SOILS OF SNOWDON

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The physical background and a description of the soils of the Snowdon massif (Caernarvonshire, North Wales) are given.

CONTENTS

I. INTRODUCTION

THE Snowdon massif in Caernarvonshire, North Wales, centres on Yr Wyddfa* (grid reference SH 610544, O.S. 1 inch to 1 mile Sheet 107), which, at 3,561 ft. (1,168 m.) O.D., is the highest peak in England and Wales. Four thousand one hundred and fifty acres (1,680 ha.) of this mountain group, including the valleys of Cwm Dyli, Cwm Merch and Cwm y llan, have been declared as the *Y Wyddfa—Snowdon National Nature Reserve*, under Nature Reserve Agreements reached with the landowners. The boundaries and main features of the Reserve are shown on a sketch-map (Fig. 1).

Snowdon has been the centre of classic geological studies (e.g. Ramsay, 1860, 1866; Williams, 1927), but neither a detailed investigation of glacial geology nor any map or general account of the soils of Snowdon has previously been published. Brief references, however, are given in the booklets; *Cwm y Llan Nature Trail* and *The Miners Track* (The Nature Conservancy, 1966, 1968). Data for soils on Bedded Pyroclastic rocks have been given by Hughes (1958) and analyses contrasting one of these soils with one on rhyolite-dominated glacial drift are given by Hughes, Milner and Dale (1964).

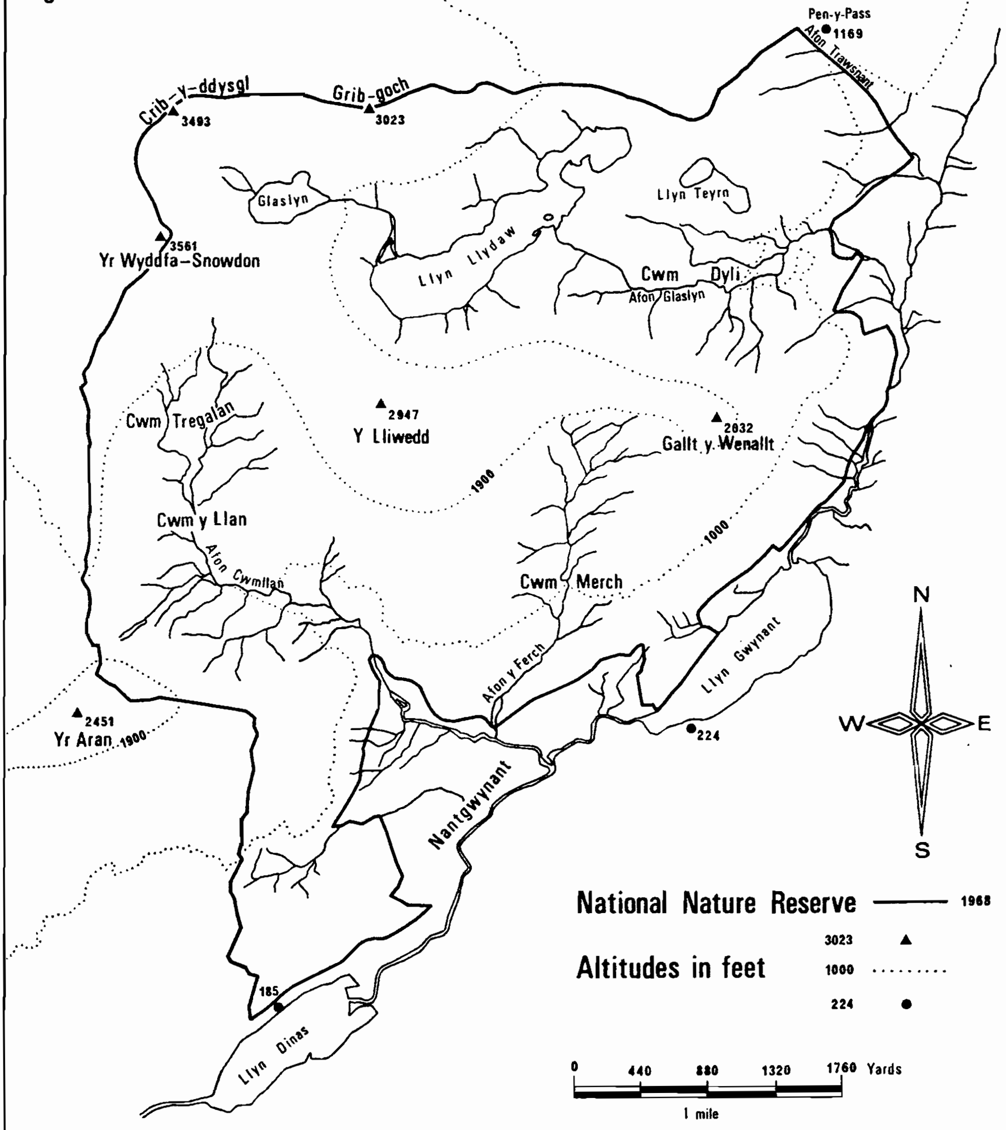
II. THE PHYSICAL BACKGROUND

(1) *Solid Geology*

The synclinal structure of Snowdon was recognized as early as 1831 by Sedgwick on his visit to North Wales (cited in Williams (1927, p. 347). Thirty-five years later, Ramsay's Geological Survey memoir was published (1866), and the information given in this has formed the basis for all subsequent work. Later studies culminated

* Spelling of place names follows Ordnance Survey practice throughout.

Fig. 1 Locations & Relief



in a comprehensive account of the geology of the district between the Llanberis Pass, Nantgwynant and the Gwyrfai valley (Nant-y-Betws), by Williams (1927) incorporating a geological map and a generalized map of the superficial deposits, together with petrographic descriptions and structural interpretations. This remains the key work in its field, and the following summary is based on it.

The rocks of the Reserve are of Ordovician age, with the possible exception of the intrusive dolerite. The Ordovician period was one of intense volcanic activity so that lavas and ashes comprise a large part of the area. Igneous rocks of different types occupy the whole of Cwm Dyli and Cwm Merch and a large part of Cwm y llan, but, in the latter, sedimentary rocks also outcrop.

Williams' (1927) succession is as follows, beginning with the youngest strata:

Upper Rhyolitic Series	– Acid lavas and ashes.
Bedded Pyroclastic Series	– Iron and magnesium rich ashes, including calcareous pumice-tuffs, with subordinate rhyolitic rocks.
Lower Rhyolitic Series	– Acid lavas and ashes.
Gwastadnant Grit.	
Llandeilo Slate.	

This sequence was intruded by igneous rocks of two types:

Acid Intrusive Rocks	– Fine grained quartz-felspar rocks.
Dolerites	– Fine to medium grained basic rocks, relatively high in iron, magnesium and calcium.

The Ordovician rocks of Snowdonia were subjected to intense crustal folding during the Caledonian earth-movements which acted generally in a south-easterly to north-westerly direction against the stable Pre-Cambrian mass of Anglesey. Snowdon is in the centre of a major downfold, the Snowdon syncline, the structure of which is best seen in the Reserve on the western face of Cwm y llan and Cwm Tregalan. Bedded Pyroclastic Series rocks, which are among the softest in the area, form the core of the Snowdon syncline, and comprise the summits of Yr Wyddfa and Crib-y-ddysgl, probably because compressed rocks in such situations have greater resistance to erosion than those stretched on the crests of anticlines.

Slate was formerly extracted from the South Snowdon quarry in Cwm y llan, and lead, copper and zinc have been mined in the three valleys. The location and history of the copper mines of the Snowdon area are summarized by Neill and Neill (1963).

(1a) *Rock Chemistry*

Available chemical analyses of rocks from the Reserve are given in Table 1 (part A from data in Williams (1927) and part B from partial analyses made at Bangor). The data given can only be taken as indicative of broad trends in composition since there is considerable variation within the rock groups, especially in elements such as calcium and potassium which are important to soil chemistry and plant nutrition.

The pumice-tuffs have high contents of iron and magnesium, mostly in micaceous minerals of the chlorite group (Ball, 1966*b*), relatively low silica and potassium, and variable calcium. Higher levels of the latter element, for example in sample A452, are due to calcium carbonate filled vesicles, but where these are absent or have weathered out, calcium is quite low.

Rhyolites are composed mainly of quartz and alkali felspars, so that they contain a high proportion of silica with relatively high potassium and low iron, magnesium, and calcium contents.

Dolerites contain intermediate levels of silica and have more in common chemically with pumice-tuffs than with rhyolites. The Snowdon dolerites have higher potassium and lower calcium levels than are generally typical of this rock type. Calcium is present in calcium silicates, rather than in the carbonate form.

