPatrick (1956). The survival of drift mantles on some flat hill-tops and

Major Soil Gp.	Drainage Class	Agricultural Soils		Natural Soils
		Hard Shales	Soft Shales	
Podsols	Free			(Hiraethog)
Brown Forest Soils		Powys	Dinam	Manod
		Penrhyn	Corwen	Cymmer
Gleys	Imperfect	Sannan	Gwern	(Hiraethog)
	Poor	Cegin	Ilar	Ynys

Fig.1. Sedentary, Colluvial and Drift Soils based on mineral residues derived from Silurian and Ordovician Shales and Grits. (After Roberts and Crompton and after Stewart.)

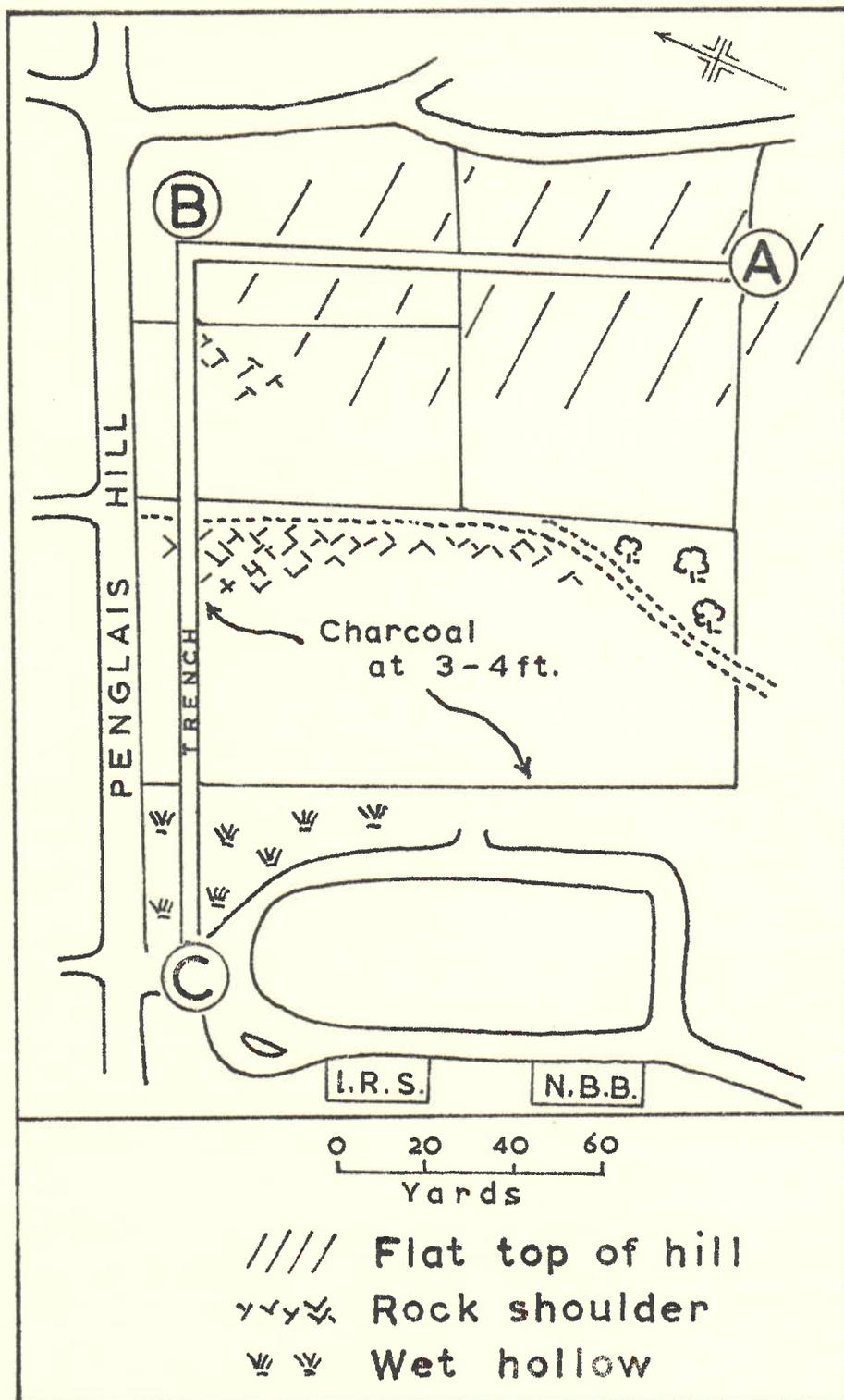


Fig.2. Plan of Transect (After Stewart)

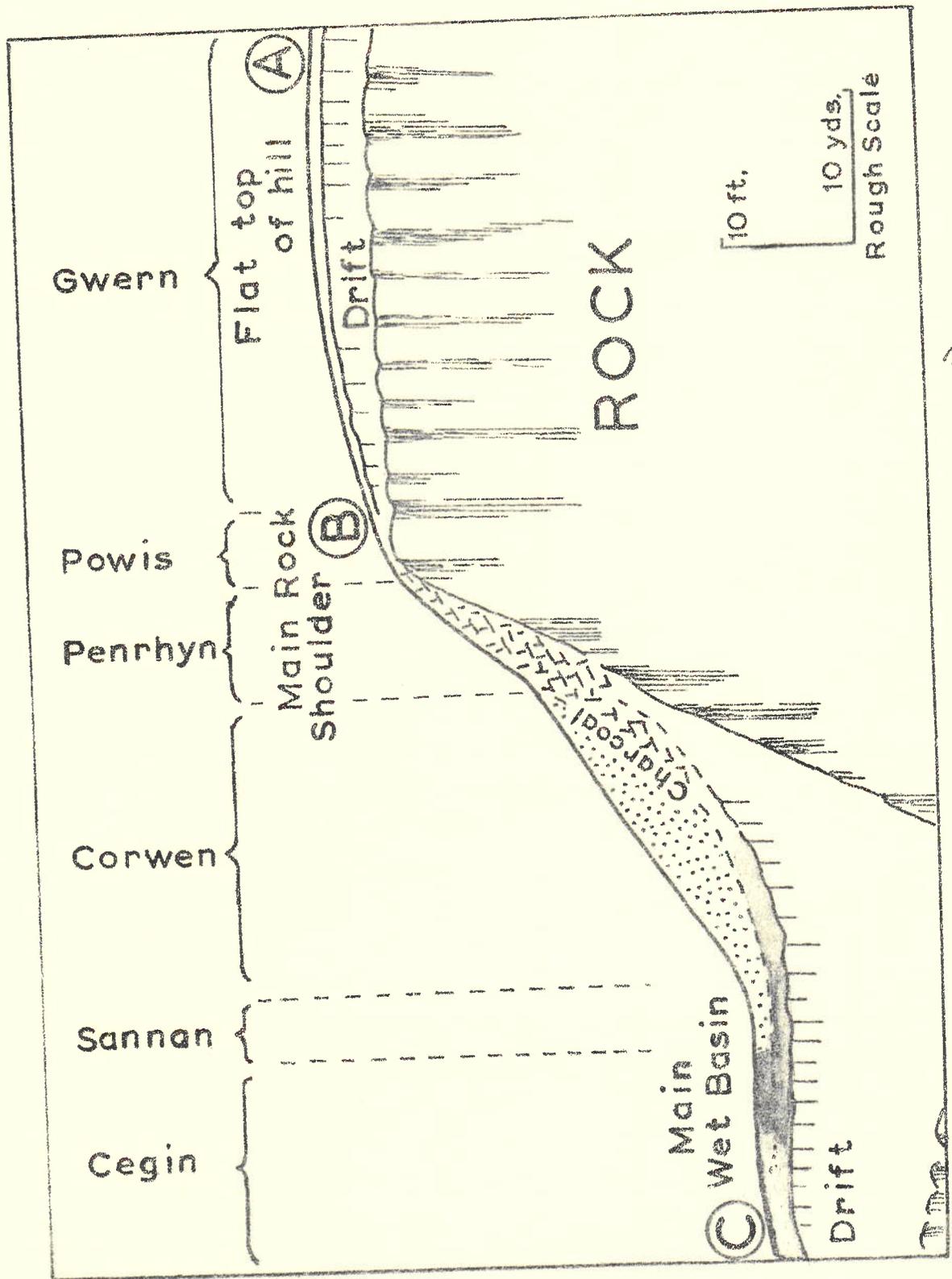


Fig 3. Transect (simplified)

some gentle slopes may well have occurred only where the environmental conditions of aspect and exposure ensured the maintenance of a permanently frozen subsoil under the periglacial conditions that followed the retreat of the ice-sheet. On south-facing and relatively steep slopes erosion by solifluxion may have led to its removal. On the lower slopes and terraces consolidated drift deposits are partially buried beneath erosion debris. Here the blue grey, indurated horizon reappears at 2 - 3 ft. and, though it may affect drainage where it occurs within the profile, it should not be interpreted as a normal gleyed horizon.

The Soils.

Under agricultural conditions variations in profile morphology depend mainly on variations in parent material and drainage. In the transect there are minor but nonetheless significant variations in the parent material. These variations are physical rather than chemical. Drainage is affected both by relief and the variations in parent material.

Elsewhere on the farm, soils similar to those seen on the flat hill-top section of the transect have been named Gwern. This soil seems to occur on the tops of flat-topped hills where the surface is unlikely to have received erosion increments off neighbouring hill slopes. It also occurs on the long gentle slopes beneath the hill-top. On these gently sloping sites a relatively thin erosion mantle would seem to have added a sufficient increment to the top-soil to allow of the development of a shallow, comparatively light-textured, rather loose, yellowish B horizon beneath the plough layer. Beneath this shallow B horizon the fossil, indurated permafrost layer seems to prevent any further profile development. These soils, with their well-defined plough layer, (the A1), brightly coloured subsoil, (the B2), and blue gleyed, indurated base have the morphology of imperfectly drained soils but, since there seems to be a distinct lateral movement of ground-water along the top of the fossil, indurated horizon, these soils should be grouped along with the "iron-pan" soils as soils with impeded rather than imperfect drainage. They are in effect, shallow, slope soils with a slow lateral movement of water through them, rather than basin soils in which water tends to accumulate. Should the presence of a moving, perched water-table within 12 - 18 inches of the surface and a massive, indurated horizon limiting root development to the top-soil be considered features likely to affect choice of species, then these Gwern-type soils would appear to be of particular interest to foresters. The slope version of this

soil stood up well to last summer's (1959) severe drought, and, under grass, was said to recover well. From the top of the hill to the first rock shoulder the depth of the erosion mantle increases until, near the rock shoulder, the depth of the loose, light-textured, light-coloured B horizon may be 2 - 3 ft. Here the surface of the fossil, indurated horizon is corrugated and may sometimes reach to the plough layer or fall away into lens-like depressions now filled with typical B horizon material. The profile morphology of these deeper sections is that of a typical farm Corwen, that is, the deep, freely draining soil said by Evan Roberts (1955) to be derived from soft shale rock residues. The corrugated surface of the massive, gleyed, indurated horizon is clearly not related to present-day pedogenic processes. The transition from Gwern to Corwen would seem to depend in this case upon the progressive burial of the permafrosted horizon beneath a mantle of erosion debris until it no longer comes within the soil profile.