The rate of weathering of rocks is influenced by the relative arrangement of the constituent minerals and not simply by their chemistry. Thus both the acid intrusive rocks and the dolerites are hard and compact, and do not break down easily, although the latter contain greater amounts of ferro-magnesian minerals which are generally

Table 1. *Chemical analyses: Snowdon rocks*

(A) Analyses from Williams (1927)	Oxide Content, Weight %											
	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	H_2O^+	H_2O^-
Upper Rhyolitic Series: Rhyolite, Gallt y Wenallt (Analysis XV)	75·3	10·4	0·3	2·0	0·8	1·8	2·8	4·4	0·3	0·2	0·7	0·1
Bedded Pyroclastic Series: Pumice-tuff, Snowdon Summit (Analysis XI)	44·7	15·8	1·8	12·8	14·5	0·4	0·1	Trace	1·0	0·5	7·8	0·3
Dolerite: Biotite-rich from south-eastern edge of the Cwm Dyli intrusion (Analysis XXVIII)	60·5	14·3	3·7	4·5	2·1	2·3	4·4	4·0	1·7	0·1	2·1	0·1

(B) Partial analyses by X-ray fluorescence spectrography: (Nature Conservancy, Bangor)	Oxide Content, Weight %							
	SiO_2	Total Iron as Fe_2O_3	CaO	K_2O	TiO_2	MnO	Ignition Loss 800° C.	H_2O^-
Bedded Pyroclastic Series:								
Vesicular pumice-tuff, north-east of Llyn Llydaw (Sample A 452)	46	13·0	7·9	1·8	2·0	0·14	6·5	0·1
Alluvium derived from pumice-tuff, eastern end of Llyn Llydaw (Sample 633)	48	13·3	0·3	0·5	3·0	0·29	6·5	2·1
Non-vesicular pumice-tuff, near Pen-y-pass (Sample 760)	54	14·3	1·9	0·8	1·9	0·28	4·5	0·3
Rhyolitic Series:								
Rhyolitic ash, near copper mill, Llyn Llydaw (Sample 167)	62	4·9	0·3	4·0	0·7	0·22	2·9	0·2
Rhyolitic ash, Crib-y-ddysgl (Sample 194)	68	8·6	0·1	4·4	0·4	0·27	1·7	0·1
Rhyolitic ash, Cwm Merch (Sample 762)	80	5·3	0·5	3·5	0·4	0·10	2·1	0·2
Rhyolite, near Pen-y-pass (Sample 761)	83	6·9	0·1	3·2	0·4	0·19	1·9	0·1
Dolerite:								
Craig Llyn-Teyrn (Sample 44)	56	10·7	3·8	3·1	1·9	0·21	2·0	0·3
Craig Aderyn (Sample 133)	59	10·4	3·0	4·0	1·7	0·23	1·7	0·3
Llandeilo Slate:								
Cwm y llan quarry	60	9·1	0·3	5·2	0·8	0·13	3·9	0·6

NOTE: H_2O^- = water loss at 105° C.; H_2O^+ = water loss above 105° C.; Ignition loss at 800° C. is largely composed of loss of structural water.

considered to be less stable than quartz and felspars. The only rocks covering wide areas which weather rapidly are the soft ashes which make up a proportion of the Bedded Pyroclastic Series.

(2) *Glacial Geology*

In his classic work of 1860, Ramsay wrote that "The signs of a glacier are so evident in Cwm Llydaw (Cwm Dyli) that is is needless to describe all the details. At the outflow of the lake (Llydaw) there are moraine-like mounds, formed of earthy matter, stones and angular and subangular blocks, which even now partly dam up the lake and when I first knew it, raised it to a still higher level, ere the channel of the brook was sacrilegiously deepened to lower the water, for the sake of saving a few pounds in the construction of an ugly causeway." His maps plot glacial striae and moraine features in and around the Reserve and give the general directions of movement of the Snowdon glaciers.

Williams's (1927) map of "superficial deposits and glacial striae" shows the concentrations of glacial drift in Cwm Dyli and Cwm y llan and the greater extent of moraine features in the former. However, he also included areas of vegetated scree, some peats, and post-glacial colluvial soils in his "drift", so that his map gives only a broad indication of the distribution of till.

In a geomorphological study of Nantgwynant, Johnson (1962) has referred to an ascending series of cwms in the valleys of Cwm Dyli and Cwm y llan and has also suggested that ice from Cwm Dyli and Cwm-y-ffynnon moved both north-easterly along Nantygwryd and southerly down Nantgwynant.

During the soil survey reported here it was possible to map the main drift areas with more precision (Soil Parent Material map*) and to assess qualitatively, by stone content, the main rock types contributing to the tills. It must be emphasized that small patches of till or relict material derived from it occur outside the areas mapped as drift and that rock outcrops occur within the latter. The map shows that drift composition is related to the solid geology of the individual valleys, the tills having been deposited by separate valley glaciers rather than by a general ice-sheet. For example, slate becomes a conspicuous constituent of the drift in Cwm y llan below the outcrops of Llandeilo slate, but is absent from the other valleys in any appreciable proportion.

There are also differences between the three main valleys in the extent and morphology of the drift cover. Cwm Merch contains no large area of till. Cwm y llan, from the slate quarry to Plascwmllan, is occupied by smoothly sloping drift extending up the valley sides. The only drift features of sharp relief in Cwm y llan occur at its head in Cwm Tregalan where a large rock-cored morainic ridge is associated with smaller moraines. The alignment of the main feature parallel to the western steep side-wall of the cwm suggests that it may be a pro-talus rampart, formed from material sliding over a persistent Late-glacial snow patch. In Cwm Dyli, in contrast, fresh hummocky morainic drift occupies the valley floor from Llyn Llydaw to the lip of the hanging valley above Nantgwynant. The sides of Cwm Dyli above the moraines are, however, also partly mantled by smoothly sloping drift.

These observations support the following interpretation of glacial history. During the final retreat stages of local glaciers in Snowdonia, ice first disappeared from

* In cover-pocket.

Cwm Merch, secondly retreated from southward-facing Cwm y llan into Cwm Tregalan, and ultimately vacated Cwm Tregalan and easterly-facing Cwm Dyli. This sequence of ice retreat is in accord with the evidence of Seddon (1957) and Watson (1960) that the Late-glacial cwm glaciers in Wales had a predominantly north or north-easterly aspect. Snowdon having the highest precipitation in North Wales both now and probably also in the Late-glacial period (Seddon, 1957), it is reasonable that a small cwm glacier or permanent snow patch could be maintained in Cwm Tregalan, although this is of southerly aspect, and that a larger glacier would occupy Cwm Dyli.

The stratigraphy of peat deposits within the belt of fresh moraines on Snowdon has not been studied but it can be suggested by analogy with Cwm Idwal (Seddon, 1962), that the till sheets showing subdued relief were deposited in Late-glacial Zone I (Pre-Allerød), and that the fresh morainic drifts were deposited in Late-glacial Zone III (post-Allerød). During the latter, periglacial processes of solifluction occurred peripherally to the cwm glaciers as a result of the seasonal thawing of upper horizons of permafrost. These processes produced the uniform slopes now seen in Cwm y llan and on the sides of Cwm Dyli. Cwm Merch is a shorter valley of steeper gradient in which less drift will originally have been deposited, so that its subsequent removal will have been more rapid.

It has been stated that the glacial tills of the mapped area result from individual valley glaciers originating within the Reserve but there are two exceptions to this. A small area of drift with subdued relief at Pen-y-pass is separated from the moraines in Cwm Dyli by a drift-free spur, but is continuous in a narrow strip along the valley floors from the Pen-y-pass watershed in both north-westerly and south-easterly directions. Similar drift occurs in the basin of Llyn Cwm-y-ffynnon (SH 649562) to the north and it is possible that the Pen-y-pass drift was derived from this source, and can be ascribed to the same period of deposition as the soliflucted till of Cwm y llan and the upper slopes of Cwm Dyli. Secondly, patches of drift adjacent to Llyn Gwynant are considered to have been deposited by the main Nantgwynant glacier.

Erosional features resulting from ice action which are evident in the Reserve include steep back walls of cwms; over-deepened lake basins; ice-smoothed and striated rock surfaces; roches moutonnées and hanging valleys. An example of a steep back wall is Clogwyn y Garnedd behind Glaslyn. Jehu (1902) recorded the maximum depth of Glaslyn as 127 ft. and of Llyn Llydaw as 190 ft. and showed that both occupy basins held in behind drift-covered rock bars. On the harder rocks little affected by post-glacial weathering, such as the rhyolites and grits, ice-smoothed surfaces with striae are frequent up to about 1,800 ft. Large examples of roches moutonnées are present, such as Craig Aderyn (SH 639543) and Clogwyn Pen-llechen (SH 642545) in Cwm Dyli, and Craig-ddu (SH 618527) in Cwm y llan. Cwm Dyli, Cwm Merch and Cwm y llan are hanging valleys, the breaks of slope above Nantgwynant occurring at 900, 1,000 and 750 ft. respectively. Davis (1909, p. 331) stated that a marked notch in the rock barrier over which the Afon Cwmllan flows (at SH 623517) was the only such feature in 10 valleys radiating from Snowdon. This notch he attributed to water erosion subsequent to ice retreat, which supports the concept of an earlier ice recession in Cwm y llan than in Cwm Dyli.

Scree formation by frost-shattering is considered to have taken place principally as a periglacial process in the Late-glacial period. This is certainly true of screes at the lower altitudes (Ball, 1966*a*), for example above Llyn Dinas (SH 617498), where block scree overlies an erosion payment on till (Ball, 1967). Some accretion of fresh material to the highest level screes on Snowdon has occurred post-glacially and is still occurring, but it is thought that re-sorting of Late-glacial material is the main active process.

(2a) *Drift Texture and Chemistry*

Mechanical analyses of nine samples of glacial drift from the three main valleys (by Bouyocos hydrometer) show them all to be very light-textured, the mean values being 4 per cent clay (< 0·002 mm.), 24 per cent silt (0·002–0·02 mm.) and 72 per cent sand (0·02–2·0 mm.). Partial chemical analyses of these drifts are given in Table 2. Although many more samples would be needed for an adequate study, the drift chemistry correlates with inferences drawn from mineralogical examination and field identification of stones. Cwm y llan samples with a high slate content contain higher total potassium than the other drifts. Calcium levels are very low throughout, but the lowest levels occur in Cwm Dyli in localities where rhyolite is thought to dominate the drifts. The single Cwm Merch example has higher titanium and calcium levels and lower potassium, as expected from a drift dominantly derived from rocks of the Bedded Pyroclastic Series.

(3) *Geomorphology*

It has been shown that the solid geology is complex, both in rock type and structure, and that glacial processes have been of great importance in shaping the land-

Table 2. *Chemical analyses: Snowdon drifts*

Partial analyses by X-ray Fluorescence Spectrography; (Nature Conservancy, Bangor)	Oxide Content, Weight %					
	SiO_2	Total Iron as Fe_2O_3	CaO	K_2O	TiO_2	MnO
Cwm y llan:						
Below slate quarry dressing sheds, at 2 ft. depth in section	64	9·6	0·28	3·4	1·1	0·34
Below slate quarry dressing sheds, at 18 ft. depth in section	64	9·5	0·36	3·4	1·1	0·31
River section, below Craig-ddu, at 3 ft. depth in section	63	10·1	0·14	3·7	0·9	0·24
Below Plascwmllan, at 1 ft. depth in section ..	64	8·8	0·16	3·3	0·9	0·30
Below Plascwmllan, at 4 ft depth in section ..	67	9·2	0·15	3·7	0·9	0·24
Mean of 5 Cwm y llan sites	64	9·4	0·22	3·5	1·0	0·29
Cwm Merch: at c. 1,500 ft. near old mine, at 2 ft. depth in section	53	12·8	0·56	0·9	3·1	0·24
Cwm Dyli:						
Moraine at eastern end of Llyn Llydaw (South shore) (1)	68	9·0	0·09	2·7	1·2	0·27
Moraine at eastern end of Llyn Llydaw (South shore) (2)	70	8·0	0·09	2·9	1·1	0·15
((1) and (2) are 20 ft. part)						
At western end of Llyn Llydaw (North Shore) at 2 ft. depth in section	64	10·4	0·11	2·3	1·6	0·18
Mean of 3 Cwm Dyli sites	67	9·1	0·10	2·6	1·3	0·20

forms seen today. This is not, however, the complete explanation of the present pattern of mountain ridges and deep valleys. Folding and uplift of the Ordovician rocks produced a land surface which subsequently has been subjected to periods of submergence, further folding and uplift and to stages of intense erosion. An interpretation of this history has been made by Brown (1960), summarized below, based on the correlation across Wales of the heights of recognizable summit or plateau features to form a sequence of hypothetical surfaces.

The oldest of these surfaces, represented by the tops of the highest peaks now found in Wales, is considered to result from marine planation in pre-Cretaceous times. On this surface, the "Summit Plain", it is postulated that Mesozoic sediments were deposited before early Tertiary uplift created a dome centred on Snowdonia. A radial pattern of river drainage developed on this dome and, after prolonged erosion had removed the Mesozoic cover, the rivers cut down into the Ordovician rocks to give the present regional drainage pattern which, in many cases, disregards the major rock structures. Sub-aerial erosion with intermittent uplift of the now re-exposed Ordovician rocks continued during Tertiary times to give a series of "upland plains". The first below the "Summit Plain", the "High Plateau", is thought to be of Miocene age: a fragment of this surface in the Reserve is said to be the ridge extending for approximately three-quarters of a mile eastwards from the foot of Grib-goch at an altitude between 1,900–1,750 ft.

The framework of the landforms of Snowdonia is thus considered to be of great age. In the Pleistocene period, the pre-existing major river valleys such as Nantgwynant were greatly deepened by glacial erosion. Ice created cwms in feeder valleys ultimately separated by narrow ridges (arêtes) such as Y Lliwedd, which divides Cwm y llan from Cwm Dyli, and Crib-y-ddysgl and Grib-goch which separate Cwm Dyli from Cwmglas-mawr to the north. The importance of glacial erosion in the Snowdon area has been described by Davis (1909). Material deposited by ice is responsible for the detailed morphology of the valley floors and sides, as discussed previously.

The geomorphological effect of post-glacial processes has been relatively slight, for example hollows have been infilled by peat accumulation, and streams have produced minor erosional and depositional features. Other forms of contemporary erosion include the following: gullying which is frequent on steep slopes in the areas of deeper soils and scree; rotational landslip movement affecting the areas where a relatively deep colluvial soil cover is found; and the stripping by sheet erosion of small patches of thin soils on sloping rock surfaces. However, comparison of the present situation with prior records, for example photographs of the Glaslyn area (Jehu, 1902) and of Llyn Llydaw in early editions of the Ward Lock guides (e.g. 1912), suggests that no widespread changes have taken place in the soil and vegetation cover during this century. Recently, erosion has increased along the main tracks, especially in Cwm Dyli, as a result of the greater numbers of people using these routes.

(4) *Climate*

Few statistics are available, the only figures which cover a relatively long period being those for rainfall obtained by the Central Electricity Generating Board (C.E.G.B.) from which Figure 2 and Table 3 have been prepared.

Table 3. *Mean monthly rainfall (inches): Snowdon*

Site*	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Llyn Teyrn (a) ..	16·8	11·6	9·9	9·4	7·4	9·8	10·6	13·1	15·8	13·0	15·0	17·3
Llyn Llydaw (a) ..	14·1	9·8	8·5	8·4	6·8	8·5	10·4	12·1	13·4	12·0	13·0	15·0
Grib-goch (a) ..	17·4	13·1	12·4	10·3	8·6	11·4	14·3	15·4	17·9	14·9	16·4	17·0
Cwm y llan (b) ..	13·2	8·6	7·7	7·9	6·2	7·6	9·3	11·0	12·6	10·6	12·8	14·1

* Location details as Fig. 2. (a) 1945–1965. (b) 1947–1965.

Figure 2 gives graphs for annual rainfall between 1945 and 1965 at gauges located near Llyn Teyrn and Llyn Llydaw in Cwm Dyli, near the summit of Grib-goch, and in the lower part of Cwm y llan. The annual means at these sites are respectively 149·6, 132·4, 166·5 (21 year records) and 119·7 (19 year records) inches per annum. The figures do not show a consistent relationship between higher rainfall and greater altitude but it is probable that the positioning of the gauges is significant. That at Llyn Teyrn is in an open situation while those at Llyn Llydaw and Grib-goch are somewhat protected from the prevalent westerly winds. Rainfall, however, increases generally with altitude and there is additionally a suggestion that it is less in Cwm y llan than in Cwm Dyli, since the Llyn Teyrn and Cwm y llan gauges are at the same altitude and in comparatively open sites. Table 3 gives the monthly means for the same four stations over the 1945–1965 period, and from this it is seen that rainfall is well-distributed throughout the year with minima in May at all four sites and maxima in December at three sites and in September at one. However, the variation from year to year in both monthly and annual rainfall at any one site is of a similar order to the range between locations. Earlier rainfall data from C.E.G.B. gauges in the area are given in Carr and Lister (1948), which also show a trend to higher rainfall with greater altitude. At Pen-y-Gwryd (annual rainfall 135 inches), half a mile north-east of the Reserve, Carr and Lister give the average number of days per year with more than 0·01 inches of rain in the period 1910–1917 as 243, and this or a higher figure is likely to be typical of the Reserve.

Between 1959 and 1966 a Climatological Station was operated by the C.E.G.B. near the Cwm Dyli power station (SH 653542) for the Meteorological Office. As its location is representative only of a very small proportion of the Reserve fringing Nantgwynant and the records are for a relatively short period they are not quoted here. To remedy the lack of meteorological data at higher altitudes, instruments were set up by the Nature Conservancy in 1966 near Llyn Llydaw which should provide more comprehensive relevant data in the future.

III. The Soils

(1) *Survey Methods*

The Ordnance Survey 6 inch to 1 mile sheets were used for the soil survey (Soil Map*). Because of the lack of plotted contours above 1,000 ft. at this scale and the differences between relative area on the ground and on the map due to the large range in altitude, precise position establishment was difficult. Soil unit boundaries therefore

* In cover-pocket.