On the rock shoulder itself there is a covering of little more than 6 ins. of soil. The shallow soil profile is similar to that described elsewhere on the farm as Powis, that is, a very shallow soil derived, according to Evan Roberts (1955), from hard shales. Powis is clearly a soil directly influenced by the relatively fresh rock that so closely underlies the surface. As this past summer (1959) showed, this soil is very liable to drought.

Below the Powis shoulder the underlying rock falls away steeply and a rather stony soil succeeds Powis down the slope. The slope zone occupied by the fairly deep soil formed on this rather stony substrate would appear to be that described in Glentworth's (1954) "Hydrologic Sequence" as 'excessively drained'. This, plus the presence of more easily weathered, fresh rock residues, may account for the overall red tinge in the colour of the soil. It would appear, therefore, that there is a narrow zone of Penrhyn in this key transect though its extent is limited by the small extent of the steep, colluvial zone beneath the Powis shoulder. Penrhyn, like Powis, is a freely drained soil mainly, or at least partly derived from comminuted fresh rock residues, and distinguished from the Corwen series, its "soft shale" analogue, by its relatively high stone content and overall redder tinge.

The well-defined charcoal band mentioned earlier (vide p.) as occurring at 3 ft. within the erosion debris beneath the main rock shoulder, in fact occurs where Corwen succeeds Penrhyn down the slope, that is, where the mantle of relatively light textured, light coloured, easily friable erosion debris is built-up to considerable depth forming

the parent material of the soil in the middle and lower concave slopes of the hill. This charcoal band, plus the numerous charcoal fragments found throughout the erosion debris may well be as good an indication as any of the nature of the parent material of the Corwen series. In clear contrast to Gwern, Corwen is a deep, freely drained soil, friable and, in this case, a relatively light-textured loam throughout. There is a noticeable lack of any marked profile differentiation. This, and its overall yellow colour may owe something to the fact that its parent material is mainly derived from previously weathered and transported rock residues originating within the drift mantle. Its parent material is, therefore, at least one weathering cycle older than the fresh rock residues in the parent materials of Powis and Penrhyn. For those interested in the hard shale/soft shale controversy it is suggested that herein lies the clue to the morphological distinctions that impressed Evan Roberts (1955); the cause may well lie in the nature of the parent material but not so much its hard or soft shale origin as the extent to which it contains fresh rock fragments rather than previously weathered drift residues. Corwen, by comparison with the other soils on the farm, is a moderately, freely drained soil, not liable to drought and easily worked.

In the key transect studied, the blue-grey, fossil, permafrost horizon re appears, with its surface somewhat corrugated, first at the base of the profile, and then, undulating occasionally into the plough layer as the lower hill slopes level out into the broad basin.

Within the basin the soil is similar to the hill-top Gwern with the distinctive presence of an indurated, fossil, permafrost horizon causing a marked drainage barrier within the profile. However, this basin version of the Gwern series has a deeper, heavier-textured top resulting, it would seem, from additions of clay, silt and fine sand resorted by water action from the Corwen erosion residues left higher up the slope. The result is a soil which, from its poorly drained, basin site, silt loam to clay loam surface and impeded drainage is a wet soil and difficult to manage. This is Cegin, the poorly drained member of the so-called hard shales suite. Ilar, its soft shale analogue, is a soil formed entirely in a deep accumulation of silt and clay, so well resorted that few if any stones are present and the mineral fraction is about 75% silt plus clay. It may be that the parent material of these Ilar soils was laid down under water in a former landscape dotted with small ponds and ribbon lakes. They are very difficult to work and difficult to drain.

These then are the soils of the key transect. They are essentially soils based either directly on outcrops of Ordovician and Silurian Shales and Grits, or on drift derived from these rocks, or they may be based on resorted erosion residues derived from the drift, or partially resorted colluvium influenced to varying extents by the inclusion of fresh rock. The different hill zones represented in the key transect described might be expected to vary in their presence and extent according to the overall configuration of the landscape.

For the forester the interest in the soil pattern herein explained lies in the fact that the soils being afforested in much of Mid-Wales are the natural upland analogues of the lowland agricultural soils here described.

This paper has endeavoured to show, with the minimum of pedological jargon, how important it is to study soils within the context of the landscape pattern into which they fit and from which they derive so much of their morphology. In hilly areas such as Mid-Wales, it is essential to realise that there may be profiles of accumulation as well as profiles of weathering.

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Preliminary views on soil profile development and forest history inWales.

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Forestry is long-term job; rotations involve - or will involve - may decades and several generations of foresters. However, the thirty years or so of afforestation in Wales represent a small, contemporary episode within a vast and varied post-glacial period embracing almost fourteen thousand years and the emergence of prehistoric, and historic, man in this area. The date 12,000 B.C. when the last major glaciation was terminated in Britain is perhaps only yesterday in the geological time-scale. Nevertheless, from the ecological point of view, the climatic vicissitudes of the post-glacial have ranged from sub-arctic to moist-oceanic and to warm-continental; in response, pine and birch succeeded tundra and were themselves displaced by mixed alder-oak woodland.

The techniques of pollen analysis and radio-carbon dating have enabled a quite precise re-construction of the post-glacial chronology (Godwin, 1956), vide Figure 4. Available evidence for Wales as such, however, is relatively sparse and only hypothetical inferences can be made concerning local vegetation and soil history in the Principality. It is essential to interpret the vegetation succession and its ultimate degradation by man in relation to the underlying soils on and within which varied climates, cold and warm, dry and wet, have registered, and varied plant covers, first tundra, then conifers, then deciduous trees and finally introduced grasses or crops or trees, were in turn established. Effects, both positive and negative, have accumulated in the soil profiles, some to suffer obliteration or at least modification, others to survive and persist in fossilised form today. Among such effects may be included, for example, the induration of layers subjected to prolonged perma-frost, and variation in the depth, thickness and disposition of these layers according to the differences in rates and amounts of freezing and thawing on sites of different altitude, aspect and angle of slope under a peri-glacial climate; or again, the contrasts in the pattern of solifluction resulting from those differences. Stewart (1961) has postulated that indurated layers occurring in certain contemporary Cardiganshire soils are fossil permafrost horizons. The alteration of relatively warm with relatively cold period, e.g. in the Late Glacial Period (vide Figure 4), would permit a series of solifluction cycles to take place, and Stewart herein (vide pp. -) has identified superimposed layers of accumulated mineral residues in other contemporary Cardiganshire soils as being the consequence of such cycles. On the other hand, many re-distributed deposits must have been eroded away. The alternation of dry Boreal and wet Atlantic phases and of relatively low and high

FIG. 4 HYPOTHETICAL RECONSTRUCTION OF THE POST-GLACIAL CHRONOLOGY FOR WALES (adapted from GODWIN)

DATING	PERIODS	CLIMATES	CULTURES	VEGETATION	FOREST TYPES	GROUND CONDITIONS	PROBABLE SOIL CONDITIONS				
2000	Sub-Atlantic	Temporary warming (Resumption of oceanic) (Cool)	Contemporary	Afforestation	Semi-natural moorland grasses	Chemicalisation	Possible degradation, formation of surface grass-mat and organic layer.				
1000			Late Victorian					Alder to Birch	Afforestation	Increasing effects of grazing	Rapid deforestation and erosion.
A.D.	Sub-Boreal	(Return to Continental: Less warm and drier.)	Anglo Saxon	Deforestation	Oak Elm Birch Beech	Ploughing. Renewal of peat formation.	Burning and charcoal deposition. Relatively higher water-tables. Promotion of gley and bleaching of A ₂ 's.				
B.C.			Romano-British					↑			
1000			Iron Age								
2000	Atlantic	(Warmest; (climatic optimum) (Oceanic: wet all year.)	Bronze Age	Forest	Alder Oak Elm Lime	Relatively dry land surfaces	Low water tables. Brown earths probably extended at the expense of gleys. Beginnings of deforestation, burning and deposition of charcoal.				
3000			Neolithic								
4000	Boreal	(Continental (with dry summers	Mesolithic	Forest	Pine-hazel Pine	Extensive peat formation	High water tables; resumption of gleyed conditions. Mixed deciduous litter in warmer climate, brown earths indicated.				
5000								Rapidly warming			
6000								Less cold			
7000	Pre-Boreal	Rapidly warming		Forest	Birch Pine	Organic muds	Increasing thaw. High water tables. Gleys; probable mor humus and tendency to podzolisation.				
8000								Less cold			
9000	Upper Dryas	Cold (Peri-glacial)		Forest	Park tundra (birch copses)	Solifluction and mineral deposits	Secondary frost shattering followed by secondary erosion.				
10000								Temporarily milder			
11000	Lower Dryas	Very cold (peri-glacial)	Upper Palaeolithic	Forest	Birch-woods	Temporary thaw Organic muds	Shallow peat accumulation in basins. High water table. Gleys.				
12000								Temporarily milder			
12000	Late-Glacial			Open vegetation Slow recolonisation	Park tundra (local birch) Arctic waste	Solifluction Permafrost	Primary cycles of re-distribution of mineral residues. Frost-shattering (especially of shale rock). Deeply frozen 'tundra' soils.				

macro-rainfalls must have caused fluctuations in water tables and the degree and extent of gleying in soils in addition to decelerating or accelerating the rate of accumulation of surface organic layers or peat both in lowland or coastal plain and valley and also on the hills and mountains. Both lowland and hill peats exist today as legacies of past oceanic climatic phases; the consequences of fluctuating water tables and variably gleyed conditions associated are, however, much more difficult to diagnose. The coniferous forests of Boreal times would suggest the development probably of a mor type humus on the surfaces of soils at the time with a slow rate of incorporation of organic matter and negligible earth-worm populations; tendencies to podzolisation are indicated. However, the succeeding longer stage of colonisation by a more thriving, mixed deciduous woodland which reached its zenith at the climatic optimum of about 4,000 - 2,000 B.C. favoured the development of brown earth characteristics since the litter was milder and more quickly assimilated by more vigorous soil populations. More recently, deforestation by man, gradual in the Neolithic and Bronze ages but more rapid since especially after the twelfth century, exposed soil surfaces to an erosion potential greater than before, and the burning of woodland led to the deposition of charcoal fragments which can be identified today in many soil profiles in West Wales. Robinson (1950) asserted that erosion was extensive leaving behind what he termed 'truncated' podzols; this theory was supported by Roberts (1955) but both Taylor (1957) and Ball (1959) prefer to restrict the possibility of catastrophic erosion to the steeper slopes only. Stewart (1961) on the other hand has revived support for the theory in the light of the discovery of abundant charcoal fragments in lenses 2' - 4' below the surface on lower concave slopes in West Cardiganshire. The consequences of erosion in historic times after deforestation might well have been to provide the latest major cycle in the re-distribution of mobile mineral residues by eroding them from convex sites to be accumulated in concave sites. Finally, the creation of the virtually treeless, moorland vistas of today (where conifers and deciduous trees once grew in abundance) by centuries of grazing, first by cattle and sheep, then by sheep and now mostly by sheep alone, is essentially a gesture of superimposition by man in defiance of what is still a climate eminently suited to trees.