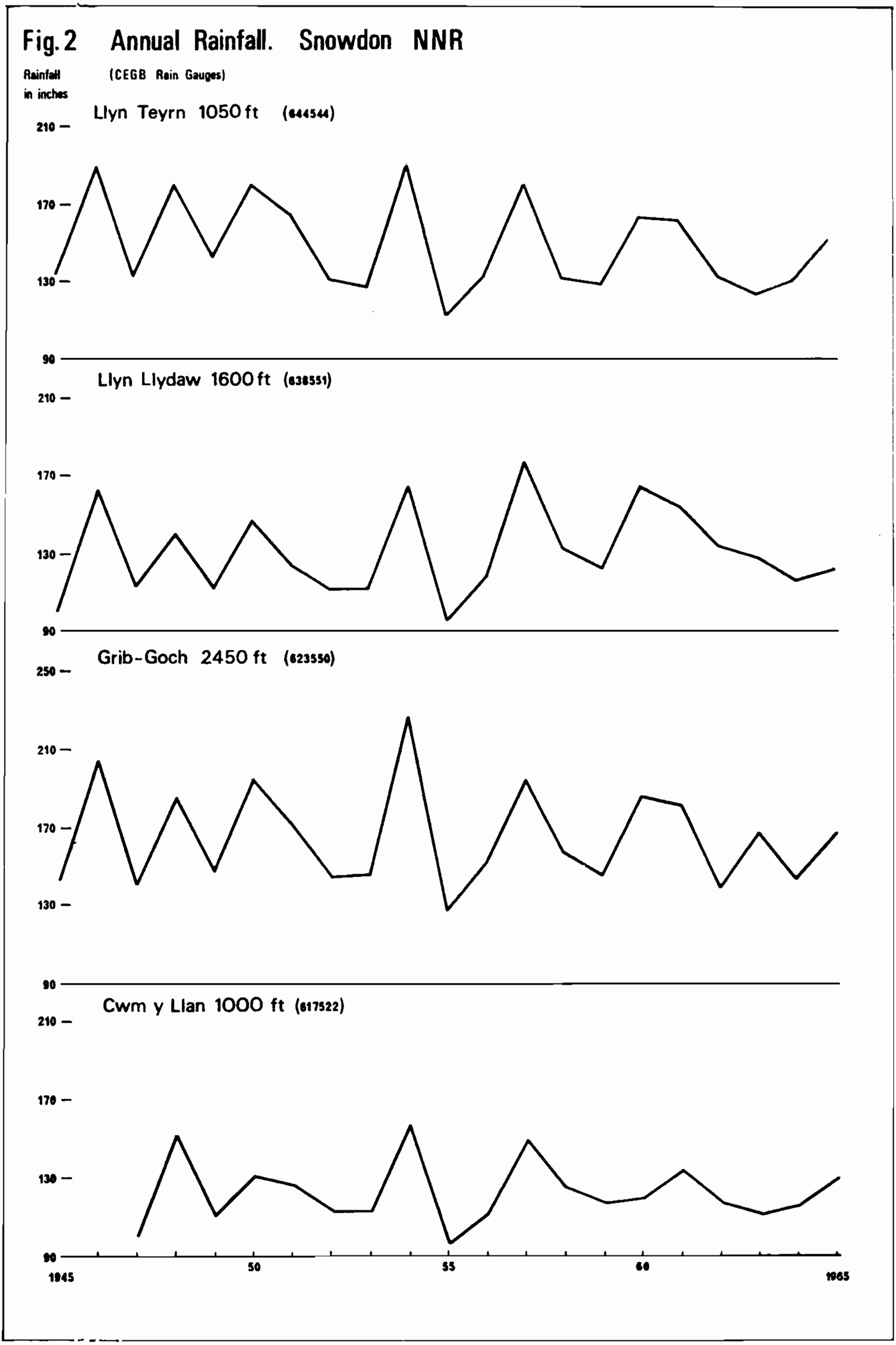


Fig. 2 Annual Rainfall. Snowdon NNR
Rainfall in inches
(CEGB Rain Gauges)
Llyn Teyrn 1050 ft (644544)
210
170
130
90
Llyn Llydaw 1600 ft (638551)
210
170
130
90
Grib-Goch 2450 ft (623550)
250
210
170
130
90
Cwm y Llan 1000 ft (617522)
210
170
130
90
1945
50
55
60
1965

could not be mapped with high accuracy (ignoring for the moment the transitional and complex nature of most boundaries), except where they approached marked topographic features such as lake margins, streams or walls.

Identification of soils was made by boring with a soil auger along transects chosen in relation to the relief and at a frequency controlled by the complexity of soil distribution. Boundaries of mapping units were plotted which defined either areas of essentially uniform soil types or of intricate mixtures of several soils which could not be separated at the mapping scale employed. Pits were dug to confirm auger identification of soil types and representative profiles were described and sampled for laboratory analysis.

Within complex mapping units in Cwm y llan a technique for determining the proportions of soils present in the complexes was briefly investigated. Using this method, subjective selection was made of "representative" points, from which a measuring tape was extended for 50 feet in four directions at 90° to each other to form a "cross transect", along which auger borings were taken at 10 foot intervals. This gave 20 records of soil type around each sampling point. Results were then combined to give a quantitative assessment of the different soil types present. This technique was not extended to the whole area but it appears to be a useful compromise between an entirely subjective approach and a statistically objective but laborious sampling programme.

(2) *Soil Classification*

Soil classification units are based on profile characteristics. The soil profile consists generally of recognizably distinct horizons which differ in features such as colour, texture, structure and organic matter content and type. Horizon designation by letter systems is widespread in order to permit comparison of equivalent horizons between profiles. Such systems exist in varying degrees of complexity, one used in the area being that given in Ball (1963, p. 25) after Kubiena (1953). However, the use of a horizon notation based on visual impressions of the profile may imply an understanding of operative processes which one may not have, or alternatively add little to the straightforward description. Because of this we have omitted such a notation from the profile descriptions.

Soils of comparable horizon sequences which result from the influences of similar physical, chemical and biological soil-forming processes are classified as *Major Soil Groups* and *Sub-Groups*. The classification units are based on concepts of ideal type profiles. In the field, soil characteristics change in response to the interaction of many environmental factors so that a majority of profiles may not correspond exactly to the ideal concept of the classification unit. A mapping unit therefore must include soils, the profile characteristics of which represent a range of variation about the type profiles for the group or groups contained in the unit. Soils of a particular Sub-Group formed on a defined parent material are the basic classification units used in this survey. This unit is the *Soil Series* which is normally defined and named from geographic localities where it was first described in regional surveys. Some soils on Snowdon correspond to previously named Series but many do not and therefore it has been thought preferable to omit any attempt at Series naming in this account.

Eight parent material groupings and three other land categories have been employed in this survey and their distribution is given on the Parent Material Map.

This has been derived from identifications of the stone contents of the dominant mineral soils, or of the rock types underlying relatively shallow organic soils.

The classification described below and given in Table 4 uses a terminology for Major Soil Groups and Sub-Groups which has been applied in North Wales in Soil Survey practice (e.g. Roberts, 1958; Ball, 1963). Table 4 shows the Sub-Groups which occur on the individual parent materials, with each "box" forming a Soil Series and, together with the key to the Soil Map, demonstrate that the majority of mapping units are not single Soil Series but are complexes of two or more Series.

Brown Earths

Soils of this Group show only a gradual change in morphology from the surface to the parent material and have an upper horizon in which organic matter is intimately mixed with mineral matter by the action of soil fauna, mainly earthworms, to give mull humus. Colours are brown to grey-brown throughout and are related to the soil drainage which is either free or imperfect, and to the absence both of strong weathering and of transport and deposition of iron compounds.

Freely-drained Brown Earths are conventionally divided into high- and low-base status soils by virtue of their natural acidity. Only the latter Sub-Group, called *Brown Earths of Low-Base Status*, in which the pH in the lower horizons is less than 6·5, is present on Snowdon. *Brown Earths with Gleying* are imperfectly drained and transitional to poorly-drained Gleys, but they have drainage impedance only in their lower horizons (conventionally below about 12 in.).

Podzolized Soils

In freely-drained soils in which leaching of calcium and magnesium and the consequent lowering of pH has proceeded to a stage at which earthworms cannot survive, the formation of mull humus no longer occurs. Plants adapted to more acid conditions spread and their dead residues accumulate as an organic surface horizon. Leachates from this organic horizon cause a more rapid weathering of mineral particles than occurs in Brown Earths, releasing larger quantities of iron oxides.

Brown Podzolic Soils have profiles in which the organic surface horizon overlies an orange or reddish brown horizon of iron enrichment, the result of weathering *in situ*, with only subordinate iron movement down the profile. No separate classification of imperfectly drained variants has been made in this survey although they are present. Further development in the trend of podzolization gives *Peaty Podzols* in which iron has been translocated from a horizon immediately beneath the peaty surface and redeposited lower in the profile, sometimes as a concentrated thin "pan" layer, sometimes more diffusely. Such soils therefore have a black surface horizon, a pale grey second horizon and beneath this an orange or red brown horizon, which merges into the little-altered parent material. The shift of clay size material down the profile, characteristic of some podzolic soils, is not generally identifiable in these upland podzols. *Peaty Gley Podzols* which are transitional between Peaty Podzols and Peaty Gleys have mottled sub-surface horizons indicative of imperfect to poor drainage.

Table 4. *Classification of soil mapping units*

Rock Outcrop	Rock Scree	Basin Peat
1.	2.	3, 20.

Parent Materials		Major Soil Groups and Sub-Groups:							
		Brown Earths		Podzolized Soils		Gleys		Organic Soils	
Solid Rocks directly underlying Soils	Glacial Drifts directly underlying Soil	Brown Earths of Low Base Status	Brown Earths with Gleying	Brown Podzolic Soils	Peaty Podzols and Peaty Gley Podzols	Gleys (Non-Calcareous)	Peaty Gleys	Peat Rankers	Deep Peaty Soils
Rhyolitic Series				4				4, 5	
Rhyolitic Series scree								6	
Bedded Pyroclastic Series		7, 8, 9, 10	9, 11	7, 8	12	11	11	7, 8, 9, 12	7, 8
Bedded Pyroclastic Series scree		13, 14		13					
Llandeilo slate and Gwastad-nant grit				15				15, 16	
Llandeilo slate scree		17		17					
Dolerite								18	
	Drift mainly derived from rhyolite				19, 20		20		20
	Drift mainly derived from rhyolite and Bedded Pyro-clastic rocks		21	22, 23	24	21			23
	Drift mainly derived from rhyolite and dolerite			25					
	Drift mainly derived from rhyolite, Bedded Pyro-clastic rocks and slate			26	27, 29		27, 28, 29	28, 29	28, 29

Gleys

Mineral soils which are more or less permanently waterlogged are typically grey in colour as a result of the presence of reduced iron compounds, and the growth of roots in such soils is largely confined to surface horizons. *Non-calcareous Gleys* are the poorly drained associates of Brown Earths of Low-Base Status and Brown Earths with Gleying. Their surface horizons are relatively high in organic matter but are not peaty, and their lower horizons are grey with, in some instances, minor yellow or brown mottling caused by oxidation in temporary dry periods. *Peaty Gleys* occur on more acid parent materials and in wetter situations where peaty humus accumulates at the surface. Poorly drained soils with less than 12–15 in. of peat overlying mineral material are conventionally classified as Peaty Gleys; those having greater depths of highly organic matter being classed with Organic Soils.

Organic Soils

Shallow immature soils in which a single surface horizon directly overlies parent material are defined by Kubiena (1953) as Rankers. *Peat Rankers* are soils in which the profile consists simply of a shallow organic horizon generally overlying rock but in some cases on pedologically unaltered compact drift. Occasional less organic immature thin soils (Brown Rankers) occur but have not been separately classified. Very poorly drained soils of medium to high organic content greater than 15 in. in depth are defined in this survey as *Deep Peaty Soils* and generally occur on slopes. Soils composed almost entirely of organic matter accumulated in hollows are mapped separately as *Basin Peat*, but these two variants merge in some locations.

(3) *Description of the Mapping Units*

The mapping units are described in numerical order. Representative profile and analytical data for the majority of the soil groups on the range of parent materials found are given in Appendices 1 and 2.

1. Rock Outcrop. (Profiles S.1, 2.) Bare rock, generally consisting of steep cliffs, is estimated to comprise more than 80 per cent of the ground in Unit 1 occupying the greater part of the Reserve above 2,000 ft. in a continuous tract from Grib-goch to Yr Wyddfa and Bwlch Maderin (SH 605530) with an arm extending across Y Lliwedd, and smaller areas at lower altitudes. The unit is not subdivided into different rock types, but this can be done by reference to the geological map (Williams, 1927). The area below Yr Wyddfa is composed of rocks of the Bedded Pyroclastic Series while Grib-goch, Crib-y-ddysgl and Y Lliwedd are rhyolitic. These differences produce contrasts in the vegetation of ledges which carry soils of Ranker types. The southern slopes of Y Lliwedd are less steep, being broken bouldery ground with the eroded remnants of a former soil cover (e.g. S.2). The rather fissile rhyolitic ash of Crib-y-ddysgl gives outcrops with crevices infilled with loose weathered material (S.1).

   The very steep slopes and cliffs are exposed to the effects of high winds and precipitation which are largely responsible for maintaining the extent of bare rock.

2. Rock Scree. Unit 2 occupies uniform slopes of about 30–35° composed of thick accumulations of angular fragments of rock. Such slopes are partly

soil and vegetation covered (Units 6, 13, 14, 17), but screes at high altitude, especially those on acid igneous rocks, are almost bare. These are on the south of Grib-goch and below the cliff on the north-east face of Y Lliwedd. Small areas of block scree occur at low altitude in Nantgwynant.

3. Basin Peat (S.3). Peat *sensu stricto* is mapped in Unit 3, mainly occupying infilled basin sites. Near the slate quarry in Cwm y llan, areas of this unit contain less pure peat and are transitional to the sub-group of Deep Peaty Soils (see Table 5). No borings have been made in the Basin Peats to determine their maximum depth or the nature of the underlying materials. Late-glacial and post-glacial vegetation history, which has been described for other sites in Snowdonia (Seddon, 1962), has not been studied in the Reserve, but birch fragments have been found in the peats in Cwm Dyli and at Bylchau Terfyn, above Llyn Dinas.

Solid Rock or Scree parent materials

4–5. Units 4 and 5 overlie rocks of the Rhyolitic Series.

4. Brown Podzolic Soil, Peat Ranker (S.4, 5). Unit 4, mapped as a strip along the Watkin path above the South Snowdon quarry, is one which gave difficulty in classification as it was found to be complex both in soil type and parent material. It has been separated from the more widespread Unit 5 because it contains small pockets of drift or colluvium mainly composed of rhyolitic rocks, on which mineral soils of Brown Podzolic character occur. Additionally, thin beds of chloritized volcanic ashes similar to those of the overlying Bedded Pyroclastic Series outcrop along the Watkin path.

5. Peat Ranker (S.4, 5). Unit 5 is one of the most widespread in the Snowdon Reserve. The characteristic soil overlies either unweathered massive rhyolites or, where the rhyolitic rocks are of more fissile character, a thin zone of weathered rock. Deeper peats are present in hollows, which may contain glacial drift remnants, and there is a proportion of bare rock. Although in the field the soils appear highly organic, loss-on-ignition figures for the type profiles are lower than might be expected owing to a content of sand-sized particles of rhyolitic rock of small volume but relatively great weight. The extent of the Peat Rankers results from slow post-glacial weathering of the rhyolitic rocks, coupled with the very high rainfall distributed throughout the year. The latter encourages the initial establishment of lichens and mosses on the rock surface and a thin peaty soil then accumulates. Colonization by higher plants proceeds, the dead remains of which increase the depth of the organic soils. The rate of formation of these soils is thought to be very slow, so that losses of soil cover through erosion cannot be rapidly replaced by natural means.

6. Peat Ranker (S.35) on scree formed from Rhyolitic Series rocks. A single small area of partly soil-covered and vegetated scree is found between the rock outcrop of Craig-ddu in Cwm y llan (SH 618527) and drift-derived Brown Podzolic Soils of Unit 26.

7–12. Units 7–12 overlie or are formed from Bedded Pyroclastic Series rocks. The Bedded Pyroclastic Series as a stratigraphic unit is found in the north of the Reserve from Pen-y-pass to Grib-goch and as a wide tract in the east and south-east from Afon Glaslyn in Cwm Dyli through Cwm Merch to Llyn Dinas. It is believed that differences in weathering rates of rock types within this Series are responsible for the major distinction between Cwm Dyli where Brown Earths and Brown Earths with Gleying, formed from rapidly weathering fissile ash, are widely distributed, and Cwm Merch and the southern sector where podzolic and peaty soils are dominant. These differences are conspicuous and not apparently accounted for by the effects of altitude and aspect on soil development.

7. Brown Earth (S.6, 7), Brown Podzolic Soil (S.9), Peat Ranker (S.10), Deep Peaty Soil (S.12). The same soils are present in both Units 7 and 8 but their relative extents differ. Unit 7 is estimated to contain approximately equal areas of the four sub-groups, and occupies the lower reaches of Cwm Merch extending across Afon Cwmllan to the west, with a small area above Llyn Dinas on Gallt y Llyn. Brown Podzolic Soils occur more widely in this unit than in either Units 8 or 9, and are sometimes formed over small pockets of drift.

8. Brown Earth (S.7), Brown Podzolic Soil (S.9), Peat Ranker (S.10), Deep Peaty Soil (S.12). Unit 8 occupies the upper reaches of Cwm Merch and a small strip along the Pyg track above Llyn Llydaw. It is dominated by peaty soil types, with subordinate Brown Earths and Brown Podzolic Soils. The boundary of the main area of this unit with Unit 7 is a merging one, as there is a progressive decrease in the importance of mineral soils in the higher sectors of Cwm Merch. In contrast there is a much sharper junction with Unit 9 over the crest of the Y Lliwedd–Gallt y Wenallt ridge on the north-facing slopes of Cwm Dyli, where deep mineral soils are dominant. In the Pyg track sector small relict patches of drift are present but were not of large enough extent to map separately.

9. Brown Earth (S.6, 7, 8), Brown Earth with Gleying (S.13), Peat Ranker (S.10, 11). The main extent of Unit 9 is on the south side of Cwm Dyli, its upper limit being at about 1,600 ft. To the east, the unit continues down the wooded north-eastern slopes of Gallt y Wenallt to the Reserve boundary, and in the north, the soils merge into drift-derived units. A smaller area, mainly of Brown Earths with Gleying, is mapped in the north of Cwm Dyli near Pen-y-pass. Brown Rankers occur also in Unit 9 and, together with Peat Rankers, dominate the steep slopes mapped in this unit above the north-eastern end of Llyn Llydaw.

South of Cwm Dyli is the most extensive tract in which mineral soils derived from Bedded Pyroclastic Series rocks occur, although Unit 10 contains the largest continuous areas of freely-drained Brown Earths. The soils of highest pH and base status on the Reserve are found in Unit 9 in woodlands at low altitude, as are the remains of the highest altitude former farm holding (SH 647538) at approximately 1,200 ft. The significance of soils of this unit and associated Units 10 and 11, with regard to the past and present agriculture and ecology of the Reserve has been discussed elsewhere (Hughes, 1958; Hughes, Milner and Dale, 1964).

At higher altitudes in the unit, the Brown Earths are colluvial soils of rather lighter texture and of weaker structure (e.g. S.7) than at lower altitudes (e.g. S.6). The woodland soils include shallow Ranker types on ledges (S.11) and deeper Brown Earth variants (S.8).

10. Brown Earth (S.6). Unit 10 is one of the minority of units mapped as a single soil series. It occurs in a discontinuous band from the north-eastern end of Llyn Llydaw to the saddle between Grib-goch and Crib-y-ddysgl. Active and stabilized erosion gullies, rotational landslips, and the accumulation of transported material on the lake floor all demonstrate the instability of the steep slopes on which the unit is found. In addition to and perhaps because of the intermittent downslope movement of soil, although the level of calcium is not particularly high, earthworms are able to live, and help to maintain a relatively rapid turnover of organic matter, preventing the formation of mor humus and the development of a podzolic profile such as that on gentle, stable slopes in Unit 12.
    Soils of Unit 10 are being used for ecological studies by the Bangor Research Station of The Nature Conservancy and a detailed investigation has been made of chemical variability within the surface horizon (Ball and Williams, 1968).

11. Brown Earth with Gleying (S.13), Gley (S.32), Peaty Gley (S.14).
    The area in Cwm Dyli occupied by Unit 11 contains a substantial proportion of poorly and very poorly drained soils in a transition zone to the valley floor drifts. Peaty Gleys are found in a depression near the upper boundary of the unit and Gley soils dominate the eastern section. Approaching the lower boundary, the drift influence increases so that Brown Podzolic variants occur, which merge into the soils of Unit 23. A second area of Unit 11 mapped near Bylchau Terfyn occupies a ridge bordering Basin Peat.

12. Peaty Podzol and Peaty Gley Podzol (S.15), Peat Ranker (S.10).
    Unit 12, mapped on the northern margin of the Reserve north-east of Llyn Llydaw, contains Peaty Podzolic soils which are found in gently sloping hollows between rock ridges with Peat Rankers. In contrast to the soils of Unit 10, leaching has produced a podzolic profile where sufficient depth of mineral material has accumulated. The paucity of quartz or other minerals resistant to weathering in the pumice-tuffs is probably responsible for the absence of the greyish-white leached horizon beneath the surface humus found in type podzols.