∅ The rich brown colour and varied mineralogy of the 'B' horizons of many contemporary brown earths, brown podzolics and some podzolics may be partly attributable to this period.

The organic top, (derived from the closely matted roots of *Molinia*, *Nardus* and other plants on the Welsh moorlands, reducing heat penetration and water percolation down into a soil compressed and undisturbed for so long) sits unconformably on 'B' horizons possessing properties derived from a previous, more natural woodland environment. On lower, cultivated ground - and to some extent on high ground also - the cultivation and fertilisation of surface layers to grow grass and crops have also made their marks.

Thus, a combination of natural and man-derived factors is expressed in contemporary soil profiles by a complex not accumulation of fossil and contemporary features, the former derived from previous climates, vegetation or human usage, the latter being functional within the present-day pedogenic processes as adapted by human usage.

It is hoped that a selection of major points from the chronology summarised in Figure 4 will suffice to demonstrate that the study of the post-glacial evolution of Welsh forest-soils may well reveal trends of relevance to the selection and establishment of tree species for planting in particular soil or slope environments.

Most ground used by, on available to, the Forestry Commission in Wales is more or less sloping. In addition to the familiar ecological contrasts between northerly and southerly aspects, the moistness of the former compensating for the warmth of the latter, the planting potential of these slopes is very much a function of their soil climates in relation to the water table, water-holding capacity, diurnal temperature ranges in the growing season, and root penetrability of the soil in combination with the topographic, biological and chemical factors operative at a given site. Fundamental among these variables is the physical nature of the soil profile and its individual horizons, which have often been affected by periglacial and post-glacial events. Slopes of southerly aspect, having been soliflucted early and extensively, often exhibit relatively shallow soils and sub-soils with solid rock near to the surface; the tendency for such slopes to dry out in dry spells weather is further accentuated by the relatively low water-holding capacity of soils and sub-soil. In contrast, north-facing slopes, having been soliflucted late and less extensively, display deeper soils developed on heavier and thicker material giving higher moisture capacities. These are generalisations but, so far as practicable and applicable, southerly slopes should be preferred for the earlier, less sensitive but drought-resistant species as compared with the reservation of northerly slopes for the later more tolerant moisture-loving species. Prior to planting, southerly slopes, with an early and more nutritious response of grass, have been usually closely grazed and tramped and have developed a dense mat with underlying organic layer. This latter not only reduces

and delays soil-warming but also favours lateral movement of rain-water downslope either at the bottom of the grass where the organic layer begins or, at times of heavy rain, through the grass itself. This creates intermittent moisture deficiency in the mineral horizons of these soils which can affect tree growth at certain stages. To mention irrigation in the same breath as the Welsh hill climate may sound quite ludicrous yet irrigation has been applied in Dovey Forest to certain Sitka stands and has made economic, as well as ecological, sense. Local irrigation needs for certain forest crops on slopes of this type in Wales might well be unexpectedly high. Some device for the contour control of water is indicated and the more the organic mat is broken up for planting the better, provided erosion is not induced.

Field evidence indicates that soil water is transferred laterally as well as vertically through soils on sloping sites. The steeper the slope, the lighter and stonier the soil, then generally the more extensive the lateral, as opposed to the vertical, percolation. It seems reasonable to postulate that soils may be subject to lateral leaching on such slopes and, within the framework of the normal hydrological cycle of soils on slopes expounded by Glentworth (195) for illustrated by Taylor (1960) for Wales. Lower concave slopes, especially just above a depression or flat must possess an even greater and more versatile planting potential than upper convexities, the exposure of the latter usually being as much a disadvantage as the frost liability of the former.

On the flatter convexities, fossil permafrosted layers may be preserved (Steward, op.cit. 1961) creating perched water tables and giving the relatively shallow soils a higher moisture reserve which is an asset in a dry spring or summer for both agricultural or forestry crops. On the other hand sharper convexities have usually undergone quite extensive erosion and have soils which are shallow with bed-rock near the surface and which therefore are liable to drought and unprofitable to fertilise because of the rapid leaching. Concave sites, whether they be flat or basin-shaped in the centre, are even more notoriously undrainable and frost-ridden by comparison when the peaty gley profiles beneath them are contemplated.

Thus, in summary, consideration of the soil factor would emphasise the scale of the ecological variations deriving from the geometry of the land surface in Wales - variations which popular and indeed some professional and scientific opinions would regard as negligible in the so-called temperate climate of these parts. To underline the argument finally, Taylor (1958) has demonstrated that, for slopes of circa 22° at

200' O.D. in coastal Cardiganshire, growth potential, as indicated by comparative soil and soil-surface temperatures, is almost half as much again on a slope facing due south as compared with one facing due north; the slope facing due west possessed a quarter as much again as compared with the north-facing slope; the east-facing slope, however, showed a negligible advantage. These data are a first indication of possible variations in tree-growth and timber yield on sites of different in Wales.

Many of the higher plateaux in Wales, with fairly flat or gently sloping or shelving surfaces, are extensively clothed with hill-peat which varies from about 1 foot to 6 feet (more in basin sites) in depth. Also, on much of the sloping ground discussed above, an organic top layer a few inches thick is very frequent. Within the profiles of peaty podzols, the most characteristic soils of upland Wales, organic pans (B₁ horizons) are not uncommon. Thus, the majority of 'natural' forest soils and most of the soils planted or likely to be planted by the Forestry Commission are associated with surface or internal accumulation of organic materials, the origin and development of which are relevant to interpreting contemporary profiles and their planting potential. Peat sections and their inherent pollen profiles are a major source of data for the reconstruction of post-glacial (and interglacial) vegetation history (Godwin, op.cit. 1956); the two major periods of peat accumulation, the Atlantic and Sub-Atlantic, are often manifest, and woody remains, sometimes large stocks or roots, betray the preceding Boreal and, less frequently, the intervening Sub-Boreal 'forest' periods. Organic horizons within soil profiles may be created by normal pedogenic processes, may relate to a previous, now buried, profile which once had an organic 'top' or may be the consequence of periods of vegetation-burning. Peaty or organic layers are almost universally associated with drainage impedance and high water-holding capacities. The improvement of drainage and the breaking up of organic pans are essential prerequisites to peaty ground being satisfactorily reclaimed for trees or other planting. Yet the excessive release of water from bogs can upset the hydrological balance of the catchment and cause flooding, albeit temporary; rivers can become choked with organic debris which can cause the destruction of fish populations. The latter is more common in parts of the Scottish Highlands after the natural bursting of swollen, eroded bogs; the former has happened in mid-Wales in the Severn catchment. According to Geiger (1950), progressive drainage of bogs increases their already notorious liability to late and heavy frosts. Clearly, some degree of regulated drainage is needed (Taylor, 1953). Peaty ground in Wales is also (except for occasional local fen peat e.g. in

FIG. 5 SELECTIVE FIELD DESCRIPTION OF TWELVE SOIL PROFILES AT DOVEY FOREST, MONT. (examined on 27th January, 1960)

No.	Parent Material	Elevation O.D.	Site	Species & Age	Profile Description
1	Colluvial	675'	Moderate, even slope (12°)	Sitka Spruce 30 years	0" - 2" Very dark brown to black (10 YR. 2/1) organic material, raw at the surface becoming more decomposed and amorphous with depth; merging boundary. 2" - 3" Medium to dark medium grey (10 YR. 5/1), slightly bleached horizon, moderate organic content; fairly sharp boundary. 3" - 28" Light grey brown (10 YR. 6/2) medium textured silty loam, with grey yellowish brown (10 YR. 6/4) lenses, becoming paler with depth; occasional mottle. Occasional large shale fragments below 24". 28"+ Parent material.
2	Drift	650'	Concave, overlooking gorge	Sitka Spruce 30 years	0" - 4" Very dark brown to black (10 YR. 2/1) organic material, raw at the surface, becoming more decomposed with depth; merging boundary. 4" - 6" Medium grey (10 YR. 5/1) bleached horizon; low organic content; irregular, merging boundary. 6" - 18" Medium grey yellow brown (10 YR. 5/4) medium to medium heavy textured silty clay loam; abundant mottle. 18"+ Parent material.
3	Colluvial	825'	Gentle slope (7°)	Sitka Spruce 14 years	0" - 2" Black (10 Y R. 2/1) organic material raw at surface, becoming amorphous with depth. 2" - 4" Wedges or lenses of pale grey to pale grey brown (10 YR. 6/1-2) mottled material. Very sharp, wavy boundary. 4" - 14" Very thin, interrupted wavy iron pan (B ₁) merging into yellow brown (10 YR. 5/8) medium to heavy medium silt clay loam. 14"+ Parent material.
4	Colluvial	900'	Moderate slope (13°)	Sitka Spruce 14 years (much heather persisting)	0" - 3" Black (10 YR 2/1) organic material; raw humus. 3" - 4" Dark grey (10 YR. 4/1) horizon; variable thickness; moderate organic content, merging boundary. 4" - 5" Pale grey (10 YR. 6/2) A ₂ horizon; bleached; occasional mottle; sharp boundary. 5" - 18" Yellow brown (10 YR. 5/8) medium to heavy medium silt clay loam. 18"+ Parent material.

FIG. 5 SELECTIVE FIELD DESCRIPTION OF TWELVE SOIL PROFILES AT DOVEY FOREST, MONT. (examined on 27th January, 1960)

No.	Parent Material	Elevation O.D.	Site	Species & Age	Profile Description
5	(Shales)	1100'	Gentle, convex slope (5°)	Sitka Spruce and Scots Pine 17 years	<p>0" - 2" Very dark brown to black (10 YR. 2/4) organic material, merging boundary.</p> <p>2" - 3" Light grey brown (10 YR. 6/2) bleached horizon; moderate organic content.</p> <p>3" - 24" Grey yellow brown (10 YR. 6/4), then yellow orange brown (10 YR. 6/6) with depth, medium silt loam. Parent material.</p> <p>24"+</p>
6	Shales	1100'	Gentle slope (5°)	Sitka Spruce and Scots Pine 17 years	<p>0" - 3" Black (10 YR. 2/1) organic material, merging boundary.</p> <p>3" - 5" Pale grey (10 YR. 6/2) bleached, mottled horizon. Fairly sharp boundary.</p> <p>5" - 20" Yellow orange brown (10 YR. 6/6) medium silt loam becoming heavy silty clay loam with depth. Parent material.</p> <p>20"+</p>
7	Discontinuous Colluvial deposits; occasional exposures of shales	800'	Moderate uneven slope (15°)	Japanese Larch 14 years	<p>0" - 2" Very dark brown (10 YR. 2/1) organic material; merging boundary.</p> <p>2" - 4" Pale grey (10 YR. 6/2) bleached horizon; merging boundary.</p> <p>4" - 26" Light grey brown (10 YR. 6/3) mottled, medium heavy silt clay loam; irregular sharp boundary. Parent material.</p> <p>26"+</p>
8	Colluvial	700'	Moderately steep slope (26°)	Douglas Fir 30 years	<p>0" - 2" Dark brown (10 YR. 2/2) organic material; partially colonised by plants owing to thinner forest canopy.</p> <p>2" - 3" Pale grey yellow brown (10 YR. 5/3-4) slightly bleached horizon; sinuous merging boundary.</p>
9	Drift	300'	Steep slope (37°)	Douglas Fir 30 years	<p>0" - 2" Dark brown (10 YR. 2/2) organic material; merging boundary.</p> <p>2" - 3" Pale grey brown (10 YR. 6/2) bleached horizon of variable thickness; locally discontinuous.</p> <p>3" - 24"+ Pale yellow orange brown (2.5 YR. 6/4) medium textured silt loam. Parent material.</p> <p>?</p>

Grey-brown materials derived from Silurian shales and grits

Anglesey) notoriously acidic. It would appear reasonable to suggest that the extended treatment of such ground with lime and other fertilisers prior to planting might well pay dividends in rate of growth and in timber yield. The selection of the more tolerant and late-maturing species for this land is wise not only because of the dangers of late spring frosts but also in view of the extra growth potential available on this land in mid-and late summer (Taylor, 1958). The pattern of tree-rooting on bogs and in soils capped with a foot or so of peat is emphatically shallow and lateral. This restriction is due to the shallow depth of aeration and the shallow and retarded pattern of daily and seasonal warming in the surface layers (vide Taylor, 1958); other factors involved may be the artificial improvement of the surface layers or the deficiencies, physical and/or chemical and/or biological, of underlying mineral deposits. It seems pertinent to suggest that the choice of species and the method and intensity of plantings and of subsequent thinnings should take into consideration the soil profile, its peatiness and anticipated pattern, and rate, of root development.

Although the application of lime and other fertilisers to upland soils had been recommended above, and has been practised by the farmers as well as the foresters in Wales, it is well known that such applications are soon leached away in a rainy climate and require regular renewal for the maintenance of nutrient status. Many authorities have supported the view that decalcification of soils has progressively taken place since the climatic optimum of the post-glacial period (vide Figure 4) when the mixed oak-alder woodland reached its greatest luxuriance and highest altitudinal limits - probably over 2000' O.D. in Wales, (Taylor, 1957). The point has been raised as to whether up to thirty years of afforestation under conifers e.g. in parts of Dovey Forest, has had any similar effects in translocating and eliminating soluble minerals abnormally quickly, and even irrevocably, downwards from soil profiles. Davies (vide pp. herein) has shown this to occur on sandy parent materials in the New Forest. In Wales, however, the necessary combination of coarse texture, high porosity and high acidity of soils and parent material very rarely exists. The field inspection by the writer of profiles taken virtually at random in a section of Dovey Forest (vide Figure 5) revealed the presence of thin bleached layer of varying intensity in nine out of ten sites under planted conifers. On the other hand, two out of two profiles taken from unplanted sites within the stand showed no bleached layer at all. This evidence included here merely is preliminary, non-statistical and non-conclusive since it is impossible to ascertain what pre-plantation profiles were like. Indeed, many unplanted sites on similar slopes of intermediate altitude in Wales display comparable profiles with shallow and intermittent bleached A₂ layers. Whilst the suggestion that introduced conifers in Wales have initiated negligible, if any, soil degradation to date can be no more than an intelligent

No.	Parent Material	Elevation O.D.	Site	Species & Age	Profile Description
10	(Drift Grey-brown materials derived from Silty- thin shales and grits)	550'	Very gentle slope (4°)	Scots Pine and Douglas Fir 17 years	0" - 4" Dark brown to black (10 YR. 2/1-2) organic material increasingly black and more decomposed with depth. Fairly sharp boundary. 4" - 20"+ Yellow orange brown (10 YR. 6/6) medium textured silt loam. ? Parent material. (N.B. NO BLEACHED HORIZON IN EVIDENCE HERE)
11	Colluvial	650'	Steep slope (40°)	(NOT PLANTED) Clearing in plantation with some relict oak woodland	0" - 3" Very dark brown (10 YR. 2/2) organic layer; fairly sharp boundary. 3" - 13" Yellow orange brown (10 YR. 6/5) medium textured silt loam. Merging boundary. 13"+ Parent material.
12	Drift	650'	Small convexity	(NOT PLANTED) Small relict bog	0" - 16" Black (10 YR. 2/1) peat becoming very decomposed and amorphous with depth. Sharp boundary. 16" - ? Heavy textured, cleyed, light grey (2.5Y 6/0) silty clay, with angular shale fragments.

guess at the moment, it is hoped that this and other points raised in this paper will provoke more investigation and accommodation of the edaphic factor. The launching of long-term experiments now, commencing with a full-scale soil reconnaissance prior to planting followed by for instance quinquennial checks on soil developments till the forestry rotation is completed, would be ideal. The measured response to planted trees of these natural forest soils in Wales is likely to reflect the panorama of events, ecological and human, prehistoric and historical which have taken place on the very same sites over the last fourteen thousand years.

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MINERAL NUTRIENT RELATIONS OF TREES ON SOME WELSH SOILS.by Dr.L.Leyton

Synopsis. Since afforestation in Britain is largely restricted to marginal soils, it is not surprising to find that growth in many cases is limited by mineral nutrient deficiencies. This has been clearly demonstrated by the sometimes impressive responses in growth to the application of fertilizers, (Laurie, 1960). Phosphate trials laid down by the Forestry Commission in 1950 with Japanese larch on a number of sites in Wales, have revealed responses in height growth varying from nil (Wentwood) to over 30% (directly planted site at Brechfa). Attempts to relate these responses to soil phosphate content, however, have not proved very successful (Green and Wood, 1957). As an alternative, an investigation has been made to see whether the nutrient status of the trees themselves, as reflected in the mineral content of the foliage, would provide a better guide to the fertility of the sites, (Leyton, 1958). In the autumn of 1956, i.e., 6 years from planting, 5 trees were selected at random from each of the control and fertilized plots on 13 sites variously located over Old Red Sandstone (3), Pennant Sandstone (2), Silurian Shales (6) and Pre-Cambrian (2).

A distinct curvilinear relation was found between height increment in 1956 and the % P in the needle dry weight, independent of origin and treatment. From the points representing the mean site values for height increment and P status, it would appear that, under prevailing conditions, the larch at Tintern, Wentwood, Rheola and Brechfa (ploughed) are adequately supplied with P; pronounced deficiencies in P are indicated for the sites at Aberhirsant and Myherin.

Since tree growth is a function not only of P supply but also of other nutrients, it is also necessary to look at the data for these other nutrients.

There is a tendency for better tree growth to be associated with higher K contents of the needles; plotting the site mean values suggests that under the prevailing conditions, the larch at Rheola, Brechfa (ploughed), Wentwood and Tintern are adequately supplied with K whilst those at Glasfynydd, Aberhirsant and Myherin are deficient in this nutrient.

In the case of nitrogen there is again a tendency for better growth to be associated with higher needle contents. To a greater or lesser extent, however, almost all sites reveal some deficiency in this nutrient, with Brechfa (direct planting), Aberhirsant and Myherin possibly the most deficient.

By multiple regression analysis it is possible to treat tree growth as a function of many site factors and their interactions, (Leyton, 1960), calculations on these lines suggest that about 70%

of the variation in larch growth in these plantations can be accounted for by variations in the N, P and K status of the foliage. Generally speaking, all sites reveal deficiencies to some extent, but nutritional conditions appear to be best at Tintern and Wentwood (on Old Red Sandstone) and at Rheola (on Silurian Shale). The sites at Aberhirnant and Myherin appear to be the most deficient and at Brechfa, on unploughed ground, growth also appears to be limited by restricted nutrient uptake.

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NUTRITION PROBLEMS IN FOREST NURSERIES

(This is a summary of Miss Blanche Benzian's paper ["Nutrition Problems in Forest Nurseries", J. of So. of Food and Agriculture, 1959, No. 12, pp. 637-44] specially prepared for this memorandum.)

by Miss Blanche Benzian

Until comparatively recently the view was widely held that manurial methods developed for agricultural crops were unsuitable for young trees. Experience under two contrasting sets of conditions had led to this conclusion. In the first place conifers, especially Sitka spruce, growing in many of the older forest nurseries, failed, often in spite of poor growth, to respond to manuring. In the second place, on newly cleared heath or conifer forest land and often on poor soil, Rayner (1944) had found that young conifers grew well with liberal dressings of composts. She attributed this to an effect mainly on the mycorrhizal association and thought that the nutrient supply was relatively unimportant.

In 1944 a systematic study was initiated by Crowther, (1950 (a), 1950 (b), 1951) in co-operation with members ((Benzian 1955, 1956 (a), 1956 (b), 1957 (a), 1957 (b)); Crowther and Benzian (1952), (1953), Crowther, Warren and Benzian (1954)) of the Forestry Commission, of nutritional problems connected with these two main and sharply contrasted types of nursery sites. Sitka spruce was chosen as the main test crop since this was the species most widely used for afforesting exposed sites in Wales, Scotland and Northern England comprising at that time nearly 40% of all plantings and since also Sitka spruce was one of the most difficult of the common conifers to grow in nurseries.