13–14. Units 13 and 14 overlie scree formed from Bedded Pyroclastic Series rocks.

13. Brown Earth (S.16), Brown Podzolic Soil (S.17).

14. Brown Earth (S.16).
    Screes with a large proportion of soil and vegetation cover occupy considerable areas on steep slopes, especially above Nantgwynant but also in Cwm Tregalan and above Glaslyn. At higher altitudes, Unit 13 comprises both Brown Earths and soils of Brown Podzolic character. The lower altitude screes mapped in Unit 14 carry colluvial Brown Earths. Soil depth is variable but generally shallow.

15–16. Units 15 and 16 overlie Llandeilo slate and Gwastadnant grit.

15. Brown Podzolic Soil, Peat Ranker (S.18).

16. Peat Ranker (S.18).
Units 15 and 16 are found on the upper western slopes of Cwm y llan. The ridge crest is occupied by shallow peaty soils of Unit 16, merging downslope in the north into Unit 15, in which there is a patchy occurrence of Brown Podzolic Soils formed largely on slate and grit colluvium.

17. Brown Earth (S.19), Brown Podzolic Soil: on scree formed from Llandeilo slate.
Unit 17 is found as partly vegetated scree with subordinate outcrops of rock to the north and south of Bwlch Cwmllan. The soils are generally immature Brown Earths (or Brown Rankers) but there is a trend to Brown Podzolic profile types locally.

18. Peat Ranker (S.20) on Dolerite outcrops.
Although more calcium-rich than the fissile Bedded Pyroclastic Series, the massive Cwm Dyli dolerites weather slowly. Soils on these rocks are shallow Peat Rankers which tend to have a stronger crumb structure and to be drier than those formed on rhyolite or grit.

Drift parent materials

Units 19–29 are dominated by soils formed from glacial drift, in contrast to Units 1–19 in which the solid rock principally governs soil formation.

19–20. Units 19–20 overlie drift derived mainly from rhyolitic rocks.

19. Peaty Podzol and Peaty Gley Podzol (S.21).
Unit 19 is mapped on moraine features in Cwm Dyli, the relatively steep slopes of which are responsible for the dominance of freely or imperfectly drained soils. The degree of development of podzolic characteristics and of the surface organic horizon is very variable, and although profiles with strong formation of leached and depositional horizons can be found, there is, on the whole, less marked profile development than might be expected from a relatively permeable acid parent material under high rainfall.

20. Peaty Podzol and Peaty Gley Podzol (S.21), Peaty Gley (S.22), Deep Peaty Soil (S.34), Basin Peat (S3).
In the main extent of Unit 20 south of Llyn Llydaw, the drift hummocks carrying Peaty Podzols are more widely spaced than in Unit 19, with intervening gentler slopes which carry Peaty Gleys, and hollows which contain Basin Peat. In the latter, birch remains are present at approximately 1,800 ft. near the track leading from Llyn Llydaw to Y Lliwedd. Soils on soliflucted drift near Pen-y-pass have also been mapped within Unit 20.

21–24. Units 21–24 overlie drift derived mainly from rhyolitic and Bedded Pyroclastic Series rocks.

21. Brown Earth with Gleying, Gley (S.33).
Unit 21 occupies two small areas, south of Afon Glaslyn in Cwm Dyli, which are surrounded by Basin Peat. The parent material of these soils is thought to be transitional between colluvium formed from rocks of the Bedded Pyroclastic Series (Unit 11) and drift derived mainly from rhyolitic rocks

(Unit 19). The rapidity of profile change is very great, and some of the soils are imperfectly drained Brown Podzolic variants which compare with those found in Unit 23.

22. Brown Podzolic Soil (S.23).
The principal area of Unit 22 is mapped on the largest of the moraine ridges in Cwm Tregalan. The contribution of Bedded Pyroclastic Series rocks to the drift is thought to be responsible for these soils being less podzolic than those on dominantly rhyolitic drift (for example, S.21).

23. Brown Podzolic Soil (S.23), Deep Peaty Soil (S.24).
Between the main Cwm Tregalan moraine ridge and the scree slope to its north-west, an area mapped as Unit 23 is a complex of drift mounds with peat-filled hollows. Soil S.24 was sampled as a shallow variant of the peaty soils to indicate the type of mineral material which underlies the peat. This apparently includes alluvial wash from the scree slopes of Unit 14. A small area south of the Afon Glaslyn near the mouth of Cwm Dyli also consists of Brown Podzolic variants on hummocks separated by peaty flushes. The drift parent material of the latter area contains some dolerite.

24. Peaty Podzol and Peaty Gley Podzol (S.25, S.26).
Unit 24 is mapped north-west of Llyn Llydaw and also north-west of the Cwm y llan slate quarry. Intergrades to Peaty Gleys and Deep Peaty Soils are found in Cwm Dyli. Soils of Unit 24 have a slightly higher pH and base status than the peaty variants on ryolite drift (Unit 19), which is tentatively attributed to a greater content of Bedded Pyroclastic rocks in the parent material of the former. Unit 24 in Cwm y llan occupies a smooth slope of soliflucted till, in which the proportion of slate increases to the south and east.
In a representative cross-transect, the soils were Peaty Podzolic variants (80 per cent) with subordinate Peaty Gleys (10 per cent), shallow peat on indurated drift (5 per cent), and Brown Podzolic Soils (5 per cent) (Table 5, p. 89).

25. Brown Podzolic Soil (S.27, S.28) on drift derived mainly from rhyolitic rocks and dolerite.
Unit 25 is mapped in eastern Cwm Dyli, where the drift contains a substantial dolerite contribution, giving rise to soils with a less strongly developed podzolic character than those found on mainly rhyolitic drift in similar topographic situations. Profile S.27 is typical of the Brown Podzolic Soils in Unit 25, while profile S.28 is transitional between this and the Peat Ranker on dolerite outcrops (S.20 in Unit 18), both being sampled in a sector where Bedded Pyroclastic Series rocks also contribute to the drift. Below Craig Llyn-Teyrn patches of dolerite block scree occur.

26–29. Units 26–29 overlie drift derived mainly from rhyolitic rocks, Bedded Pyroclastic Series rocks and slate.

26. Brown Podzolic Soil (S.29).
Unit 26 is mapped near Plascwmllan and fringing Llyn Gwynant, partly occupying enclosed fields. Former intensive grazing or possible cultivation

in Cwm y llan may be responsible for the present profile characteristics which contrast with the more podzolic profiles of the adjacent Unit 27.

27. Peaty Podzol and Peaty Gley Podzol (S.30), Peaty Gley (S.31).
Unit 27 occupies moderately steep slopes near the slate quarry in Cwm y llan, and also a small valley parallel to Llyn Gwynant. A cross transect from the former locality shows roughly equal extents of Peaty Podzols (45 per cent) and Peaty Gleys (35 per cent) with subordinate Deep Peaty Soils (10 per cent) and rock or boulders (10 per cent) (Table 5).

28. Peaty Gley (S.31), Peat Ranker, Deep Peaty Soil (S.36).
Unit 28 is mapped in southern Cwm y llan and around Bylchau Terfyn. As in Unit 4, there is both a range of Soil Groups and a variation in parent material. Other units dominated by drift-derived soils contain areas of rock outcrop and soils of Peat Ranker type, but in Unit 28 the latter is the most extensive Sub-Group. Cross-transects showed Peat Rankers on rhyolite to comprise 48 per cent, with Peaty Gleys (20 per cent), Deep Peaty Soils (20 per cent), and subordinate rock outcrops (5 per cent), peat on drift (5 per cent) and Brown Podzolic Soils (2 per cent) (Table 5). In order to retain only a simplified classification of parent materials as either rock-derived or drift-derived, Unit 28 has been grouped with the adjacent drift-dominated units. A further complication is the presence, as in Unit 4, of small areas of rocks of the Bedded Pyroclastic Series which, where they outcrop, for example near an old mine (SH 615517), carry Brown or Peat Rankers.

29. Peaty Podzol and Peaty Gley Podzol (S.30), Peaty Gley (S.31), Peat Ranker, Deep Peaty Soil (S.36).
Unit 29, mapped in the central sector of the valley floor of Cwm y llan, occupies gentle to moderate slopes dominated by Peaty Gleys, which contrast with adjacent areas of Basin Peat to the north and west, with the complex rock and drift areas to the east, and with Peaty Podzols on steeper slopes. However, small proportions of these other soils occur within the unit, as seen from the cross-transect data which show Peaty Gleys (55 per cent), Peaty Podzols (15 per cent), Peat Rankers (10 per cent), Deep Peaty Soils (7 per cent), peat on drift (9 per cent) and rock outcrops (4 per cent) (Table 5).

(4) *Discussion*

Chemical data for the representative soil profiles are tabulated in Appendix 2. Simple quantitative trends cannot be clearly distinguished from these data. It has been found from earlier work with soils of Unit 10 that there are large spatial variations in soil chemical quantities from point to point in a "uniform" soil (Ball and Williams, 1968), and therefore the figures quoted can be taken only as indicative of the general nutrient status and composition of the respective soils.