About 60% of the experiments were done with one year seedlings, the remainder with transplants which had one year in the seedbed and one in the transplant lines. Results were generally the same for both. The plots in the seed bed experiments were 1 sq. yd.

Although weight might have given a better indication of yield, height was the only measurement which could be made conveniently on large numbers of plants which were to be preserved and transplanted for further observation. Height is a more useful guide to performance for Sitka spruce than it is for some of the other conifers.

On the freshly cleared nurseries on poor soil a wide range of composts with and without additional fertiliser was tested in the first year and just as with farm crops the effects of the manures were found to be closely related to the amounts of major nutrients supplied. Direct application of inorganic fertilisers to the seed bed which had previously been regarded as risky was found not to be so and thereafter systematic experiments could be planned to discover the best forms, amounts, combinations and methods of application.

NITROGEN

As with agricultural crops responses varied greatly from season to season but there were several consistent results. On acid soils there was little difference (over short periods) between the forms tested and

nitro-chalk is now recommended for regular use. However, on the neutral or near neutral soils of some of the older nurseries ammonium sulphate was far superior to either calcium nitrate or nitro-chalk, an important distinction between the two types of nurseries. Nitrogen applied before sowing occasionally increased losses through damping off and it has been better to apply soluble nitrogen fertilisers as top dressings between June and September. As the best time of application depends on the weather the normal practice now is to give two or three summer top dressings to reduce the risk of missing a critical period.

Nitrogen deficiency symptoms in conifers resemble those in other crops: the needles are pale and acute deficiency results in a pinkish discolouration in the youngest part of the plant.

Phosphorus

Responses in the very acid nurseries have been consistently high; without added phosphate Sitka spruce seedlings were often too small to transplant at the end of one season. Superphosphate, previously regarded as unsuitable for conifer seed beds, proved at least as good as slag and rock phosphate.

Neither Sitka spruce nor any of the other conifers tested showed any characteristic colour symptoms due to phosphorus deficiency apart from a slight lack of lustre.

Potassium

Before 1945 the use of potassium sulphate or chloride was considered very risky but trials showed this not to be the case except that there were some indications that heavy applications may reduce yield. Since it was thought potassium might be lost by leaching two potassium minerals, mica and glauconite sand, were tested. Mica was inactive but the glauconite was promising and, as more evidence is now accumulating of loss by leaching, it may repay further study.

Potassium deficiency symptoms in Sitka spruce are very striking. A purple colour normally begins to develop in September but can sometimes be detected in July and may then change to orange or yellow tints later in the season.

Magnesium

Height responses are uncommon; they occur oftener in wet than in dry seasons. However the brilliant yellow characteristic of magnesium deficiency develops regularly in September or October in several nurseries and applications of magnesium sulphate prevent the symptoms.

Copper

Copper deficiency has been the only trace element deficiency clearly established. The symptoms of 'needle tip-burn' vary in severity from season to season and often develop rapidly during hot spells.

Observations on neutral or nearly neutral soils

Examination of soil samples from over 100 nurseries suggested that poor seedlings and transplants resulted where the soils were neutral or only slightly acid. In many cases originally acid soils had been neutralised by the use of covers of calcareous sands or composts rich in lime. An experiment carried out at Wareham showed that after 4 years the use of a calcareous cover resulted in poor growth whilst good growth was maintained with the non-calcareous cover. Seedlings on the calcareous plots were small and stunted resembling those of the so called 'worn-out' nurseries. Experiments on the acidification of soil by such treatments as sulphur, sulphuric acid, ammonium sulphate and aluminium sulphate were not consistently successful.

In several nurseries stunting is associated with root damage by fungi and in one nursery by nematodes. Sterilising agents which were tried may owe their success in some cases to chemical changes in the soil.

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NOTES PREPARED FOR FIELD MEETING HELD IN THE CONWAY
 VALLEY, NORTH WALES ON APRIL 27th, 1960.

INTRODUCTION

The meeting is intended to illustrate woodland and soil conditions in:

- 1) A deciduous woodland which can be considered a remnant of originally much more extensive lowland woods, most of which have been cleared by man. Here there are wide soil profile differences resulting from variation in drainage on essentially the same parent material.
- 2) Some of the oldest Forestry Commission plantations of the Gwydyr forest, where tree growth of a range of conifer species and their effects on the soil profile can be seen. Here, the soil profile is essentially uniform and obvious morphological differences, after almost a 40-year growth period, are concentrated in the A horizons (the surface organic horizons).

COED GORSWEN

Coed Gorswen, near Ro Wen (SH-23) 757707 1" O.S. Sheet 107) lies between 220 and 550 feet above sea-level on the west side of the River Conway, four miles south of Conway. It consists of three blocks referred to as the Lower, Middle and Upper Woods from their position on the hill-slope, which have the following respective areas: $8\frac{1}{2}$, 12 and $12\frac{1}{2}$ acres. The average annual rainfall is probably of the order of 50 inches.

Gorswen as a whole has been woodland of some kind for a considerable period. Documentary evidence suggests that woodland has existed at Gorswen from at least the early 15th century, and Coed Gorswen is specifically mentioned by Edward Ilwyd in 1699. It is probable that the extremely bouldery and frequently very wet nature of the soil hindered early clearance. There is evidence of felling and clearance of limited areas within the present confines of the wood during the last century, stages in recovery from which can now be seen. The historical background to land-use in the N.W. Conway is discussed by R.E. Hughes (1940).

Coed Gorswen may be described in general terms as a lowland, damp mixed oakwood, the oaks of which are a hybrid population between the Pedunculate Oak (Quercus robur) and the Sessile Oak (Quercus petraea), as in many of the Conway Valley woods. Pure Pedunculate and pure Sessile oakwoods are respectively characteristic of the Midland Plain and the Western seaboard of Britain, the Conway Valley representing in some degree a western extension of the

conditions prevailing in the Midland Plain. Other tree species present in Gorswon include Elm, Ash, Alder and Birch. The ground flora is also intermediate in floristic composition between those of the two pure oakwoods. On moderately well-drained sites, it includes species commonly found in Pedunculate oakwoods, for example, Dogs Mercury (Mercurialis perennis) Wood False Brome (Brachypodium sylvaticum), Enchanters Nightshade (Circea lutetiana) and Broad Helleborine. Yellow Archangel (Galeobdolon luteum) has been recorded once from the wood (it occurs elsewhere in similar situations in the Conway Valley). Soils of impeded drainage are common and carry plant communities composed largely of sedges, Flote grass (Glyceria fluitans), Reed Grass (Phalaris arundinacea), Water Mint (Mentha aquatica), Spearwort (Renunculus flammula), March Hawks Beard (Crepis paludosa), Golden Saxifrage (Chrysosplenium oppositifolia) and Skull-cap (Scutellaria galericulata).

Of the tree species, Alder is particularly abundant on very poorly drained sites and Elm appears to be confined to the freely drained soils. The abundance of Birch in the Lower Wood may indicate a seral stage in recovery from clearance. An earlier stage of recovery is definitely found within a walled enclosure in the Upper Wood, known to have been under cultivation just over sixty years ago. Regeneration in this compartment has been hindered by grazing, but undershrub and tree vegetation is spreading. The Lower Wood, in contrast to the rest of Coed Gorswon, had been protected from grazing at least over the past 25 years and has dense shrub and undershrub layers, the former dominated by Hazel, the latter by Bramble.

PARENT MATERIAL

The solid rocks underlying Gorswon are almost certainly shales of Ordovician age, but there is a thick glacial drift cover with bedrock nowhere exposed. This drift occupying a lateral valley to the Conway is of mixed origin. Many of the large boulders are of igneous rocks, including rhyolite, dolerite and volcanic ashes. Shales are particularly important in the smaller stones and the fine material of the soil. The boulders range up to many feet in diameter and are very numerous. Their numbers is so great as to suggest a correlation of this drift with the "block-field" type of solifluction deposit such as has been described from the Erzebirge and Risengobirge (Budel, 1937; quoted in Smith, 1949). It may be that periglacial frost-heaving acting on previously ice-borne glacial drift has been responsible for the bouldery material deposited as a belt across this upland valley in the region of Coed Gorswon. Similar material occurs elsewhere, for example, between Llyn Ogwen and Capel Curig, but the

main glacial valleys of the Ogwen and Llanberis are free of such large bouldery deposits. Post-glacial modification of the surface of this material has caused local areas of erosion and deposition referred to in the soil profile descriptions, while erosion surfaces occur within some profiles.

SOIL CLASSIFICATION

Soils of Coed Gorswen and similar types on drift in the lower Conway Valley have been described by Hughes (1949). He found no visible evidence of podzolisation and little formation of surface raw humus horizons, features he found more marked on sedentary soils derived from Ordovician and Silurian sediments in the region. The degree of acidity varied from pH 4.5 to 5.7 in soils of free or imperfect drainage. Exchangeable calcium status was low although higher than that of the soils on Silurian sediments and available phosphate, especially in lower horizons and in the drift, was as much as ten times greater in Gorswen-type drift soils of the lateral valleys. The slightly higher base status is attributed to the basic volcanic rocks present in the drift and the phosphate status may also be a function of parent material.

In a more recent extensive survey of the area by D.F. Ball (in lit), Coed Gorswen falls largely into a mapping unit dominated by poorly-drained soils of mixed drift origin (Cegin-Eivion Complex). Surrounding country is transitional from soil aspects in two ways. In parent material there is a gradual transition from the almost entirely shale-derived main Conway Valley drift, giving rise to soils of the Powys suite ((e.g. Roberts, 1958; Ball, in lit (2)) to the mixed igneous and sedimentary material of the lateral valleys, giving rise to Arvon and related soils (Roberts, 1958). The transition is gradual, and the boundary, located close to Gorswen on the Soil Survey map, is thus somewhat arbitrary. There is evidence from Ro Wen, one mile north of Gorswen, that mixed igneous drift overlies dominantly shale material. There is also a transition from the Brown Earth of rather uniform soil colour, mull humus and well-dispersed organic matter to a Brown Podzolic profile, of strongly acid moder surface humus, bright coloured sub-surface horizons and typically a higher level of readily-extractable Fe_2O_3 . The freely-drained soils in Gorswen are transitional between these two groups. Sharp diagnostic criteria for their separation have not yet been worked out. Whereas on the Continent Brown Earths are subdivided, the freely trained soils of Gorswen would probably be grouped as Oligotrophic Brown Earths. Brown Podzolic soils are mapped in this locality as the Manod Complex, and the Brown Earth on parent material dominated by shale, as the Denbigh series.

Detailed survey of the Reserve (Coed Gorswen) showed that although it is correct to describe most of the wood as dominated by gleyed soils, there exists a range of drainage conditions from free to very poor. Five main soil types were differentiated, corresponding to those generally described from the region by Hughes and Ball in the previously quoted studies. These were classified as:-

- a) Brown Earth (freely-drained)
- b) Brown Earth with gleying (imperfectly-drained)
- c) Non-calcareous gley (poorly-drained)
- d) Peaty gley (very-poorly drained)
- e) Peaty mud (very-poorly drained)

Some modifications of this outline are described below in the detailed soil descriptions. From this outline the distribution of these soils was mapped by Mr. J. Williams, a Cambridge student, and he opened the profile pits which are to be seen as representative of these main soils. The Lower Wood includes some freely drained soils on the southern fringe and also areas of Gley, but is dominated by imperfectly-drained soils. The Middle Wood is sharply divided at a marked change of slope into Brown Earth in the upper half and Brown Earth-with-gleying in the lower portion. The Upper Wood is in the southern half a complex of poorly-and very-poorly-drained soils, while the northern half is dominantly imperfectly-drained. A small area on the north east and a larger central sector are freely-drained. The analytical data show the moderately acid nature of the soils, with the typical higher values for pH and base-status in soils of poorer drainage. The freely-drained soil shows a marked concentration of calcium (Ca) and potassium (K) in the surface horizon resulting from organic matter breakdown.

WATER RELATIONSHIPS

When sampled in August, 1959, after prolonged drought, Soil Pit No. 1 (Brown Earth) was dry, as were most areas of the imperfectly drained soils. The "peaty gley" was moist throughout, the non-calcareous gley moist to wet and the "peaty mud" wet throughout.

Re-examination in February and March 1960 after winter rains showed a consistent level of standing water or moisture conditions in the pits.

- a) Brown Earth; no standing water, moist throughout.
- b) Brown Earth with gleying; water ran into the pits at about 15 inches depth, but none stood.

- c) Non-calcareous Gley; water stood at 4 inches below ground level.
- d) "Peaty Gley"; water stood at 4 inches below ground level.
- 3) "Peaty mud"; water stood at ground level.

There is in parts of the wood a clear relation of relief to drainage but often this is not so. Both water movement through the soil and in an intricate stream network is of considerable interest especially in the wet areas of the Upper Wood.

DESCRIPTION OF PIT PROFILESa) Brown Earth.

As has been remarked, the wood is on the fringe of a mapped boundary between the Brown Earth and Brown Podzolic soils. In the latter, acid humus overlies a bright orange brown mineral soil of higher content of mobile iron oxide than in the typical Brown Earth and the freely-drained soils of this wood are somewhat arbitrarily placed in either of these groups.

Gorswen 1: Sampled in the Upper Wood on a uniform bouldery 5 - 10° slope, profile drainage free, site drainage normal.

Profile:

- 0 - 1" Black fibrous moder humus, sharp boundary to
- 1 - 2" Very dark brown (10 YR 3/4) silty loam of crumb structure and friable consistency bound by abundant roots; fairly sharp boundary to
- 2 - 5" Brown to dark brown (10 YR 4/3) silty loam of moderate cloddy structure and friable consistency; fairly sharp boundary to
- 5 - 24" Strong brown (7.5 YR 5/7) silty loam with frequent small stones to large boulders, of many types including volcanic ash; moderate crumb structure, roots frequent above, becoming rare at 2 feet depth, colour pale yellow-brown at this depth; not sampled for full analysis.

b) Brown Earth with Gleying.

Two variants of this soil have been mapped, one over a soft gleyed subsoil, the other over hard indurated drift. The former (Gorswen 6) is comparable to the Sannan Series, the latter (Gorswen 5) to a deep phase of the Eriyat Series. (Series formed on purely shale drift in contrast to the mixed origin material of Gorswen.) Profile data for soils of this type are given in Hughes, 1949 (p.317).

Gorswen Soil Pit No.6: Sampled in lower part of Middle Wood on 3° uniform slope, imperfect profile drainage, receiving (a) site drainage.

Profile: Thin surface litter, no marked organic surface.

- 0 - 9" Dark grey brown (10 YR 4/2) silty loam with occasional rounded stones; moderate crumb structure; earthworms present; merging boundary to

- 9 - 14" Dark grey brown (2.5 Y 4.5/2) silty loam with dull mottling of yellow; weak cloddy structure; moderately friable; sharp boundary to
- 14 - 18" Light olive brown (2.5 Y 5/3) mottled with grey and yellow silty clay loam with many stones, often weathered shale; structureless and sticky when wet.

Gorswen Soil Pit No.5: Sampled near upper boundary of Lower Wood on gentle uniform slope of 3 - 8°. Profile drainage imperfect. Site drainage normal.

Profile:

- 0 - 1½" Dark brown (7.5 YR 3/2) silty loam with occasional small to medium rounded stones; strong crumb structure; friable; abundant roots; fairly sharp boundary to
- 1½ - 7" Dark grey brown (10 YR 4/2.5) faintly mottled with grey, silty loam; moderate to strong large and small cloddy structure; poorly friable; abundant roots; merging boundary to
- 7 - 15" Grey brown (10 YR 5/2.5). As above with weak cloddy structure; frequent millipedes; sharp boundary to
- 15" + Grey brown (2.5 Y 5/2) indurated stony silty loam drift with abundant stones of varied type including Pumice-tuff ashes; structureless; poorly porous; hard massive consistency; very rare roots; water flowing at drift surface.

c) Non-Calcareous Gley:

Gorswen Soil Pit No.4: Sampled in Lower Wood on a uniform gentle slope of about 5 - 8°. Poor profile drainage, normal site drainage. This soil is close to the Cegin Series mapped on drift derived purely from shale and other sedimentary rocks of Ordovician and Silurian age.

Profile: Note: The sampling here was after severe summer drought, but the soil was moist to wet throughout.

- 0 - 1" Root and litter mat.
- 1 - 4" Dark brown (7.5 YR 3/2) with some rusty mottle along root channels, silty loam; stoneless; weak, medium crumb structure; sticky; frequent roots; sharp boundary to
- 4 - 16" Grey brown (10 YR 5/2) with rusty root channels, silty loam to silty clay loam, stoneless; moderate

- to strong cloddy breaking to weak crumb; poorly friable; frequent roots; sharp boundary at horizon of large boulders representing an old erosion surface to
- 16 - 36" Yellowish brown (10 YR 5/4) with blue-grey and reddish mottling, silty clay loam of stony drift; moderate cloddy structure, poorly friable; rare roots; merging boundary to
- 36" + Grey to grey brown (2.5 Y 5/1-5/2) silty loam massive drift with abundant stones of varied types; no roots.

d) Peaty Gley:

This soil was provisionally classified as a peaty gley of very poor drainage. Later examination has shown this to be not the case. The only moderately organic surface horizon of moder humus is of good crumb structure compared to the black amorphous A_o horizon of true peaty gley, while the water level in the pit in a wet month is of the same order as in the Brown Earth-with-Gleying profile pits, much lower than in those of the Gley and Peaty Mud. The true character of the soils in this mapping unit require further study, but they may be of the nature of a recent soil forming on a surface from which material has been eroded to be re-deposited in lower areas.

Gorswen Soil Pit No.3: Sampled in Upper Wood above walled enclosure, on a bouldery 5° slope with a change to steeper slopes shortly above the sampling site. Profile drainage poor and site drainage receiving (a).

Profile:

- 0 - 7" Dark grey-brown to grey-brown (10 YR 4/2-5/2) organic silty loam; medium crumb structure; friable; abundant roots; fairly sharp to
- 7 - 10" Dark brown (7.5 YR 3/2) stony silty loam; massive compact structure; sharp boundary to
- 10 - 24"+ Grey (2.5 Y 6/1) mottled with blue-grey and reddish colours; silty loam; abundant stones; rather structureless, poorly porous drift.

e) Peaty Mud:

Areas in which very wet, dark brown, muddy organic soils occur, mainly among large boulders, are mapped under this name. Analyses show that the organic matter content is not in fact as high as field estimation indicated and that it does not strictly justify

classification as an organic soil. This unit is probably closer to a true peaty gley, greatly disturbed by cattle trampling. There may possibly be springs to account for at least some areas of this soil.

Gorswen Soil Pit No.2: Sampled in Upper Wood on bouldery but quite regular 5° slope with steeper slope shortly above the sampling site. Profile drainage very poor and site drainage receiving (a). Sampled during drought, but wet throughout.

Profile:

- 0 - 1½" Organic mat of plant litter and roots.
- 1½ - 6" Dark reddish brown (5 YR 2/2-3/2) organic silty clay loam, stoneless, structureless; soft and sticky; few roots; fairly sharp boundary to
- 6 - 24" Dark reddish grey (5 YR 3/2-4/2) similar to above; organic residues largely undecomposed; merging boundary to
- 24" + Dark grey brown (10 YR 4/1-4/2) very stony, silty loam - otherwise as above.

TABLE I
Soil Analyses from Coed Gorswen.

Profile and Horizon:	pH	Organic Carbon:	meq. Ca per 100 gm.	meq. K 100 gm.	mgm. P ₂ O ₅ 100 gm.
<u>Gorswen 1.</u>					
Brown Earth					
0 - 1"	4.5	21.60	5.2	1.24	1.60
1 - 2"	4.9	8.00	0.2	0.18	1.16
2 - 5"	4.8	4.00	0.2	0.10	0.80
5 - 24"	5.3	-	-	-	-
<u>Gorswen 6.</u>					
Brown Earth with gleying					
0 - 9"	6.5	3.12	3.6	0.40	1.48
9 - 14"	6.2	2.32	2.0	0.25	1.00
14 - 18"	5.9	0.92	1.6	0.15	1.20
<u>Gorswen 5.</u>					
Brown Earth with gleying					
0 - 1½"	4.7	9.80	2.0	0.60	1.64
1½ - 7"	4.9	3.50	0.3	0.28	1.24
7 - 15"	5.3	2.56	0.2	0.20	0.88
15" +	5.2	1.20	0.2	0.15	1.24
<u>Gorswen 4.</u>					
Non-Calcar- eous Gley					
1 - 4"	4.6	8.20	2.0	0.30	1.40
4 - 16"	5.4	2.90	0.4	0.12	1.00
16 - 36"	5.8	0.40	1.6	0.04	0.40
36" +	5.8	0.80	4.0	0.08	14.00
<u>Gorswen 3.</u>					
"Peaty Gley"					
0 - 7"	5.1	10.80	3.0	0.30	1.00
7 - 10"	5.4	9.80	3.0	4.45	1.44
10 - 24"	5.4	1.12	2.2	0.10	6.40
<u>Gorswen 2.</u>					
"Peaty Mud"					
0 - 1½"	5.1	18.40	7.0	0.50	1.24
1½ - 6"	5.3	14.40	6.8	0.10	0.72
6 - 24"	5.3	9.20	4.2	0.06	0.88
24" +	5.9	5.00	4.2	0.06	2.60

GWYDYR FOREST: PLANTATIONS IN COED DIOSGYDD

This sector of the Gwydyr estate was acquired in 1920, the areas covered by this tour having been planted:

- a) Above the Diosgydd Road in 1921, 104 acres.
- b) Below the road in 1927, 14 acres.