From an agricultural standpoint, the calcium content in all soils other than S.11 (Peat Ranker on Bedded Pyroclastic Series rocks at low altitude), would be termed low or very low. For phosphate, all soils, except for the surface horizon of Peaty Podzol S.15, would be similarly classified; but potassium in the surface horizons of about half the sampled profiles (that is those with exchangeable K greater than 0·5 milli-equivalents per 100 g. soil), would be thought of as medium to high. Even the

Table 5. *Quantitative assessment of proportion of soil sub-groups in complex mapping units, Cwm y llan*

Mapping Unit	Classification	Grid References	Soil types on cross transects (borings at 10 ft. intervals on 50 ft. transects at 90° to each other from central point, i.e. 20 observations per transect)							
			Peat Rankers	Peat Ranker Variant: Peat on Drift	Brown Podzolic Soils	Peaty Podzols-Peaty Gley Podzols	Podzol-Gley Inter-grades	Peaty Gleys	Deep Peaty Soils	Rock, Boulder, Stream Bed
3	Basin Peat	61165230		5				5	10	
		611522							20	
24	Peaty Podzol and Peaty Gley Podzol on drift mainly derived from rhyolitic and Bedded Pyroclastic Series rocks	61035272		1	1	14	2	2		
27	Peaty Podzol and Peaty Gley Podzol, Peaty Gley on drift mainly derived from Rhyolitic rocks Bedded Pyroclastic Series rocks and slate	613522				9		7	2	2
28	Peaty Gley, Peat Ranker, Deep Peaty Soil on drift as 27	615517	8	2				8	1	1
		613517	7	2	2			3	5	1
		611518	13					3	4	
		612520	10					2	6	2
29	Peaty Podzol and Peaty Gley Podzol, Peaty Gley, Peat Ranker, Deep Peaty Soil on drift as 27 ..	613521	2	5				10	3	
		610521		2		2	2	12	1	1
		610520		2		2		11	3	2
		60645200	8			5		6		1
		61425263				4		16		

soils of highest fertility in the Reserve, the Brown Earths on rocks of the Bedded Pyroclastic Series, are of low nutrient status compared with soils used for intensive agriculture.

The general low level of exchangeable calcium and magnesium is naturally accompanied by low pH values, but there is no statistically significant difference between the pH of the surface horizons of soils on a basis of either Sub-Groups or parent material. Table 6 summarizes the range and means of pH, and the mean levels of exchangeable Ca and Mg. Although the Brown Earths have the highest pH and a range which only just overlaps that of those soils with highly organic surface horizons, the difference is small and it is not possible to use either pH or the Ca and Mg values as simple distinctions between soils. Field recognition of profile characteristics is still the easiest means for assessing the overall properties of these upland soils.

Table 6. *Chemical parameters: surface horizons of Snowdon soils**

Soil Sub-groups on all Parent Materials (No. of samples)	pH		Exchangeable Calcium Arithmetic Mean		Exchangeable Magnesium[1] Arithmetic Mean	
	Arithmetic Mean	Range	me/100 g.	Approx. me/100 ml.[2]	me/100 g.	Approx. me/100 ml[2]
Brown Earths (4) ..	4·8	4·5–5·2	0·8	0·5	0·9	0·7
Brown Earths with Gleying (1) ..	4·8	—	0·8	0·6	1·1	0·8
Brown Podzolic Soils (6) ..	4·4	4·2–4·7	0·6	0·4	1·0	0·6
Peaty Podzols (5) ..	4·2	3·9–4·6	1·0	0·5	0·8[3]	0·4
Gleys (2) ..	5·2	5·1–5·2	2·3	1·7	0·9	0·6
Peaty Gleys (3) ..	4·3	4·2–4·3	0·7	0·3	1·0	0·6
Peat Rankers (6) ..	4·3	3·9–4·8	0·5	0·3	0·7	0·4
Peaty Soils and Peat (5) ..	4·3	4·0–4·5	1·1	0·4	1·7[3]	0·6
All Soil Groups: Bedded Pyroclastic Series Parent Material (11) ..	4·6	3·9–5·2	0·9	0·5	1·2	0·7
All Soil Groups: Other Parent Materials (21) ..	4·4	4·0–5·1	0·9	0·4	1·3	0·7

[1] Range of Mg values is relatively large compared to Ca.
[2] For explanation of conversion used see Appendix (2g).
[3] Using 4 values only, omitting extremes of 4·7 and 4·5 me Mg/100 g respectively.
* Profiles S.1 and 2 (from Rock Outcrop areas) and S.8 and 11 (woodland soils) have been omitted from the calculations.

Exchangeable potassium values, which have quite a large range, seemed to have the most promising possibilities for correlation with soil-forming factors and with other soil properties, such as organic matter content. However, only an apparent broad trend to greater exchangeable K with higher levels of organic matter was noted. This possibly resulted from increased cation exchange capacity, but other factors, including parent material, altitude, and vegetational differences, complicate so straightforward an interpretation. When a limited range of soils is considered, for example Brown Earths, Brown Earths with Gleying and Brown Podzolic Soils, all on rocks of the Bedded Pyroclastic Series, there is only a very slight correlation of K with organic matter content and no relation between K and altitude.

The carbon/nitrogen (C/N) weight ratios included in Appendix 2 give a general indication of the nature of the soil organic matter, differences in which are caused by both the chemistry of the litter and the range of decomposer species present. The mean C/N for all surface horizons is 12·5 and for all sub-surface horizons is 13·7. Lower C/N ratios are the result of faster rates of decomposition of the plant residues. No overall relationship of C/N ratio to pH is seen from the profile data as a whole but there is a broad association with Soil Group, the ratios in the surface horizon falling in the order Deep Peaty Soil and Basin Peat > Peaty Gley > Peaty Podzol > Brown Earth with Gleying > Brown Podzolic Soil > Peat Ranker > Brown Earth. If however only the soils on rocks of the Bedded Pyroclastic Series are considered, there is a trend to greater C/N ratios with increasing organic matter content, and an inverse correlation between C/N ratio and pH, which is most marked in the surface horizons, from 8·5 at pH 5·1 to 15 at pH 4·3. As with exchangeable K, there is no discernible relationship between C/N ratio and altitude.

Jenny (1941) defined the factors influencing soil formation as climate, organisms, topography, parent material and time. In attempting to relate these factors to the soils of the Reserve some general inferences can be drawn, in spite of the complexities previously discussed.

There is only a possible slight indication of the effect of climate. In Units 13 and 14, on scree formed from rocks of the Bedded Pyroclastic Series, Brown Podzolic characteristics become more apparent at higher altitudes where rainfall is greater and temperatures decrease.

An influence of macro-organisms is seen in Unit 10 where the maintenance of Brown Earth profiles is assisted by earthworms. These produce mull humus, while the cast-forming species and the moles which prey on them also serve to transfer soil from lower horizons to the surface, thus providing a check to normal leaching processes. The distribution and effects of soil micro-organisms have not been studied.

The topographic influence on soil formation is most usually seen in the catenary relationship on a single parent material under a uniform climate, where the soil is directly related to slope, but it will be clear that these conditions do not generally apply on Snowdon. However, on the drift parent material of Units 27 and 29, the steeper slopes of the former support a high proportion of the free to imperfectly drained Peaty Podzol variants while the latter is dominated by very poorly drained Peaty Gleys (Table 5, p. 89).

The effect of parent material on soil formation is the most readily distinguishable factor. The importance of the rate of weathering can be seen from Table 4, p. 81, which shows that rocks of the Bedded Pyroclastic Series are the only parent material on which a full range of Soil Groups is found. In contrast, only Peat Rankers occur on the equally widespread rhyolitic rocks (Brown Podzolic Soils in Unit 4 probably being formed on drift pockets). The dolerites and sedimentary rocks are less widespread but also give rise to only one or two Soil Groups. If distribution of Sub-Groups on different parent materials is considered, Brown Earths are found only on the Bedded Pyroclastic Series and on slate scree. Brown Podzolic Soils are developed on the widest range of parent materials, occurring to a significant extent on several rock types and on three of the four drifts. Peaty Podzol variants are widely distributed over acid drifts on moderately steep slopes but are otherwise limited to level sites underlain by rocks of the Bedded Pyroclastic Series.

Differences in rates of weathering have been discussed in Section II–(1) as a parent material aspect of soil formation. The effect of the time factor considered from another standpoint, that of different periods available for profile development on a uniform parent material, cannot be distinguished.

IV. CONCLUSION

In mapping the soils of Snowdon the published studies of its geology have provided acceptable parent material categories for areas where the soils are directly related to solid rock. Four different glacial drifts have been mapped by identifying predominant rock types in till where this underlies the soils, and in addition, observations on the relief of the deposits have enabled an interpretation of the deglaciation history of the Reserve to be made, Section II–(2). In any geological or soil survey of such a complex region, to put a boundary on a map implies a decision and confidence as to its reality that the surveyor may not always feel but which the user often infers. To those who take the accompanying maps into the field it will become apparent that some lines divide areas which are sharply differentiated from each other, but that elsewhere the boundaries are subjectively placed to separate merging units. This applies to both the Parent Material Map and the Soil Map of the present survey. Despite these considerations the units delineated clarify the broad and, in some instances, the detailed soil pattern of a small but intricate mountain area. It is hoped that the maps and their interpretation in this paper will provide a background for a wider understanding of the interplay of causal factors on soil formation in Snowdonia, where there is plainly much scope for further study of the earth sciences.

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REFERENCES

BALL, D. F. (1963). *The Soils and Land Use of the District around Bangor and Beaumaris.* Mem. Soil Survey of England and Wales. H.M.S.O., London.

BALL, D. F. (1964). Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. *J. Soil Sci.*, **15**, 84–92.

BALL, D. F. (1966a). Late-glacial scree in Wales. *Biul. peryglac.*, **15**, 151–163.

BALL, D. F. (1966b). Chlorite clay minerals in Ordovician pumice-tuff and derived soils in Snowdonia, North Wales. *Clay Miner*, **6**, 195–209.

BALL, D. F. (1967). Stone pavements in soils of Caernarvonshire, North Wales. *J. Soil Sci.*, **18**, 103–108.

BALL, D. F. and WILLIAMS, W. M. (1968). Variability of soil chemical quantities in two uncultivated Brown Earths. *J. Soil Sci.*, **19**, 379–391.