General Site Description

Location: Immediately west of Bettws-y-Coed (centre approximately SH(23)780573, O.S. 1" map sheet 107).

Rainfall: About 55 inches per annum.

Slope: Irregular terraces varying from 7 to 20° slope.

Elevation: 150 to 300 feet.

Aspect: South, moderately exposed.

Previous land-use: The greater part of the area was formerly broadleaved oak high forest with scattered larch and spruce, clear-felled in 1914-1918. Site 4 (below) was a cultivated paddock belonging to the cottage, Gallt-y-Rhiw. Local information is that the last tenant lived there over 100 years ago, the oldest local inhabitant of 83 years having no memory of it inhabited. The paddock was cultivated for potatoes and was noted for its early crop. The paddock is thought to have been first planted with trees in the Forestry Commission plantings 39 years ago.

After felling, the vegetation was mainly bracken and grass, with gorse higher up the slope on shallow rocky soils. There was scattered Oak, Beech, Sycamore and Birch coppice.

Forestry Commission plantings: The basic principles governing choice of species are ground flora as soil indicators and the side exposure. Based on this, Douglas Fir (Pseudotsuga taxifolia) was planted on lower valley slopes and on the firmer soils of the valley bottom. Rising up the glaciated valley slope as more exposure was encountered, European Larch (Larix europea) was planted in the the early 1930's, later replaced by Japanese Larch (Larix leptolepis). On the rocky lip of the valley and on dry peaty plateau moorland sites Scots Pine (Pinus sylvestris) was formerly used and now more commonly Lodgepole Pine (Pinus contorta). Spruces are planted on wet peaty sites, Sitka Spruce (Picea sitchensis) in exposed situations and Norway Spruce (Picea excelsa) in sheltered but frosty sites. In Coed Diosgydd the opportunity was taken in these early plantings to test a wider range of species and some of these are covered by the plots to be visited. Silvicultural treatment has been the standard Forestry Commission practice. Transplants were mattock-planted at 5 ft.x 5 ft. spacing, with weeding as required until the plants were established. Thinning commenced

TABLE NO. 2

Growth and Yield Data for the Species at Diosgydd, Gwydyr.

Species	Age of stand	Age when assessed	No. of stems per acre.	Top height ft.	Average girth b.h.g. g.o.b. ins.	Basal area sq.ft.	Volume per acre over bark cu.ft.	Yield to date from thinning per acre cu.ft.	Total yield to date cu.ft.	Periodic annual increment cu.ft. ac/a	Mean annual increment cu.ft./acre per annum	REMARKS
Japanese Larch	38	38	210	73	98	98	3500	1200	4700	-	124	Quality class 1 site 2. Underplanted with Tsuga heterophylla in 1950.
Sitka Spruce Japanese Larch Total	38 38	38 38	150 30 <u>180</u>	87 80	11½ 10	135 21 <u>156</u>	5500 800 <u>6300</u>	1600 <u>1600</u>	7900 <u>7900</u>	-	208 <u>208</u>	Planted as alternate row mixture. Last thinned 1957. Thinning yields estimated.
Douglas Fir	38	38	230	78	8¾	125	4400	1600	6000	-	158	Last thinned 1957. Total thinnings estimated.
Corsican Pine	38	36	283	61	8	134	3590	2047	5637	246*	156	* Over 5½ year period between June 1951 and January 1957.
Western Hemlock	32	30	359	65	6¾	112	3130	1808	4938	283*	164	* August 1959 - January 1957 Over 2 year period.
Abies Procera	32	30	599	48	8	150	2970	685	3655	268*	114	* 2 year period September 1954 - January 1957.

when the stand was about 25 to 30 ft. in height, essentially a low thinning, light in the early years but heavy to moderately heavy over the last 10 years or so. The thinning cycle is 3 years, the Diosgydd Bank being last thinned in 1957 when an average of 600 cu.ft./acre was taken out. Table No.2 on page 10 gives growth and yield data by species.

GENERAL SOIL CHARACTER.

The soils of this wood are in the Soil Survey mapping unit of Cymmer-Peris complex (Ball, in lit.) and would be classified as Cymmer series. These are freely-drained soils occurring on steep slopes, developed on drift or colluvial parent material from Ordovician or Silurian shale. In this locality, the rocks are Ordovician in age and dominantly sedimentary of shale type within the wood. There is some mixture, particularly where drift occurs on the lower slope, from igneous rocks and volcanic ash, but the dominant influence is shale. In comparison with the freely-drained soil of Coed Gorswen these soils are in general more strongly of Brown Podzolic character, viz. freely-drained strongly acid with mor or moder surface horizons, relatively high, readily available iron oxide, giving soil colours typical of a podzol B horizon, but without a bleached A₂ horizon typical of a fully developed podzol profile. These soils are of the type described by Professor G.W.Robinson and his colleagues (Robinson et al, 1949) as truncated podzols with the suggestion that their character was a result of erosion of incipient A₂ horizons. This does not seem to be applicable in all cases and the nature genesis and relation of these soils to Low base status (Oligotrophic) Brown Earth and to Peaty Podzol is under investigation by a number of workers in Britain and abroad. The Cymmer soil is very widespread in Wales, the English Lake District and the Southern Uplands of Scotland. It is of particular importance to foresters, since the steep slopes are not generally suitable for agriculture. Several of the woodland Reserves of the Nature Conservancy in Wales are on this general soil type. The tour of plantations of different species planted on this site is designed to show tree growth, variations in ground flora and morphological differences in organic horizons of the soil profile under each species. Analytical data given are based on single spot samples only and may not therefore be representative. They do, however, correlate well with expectation and with unpublished data of Dr. J.D.Ovington, who included work in these woods in his extensive survey some years ago of conditions on many sites under various

tree species. The general profile is seen at sites 1, 5 and 6. Elsewhere, surface horizons only are considered. Analyses for site 1 are by Soil Survey of England and Wales, Rothamsted Experimental Station, at other sites, by the Nature Conservancy, Bangor.

SITE I.

Profile on verge of forestry road, weak bracken and moss ground flora at margin of Douglas Fir (Pseudotsuga taxifolia), planted 1921.

- 0 - 1" very dark brown (10 YR 2/2) gritty organic loam to sandy loam of moder type with dominantly shale stones and occasional acid igneous; very weak crumb structure; porous; friable to loose when freed from root mesh; very high organic matter; abundant roots; occasional earthworms seen; sharp boundary to
- 1 - 5" Yellowish brown (10 YR 5/6) loam with abundant stone; weak small crumb structure; friable to loose; moderate to high organic matter; frequent roots; occasional earthworms; fairly sharp boundary to
- 5 - 22" Strong brown (7.5 YR 5/8) loam with frequent medium and large stones; very weak small crumb structure; porous; friable to loose; dark organic staining on stones; fine roots particularly as webs around stones; fairly sharp boundary to
- 22 - 30" Yellowish brown (10 YR 5/8) fine sandy loam with abundant stones; structureless; loose; rare roots.

Analysis:

	<u>0-1"</u>	<u>1-5"</u>	<u>5-22"</u>	<u>22-30"</u>
Moisture loss 100-150°	4.3	3.7	6.5	4.0
Silt (American)	35.0	40.0	28.0	46.0
Silt (International)	20.0	32.0	30.0	32.0
Clay	12.0	13.0	7.0	5.0
Organic Carbon	16.2	7.8	8.1	5.0
pH (1.2.5. Soil:Water)	4.3	4.8	4.9	5.1
Exch. Ca meq/100 gm	2.3	0.6	0.3	0.5
" Mg "	-	0.3	0.3	0.2
" K "	0.66	0.13	0.06	0.04
" Na "	-	0.15	0.15	0.13
Cation Exchange Capacity	-	20.2	25.2	13.3
Per Cent Saturation	-	5.0	4.0	6.0
Free Fe ₂ O ₃ (Deb's method)	2.3	2.9	4.1	2.5

(Note: Profile descriptions of Sites 2 to 11 are of Upper horizons only, except for Site 6).

SITE 2.

Japanese Larch (Larix leptolepis), planted 1921, underplanted with Western Hemlock (Tsuga heterophylla) in 1950. Part of this plot intersected with drainage ditches is of receiving site drainage and imperfect profile drainage, but the upper part is basically similar to the general soil of the area.

- 0 - 2" Black (10 YR 2/1) needle litter with abundant bramble and ground ivy roots and stones.
- 2 - 4" Very dark brown (10 YR 2/2) very loose fluffy mor humus of very small crumb structure.
- 4" + Brown (7.5 YR 5/4-10 YR 5/4) loam to fine sandy loam; moderate small cloddy and small crumb structure.

Analysis:

	<u>0-2"</u>	<u>2-4"</u>	<u>4"+</u>
pH	4.6	4.0	4.7
Exch. Ca. meq/100 gm	15.0	7.3	0.6
" K " "	2.0	1.0	0.3
Available P ₂ O ₅ mgm/100gm	3.88	1.28	0.4

SITE 3.

Sitka Spruce - Japanese Larch (Picea sitchensis - Larix leptolepis) mixture, planted 1921. The position of this sector of the wood below Gallt-y-Rhiw ruin and paddock may indicate a less continuous woodland history than elsewhere on the Diosgydd bank but no evidence has been found of this. The relatively high lime status and pH, with a low litter and moder humus accumulation is similar to site 4. No detailed examination for parent material differences have been made but none were obvious on inspection.

- 0 - $\frac{3}{4}$ " Dark brown (10 YR 2/2) needle litter under moss and scanty grass ground flora.
- $\frac{3}{4}$ - $1\frac{1}{2}$ " Very dark grey brown (10 YR 3/3) moder to mull-like moder organic matter; moderate medium cloddy and crumb structures.
- $1\frac{1}{2}$ - 4" Brown to dark brown (10 YR 4/3) stony loam of moderate crumb structure.

Analysis:

	<u>0-$\frac{3}{4}$"</u>	<u>$\frac{3}{4}$-$1\frac{1}{2}$"</u>	<u>$1\frac{1}{2}$-4"</u>
pH	5.0	5.2	5.3
Exch. Ca meq/100 gm	12.6	5.7	3.0
" K " "	1.6	0.9	0.68
Available P ₂ O ₅ mgm/100gm	1.48	0.8	0.44

SITE 4.

In small paddock at ruins of Gallt-r-Rhiw, Douglas Fir (Pseudotsuga taxifolia) planted 1921. The Brown Earth character of an old cultivated soil is seen in colour, structure, organic matter type and analytical figures. The very high phosphate level is notable.

- 0 - $\frac{1}{4}$ " Black needle litter under similar vegetation to site 3.
- $\frac{1}{4}$ - 1" Very dark brown (10 YR 2/2) moder to mull-like moder organic matter. Moderate small crumb structure.
- 1 - 12" Dark brown (10 YR 3/3) loam of strong medium crumb structure.
- (12" + Dull yellow brown silty loam)

Analysis:

	<u>0-$\frac{1}{4}$"</u>	<u>$\frac{1}{4}$-1"</u>	<u>1-12"</u>
pH	4.6	4.6	5.1
Exch. Ca meq/100 gm	10.8	3.3	2.2
" K " "	6.3	0.58	0.36
Available P ₂ O ₅ mgm/100gm	3.08	7.56	7.56

SITE 5.

Cleared sections along track of Brown Podzolic character under Douglas Fir (Pseudotsuga taxifolia). The sections show a) loose colluvial material, and (b) more compact drift below large protecting boulder, uphill from which is a build-up due to soil creep and colluvial action generally. Together with Site 1 and Site 6, these sections show the general uniformity of soil along this bank.

Below boulder:-

- 0 - 2" Black (5 YR 2/1) moder bumus of very small structure.
- 2" + Strong brown (7.5 YR 5/6) stony silty loam, somewhat compacted from 24 ins.

Analysis:

	<u>0-2"</u>	<u>2-12"</u>
pH	4.2	4.5
Exch. Ca meq/100 gm	0.4	0.4
" K " "	0.42	0.04
Available P ₂ O ₅ mgm/100gm	0.8	0.8

SITE 6.

Douglas Fir (Pseudotsuga taxifolia) planted 1921. The bare ground surface under this very shade-producing tree is a sharp contrast to that of Site 7, under Corsican Pine. The pit shows the typical "Brown Podzolic" profile type overlying drift, rather than colluvium in this site.

- 0 - $\frac{1}{4}$ " Needle litter.
- $\frac{1}{4}$ - 2" Black (5 YR 2/1) moder humus. Weak cloddy and moderate small crumb structure.
- 2 - 18" Strong brown (7.5 YR 5/6-5/8) loam to silty loam of weak small crumb structure.
- 18" + Light yellow brown (10 YR-2.5Y6/4) stony loam, slightly weathered drift.

Analysis:

	<u>$\frac{1}{4}$-2"</u>	<u>2-18"</u>	<u>18"+</u>
pH	4.3	4.5	4.6
Exch. Ca meq/100 gm	1.7	0.5	0.5
" K " "	0.32	0.1	0.02
Available P ₂ O ₅ mgm/100gm	0.92	0.52	0.68

SITE 7.

Corsican Pine (Pinus nigra, var. calabrica), planted 1921. The high amount of light permitted through the canopy of this species allows a grass and bracken ground flora to flourish. Higher levels of exchangeable Ca and K occur in the surface horizons compared to those of Site 6, probably attributable to a more rapid turnover of nutrients encouraged by the grassy ground flora. Regeneration is seen in this plot of Douglas Fir derived from adjoining plots.

- 0 - 1" Black (5 YR 2/1) loose fluffy litter with abundant roots.
- 1 - 2" Black (5 YR 2/1) moder humus; somewhat compact initially, breaking to crumb structures.
- 2" + Strong brown (7.5 YR 5/6) loam, moderate small cloddy and crumb structures.

Analysis:

	<u>0-1"</u>	<u>1-2"</u>	<u>2"+</u>
pH	4.3	4.2	4.7
Exch. Ca meq/100 gm	4.3	3.0	0.6
" K " "	1.6	0.7	0.16
Available P ₂ O ₅ mgm/100gm	2.12	0.92	0.4

SITE 8.

Western Hemlock (Tsuga heterophylla) planted 1927.

- 0 - 2" Dark red brown (5 YR 2/2) laminated felted raw humus of needle litter.
- 2 - 4" Black (5 YR 2/1) felted raw humus, matted by very strong tree root development. ($\frac{1}{4}$ " dull grey brown micro-podzol type A₂ horizon locally developed)
- 4" + Strong brown (7.5 YR 5/6) silty loam of moderate to strong cloddy structure.

Analysis:

	<u>0-2"</u>	<u>2-4"</u>	<u>4"+</u>
pH	3.8	3.9	4.5
Exch. Ca meq/100 gm	1.8	0.6	0.2
" K " "	1.6	1.06	0.06
Available P ₂ O ₅ mgm/100gm	1.76	2.28	0.68

SITE 9.

Silver Fir (Abies procera), planted 1927.

- 0 - 2" Dark red brown (5 YR 2/2) fibrous
felted raw humus.
- 2 - 2 $\frac{3}{4}$ " Black (5 YR 2/1) moder humus, felted
but breaking to small crumb.
- 2 $\frac{3}{4}$ " + Strong brown (7.5 YR 5/6) loam; mod-
erate small cloddy and crumb structure.

Analysis:

	<u>0-2"</u>	<u>2-2$\frac{3}{4}$"</u>	<u>2$\frac{3}{4}$"+</u>
pH	3.4	4.4	4.4
Exch. Ca meq/100 gm	1.8	0.5	0.4
" K " "	1.2	0.42	0.14
Available P ₂ O ₅ mgm/100gm	1.96	0.8	0.44

SITE 10.

A small grove of Sequoia (Sequoia sempervirens).

- 0 - $\frac{1}{2}$ " Litter
- $\frac{1}{2}$ - 2" Black to very dark brown (10 YR 2/1-2/2)
moder humus of small cloddy structure.
- 2" + Brown to strong brown (7.5 YR 5/4-5/6)
silty loam of moderate crumb structure
with abundant roots.

Analysis:

	<u>$\frac{1}{2}$-2"</u>	<u>2"+</u>
pH	4.6	4.8
Exch. Ca meq/100 gm	5.4	0.4
" K " "	0.90	0.24
Available P ₂ O ₅ mgm/100gm	1.32	0.8

SITE 11.

Remnant of young deciduous scrub (oak, birch, hazel).

- 0 - 1" Dark brown (10 YR 3/3) loam of very small
crumb structure and loose consistency,
high organic matter content, mull type.
- 1 - 3" Dark yellow brown (10 YR 3/4) loam,
strong crumb structure.
- 3" + Strong brown to brown (7.5 YR 5/6-5/4)
loam of moderate crumb structure.

Analysis:

	<u>0-1"</u>	<u>1-3"</u>	<u>3"+</u>
pH	4.8	4.8	4.7
Exch. Ca meq/100 gm	5.0	0.2	0.4
" K " "	1.38	0.60	0.16
Available P ₂ O ₅ mgm/100gm	1.88	1.08	0.52

TABLE IIINature and Depth of Organic Horizons

<u>Depth of highly organic horizons</u>	<u>Dominant type of organic matter</u>	<u>Site No. and tree species</u>
0 - 1"	Mull	Site 11 (Deciduous scrub)
	Moder to mull-like moder	Site 4 (Douglas fir in old paddock)
	Moder	Site 1 (Margin of Douglas fir)
1 $\frac{1}{4}$ - 2"	Moder to mull-like moder	Site 3 (Japanese larch/Sitka spruce mixture)
	Moder	Site 5 (Douglas fir)
	Moder	Site 6 (Douglas fir)
	Moder	Site 7 (Corsican pine)
	Moder	Site 10 (Sequoia)
2 $\frac{1}{4}$ - 3"	Mor-moder	Site 9 (Silver fir)
3 $\frac{1}{4}$ - 4"	Mor	Site 2 (Japanese larch)
	Mor	Site 8 (Western hemlock)

[Definition: Mor - raw humus with no mineral admixture.
 Moder - highly organic but with mineral material subordinate, not in intimate mixture.
 Mull-like moder - highly organic but moderately intimately mixed mineral matter.
 Mull - completely intimately mixed mineral and subordinate organic matter.]

TABLE IVAcidity of Organic Horizons

<u>Mean pH of highly organic horizons</u>	<u>Type of organic matter</u>	<u>Site No.</u>	<u>Tree species</u>
5.1	Moder - mull-like moder	3	Japanese larch/Sitka spruce
4.8	Mull	11	Deciduous scrub
4.6	Moder - mull-like moder	4	Douglas fir (paddock)
4.6	Moder	10	Sequoia
4.55	Moder	1	Douglas fir (margin)
4.3	Mor	2	Japanese larch
4.3	Moder	6	Douglas fir
4.25	Moder	7	Corsican pine
4.2	Moder	5	Douglas fir
3.9	Mor-moder	9	Silver fir
3.85	Mor	8	Western hemlock

These two tables give a general indication of the relations on this site of tree species to type and depth of organic accumulation horizons and to the pH of these horizons (with the qualifi-

cation previously made that pH, etc. was only based on a single spot sample here). The acidity order corresponds generally to the features shown in more extensive work (e.g. Ovington and Madgwick 1957), which includes a table giving the average pH over the whole rooting depth for a number of species from Gwydyr. Here the order of decreasing pH for species also considered in Table 4 above is Oak, Corsican Pine, Silver Fir, Douglas Fir, Western Hemlock.

NOTE: The material from which this handout is derived, except where specific references are given, is otherwise unpublished data of D.F.Ball, R.E.Hughes and W.A.Lindsay-Smith. The Gorswen work is within a comprehensive programme of work on soils and ecology in Snowdonia and other parts of Wales being carried out by The Nature Conservancy under Dr.R.E.Hughes. I am grateful for discussion with Dr.B.Seddon on aspects of the Gorswen material. Permits for visits to Coed Gorswen are required and may be obtained from the Regional Officer, Dr.B.Seddon, The Nature Conservancy, Y Fron, The Crescent, Bangor.

(See references overleaf p. 49)

D.F.BALL

April 1960.

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