BROWN, E. H. (1960). *The Relief and Drainage of Wales.* University of Wales Press, Cardiff.

CARR, H. R. C. and LISTER, G. A. (1948). *The Mountains of Snowdonia.* Crosby Lockwood, London.

Clarke, G. R. (1957). *The Study of the Soil in the Field.* 4th Edition. Oxford University Press.
Davis, W. M. (1909). Glacial erosion in North Wales. *Quart. J. geol. Soc.*, **65**, 281–350.
Hughes, R. E. (1958). Sheep population and environment in Snowdonia (North Wales). *J. Ecol.*, **46**, 169–190.
Hughes, R. E., Milner, C. and Dale, J. (1964). Selectivity in grazing; from *Grazing in Terrestrial and Marine Environments.* Blackwell's, Oxford. 189–202.
Jehu, T. J. (1902). A bathymetrical and geological study of the lakes of Snowdonia and eastern Caernarvonshire. *Trans. Roy. Soc. Edinb.*, **40**, 419–467.
Jenny, H. (1941). *Factors of Soil Formation.* McGraw-Hill, New York.
Johnson, R. H. (1962). Some observations on the glaciation of the Aber-Glaslyn Nant Gwynant valley, North Wales. *J. Manchr. geogr. Soc.*, **58**, 41–51.
Kubiena, W. L. (1953). *The Soils of Europe.* Murby, London.
MacPhee, W. S. G. and Ball, D. F. (1967). Routine determination of calcium and magnesium in soil extracts by atomic absorption spectrophotometry. *J. Sci. Fd. Agric.*, **18**, 376–380.
The Nature Conservancy. (1966). *Cwm y Llan Nature Trail.* (Nature Conservancy, Bangor.)
The Nature Conservancy. (1968). *The Miners Track.* (Nature Conservancy, Bangor.)
Neill, J. and Neill, R. (1963). The copper mines of Snowdon. *Climber's Club Journal*, **88**, 70–77.
Ramsay, A. C. (1860). *The Old Glaciers of Switzerland and North Wales.* Longman, Green & Co., London.
Ramsay, A. C. (1866). *The Geology of North Wales.* Mem. Geol. Surv. Gt. Brit. H.M.S.O., London.
Roberts, E. (1958). *The County of Anglesey, Soils and Agriculture.* Mem. Soil Survey of England and Wales. H.M.S.O., London.
Seddon, B. (1957). Late-glacial cwm glaciers in Wales. *J. Glaciol.*, **22**, 94–99.
Seddon, B. (1962). Late-glacial deposits at Llyn Dwythwch and Nant Ffrancon, Caernarvonshire. *Phil. Trans. R. Soc. B.*, **244**, (No. 716), 459–481.
Watson, E. (1960). Glacial landforms in the Cader Idris area. *Geography*, **45**, 27–38.
Williams, H. (1927). The geology of Snowdon (North Wales). *Quart. J. geol. Soc.*, **83**, 346–431.

APPENDIX (1)

SOIL PROFILE DESCRIPTIONS

Profiles S.1–S.36 are those quoted in Section III (3). The reference code in brackets is a laboratory index. The nomenclature of the description is a modification of that used in the Field Handbook of of the Soil Survey of England and Wales (after Clarke, 1957).

	S.1	S.2
Soil Sub-Group and Parent Material	Crevice Soil (Ranker) on Rhyolitic Series Outcrops (Lab. No. XR35).	Eroded Soil (Ranker) on Rhyolitic Series Rocks (CLRG5).
Location	Crib-y-ddysgl. (617552)	South slope of Y Lliwedd, Cwm y llan. (622533)
Relief	Crest of steep ridge. Aspect: 100° Grid.	Steep slope (*c.* 30°). Aspect: 160° Grid.
Altitude	3,100 ft.	2,900 ft.
Drainage	Excessively drained profile in shedding site.	Excessively drained profile in normal site.
	0–6″. Very dark grey brown—very dark grey (10 YR 3/2–3/1) gravelly sandy loam, abundant flakes of rhyolitic ash; weak medium crumb structure; good porosity; slightly compact; moderate organic matter, higher in top inch; abundant roots; diffuse boundary:	0–8″. Dark greyish brown (10 YR 3/2) loose sandy loam, abundant stones and boulders of rhyolitic; over boulders.
	6–12″. Very dark grey (10 YR 3/1) gravelly sandy loam; abundant flakes of rhyolitic ash, weak medium crumb structure; good porosity; loose; moderate organic matter; abundant roots; moist; over rock.	

	S.3	S.4
Soil Sub-Group and Parent Material	Basin Peat. (CL28)	Peat Ranker on Rhyolitic Series Outcrops. (CL20)
Location	South end of Llyn Teyrn, Cwm Dyli. (64055465)	Near Pen-y-pass. (645551)
Relief	Level ground at head of lake.	15° slope on rocky ledge on general 25° slope. Aspect: 80° Grid.
Altitude	1,300 ft.	1,500 ft.
Drainage	Very poorly drained profile in receiving site.	Imperfectly drained profile in normal site.
	0–6″. Black (10 YR 2/1) organic; weak small crumb structure; poor porosity; greasy; peaty fibrous organic matter; abundant roots; wet; merging boundary:	0–2″. Moss litter.
	6–24″+. Black (10 YR 2/1) organic; massive; poor porosity; greasy; peaty amorphous organic matter; abundant roots; wet; birch twigs present.	2–7″. Black (10 YR 2/1) organic; few small stones (rhyolitic); weak crumb structure; good porosity; greasy; peaty pseudo-fibrous organic matter; abundant roots; wet; over rock outcrop.

	S.5	S.6
Soil Sub-Group and Parent Material	Peat Ranker on Rhyolitic Series Rocks. (CLRG4)	Brown Earth on Bedded Pyroclastic Series Rocks. (IBPS3)
Location	Southern slopes of Y Lliwedd, Cwm y llan. (622530)	North-east end of Llydaw, Cwm Dyli. (639550)
Relief	30–35° slope on block scree. Aspect: 180° Grid.	On 25° uniform colluvial slope beneath pumice tuff cliffs. Aspect: 220° Grid.
Altitude	2,500 ft.	1,600 ft.
Drainage	Freely drained profile in normal site.	Freely drained profile in normal site.
	0–6″. Black (7.5 YR 2/0) organic; few stones (rhyolitic); weak small crumb structure; peat in hollows among boulders.	0–6″. Very dark greyish brown (10 YR 3/2) loam to silty loam, frequent small and few large stones (Bedded Pyroclastic Series rocks); strong large crumb structure; good porosity; friable; moderate organic matter; abundant roots; moist; few earthworms and earthworm channels to 24″; diffuse boundary:
		6–12″. Dark greyish brown (10 YR 4/2) loam to silty loam, stones as horizon above; moderate cloddy structure breaking to medium crumb; good porosity; slightly compact; low organic matter; frequent roots; moist; merging boundary:
		12–16″. Dark yellowish brown (10 YR 4/4–4/6); otherwise as horizon above; diffuse boundary:
		16″+. As above, but faint grey mottle; over colluvial loam, to 36″+.

	S.7	S.8
Soil Sub-Group and Parent Material	BROWN EARTH ON BEDDED PYROCLASTIC SERIES ROCKS. (CL18)	BROWN EARTH ON BEDDED PYROCLASTIC SERIES ROCKS. (XP38)
Location	East of Llyn Llydaw–Y Lliwedd path, Cwm Dyli. (633538)	Woods at foot of Gallt y Wenallt, Nantgwynant. (650532)
Relief	35° slope beneath cliffs. Aspect: 320° Grid.	Steep slope between cliffs and river. Aspect: 100° Grid.
Altitude	1,750 ft.	350 ft.
Drainage	Freely to excessively drained profile in normal site.	Freely drained profile in normal site.
	0–4″. Banded very dark grey (10 YR 3/1) and black (10 YR 2/1) sandy loam, rare small stones (Bedded Pyroclastic series rocks); moderate crumb structure; good porosity; friable; high organic matter; abundant roots; wet; diffuse boundary: 4–12″+. Very dark greyish brown (10 YR 3/2) sandy loam, rare small stones (Bedded Pyroclastic series rocks); strong medium crumb structure; good porosity; friable; moderate organic matter; frequent roots; moist; over colluvial loam to 20″+.	0–$\frac{1}{2}$″. Very dark brown (10 YR 2/2) loam to silty loam, abundant angular stones (Bedded Pyroclastic series rocks); moderate crumb structure; good porosity; friable; high organic matter; abundant roots; moist; frequent small earthworms, sharp boundary: $\frac{1}{2}$–18″+. Dark brown (10 YR 3/3) loam to silty loam; stones as horizon above; moderate crumb; good porosity; friable; moderate organic matter; abundant tree roots; moist; frequent small earthworms; over stony colluvium.

	S.9	S.10
Soil Sub-Group and Parent Material	BROWN PODZOLIC SOIL ON BEDDED PYROCLASTIC SERIES ROCKS. (CL14)	PEAT RANKER ON BEDDED PYROCLASTIC SERIES OUTCROPS. (CL16)
Location	Opposite sheepfold by Afon Ferch, Cwm Merch. (63375269)	Adjacent to former tramway above Coed-yr-allt. (627520)
Relief	25° slope on top of rocky spur, steeper slope below. Aspect: 260° Grid.	On 35° slope above tramway. Aspect: 140° Grid.
Altitude	1,300 ft.	1,000 ft.
Drainage	Freely drained profile in shedding site.	Freely drained profile in normal site.
	0–7″. Black (5 YR 2/1) silty loam, few subangular stones (Bedded Pyroclastic Series rocks); weak small crumb structure; good porosity; friable; high organic matter; abundant fine fibrous roots; moist; merging boundary: 7–14″. Dark reddish brown (2·5 YR 2/4) sandy silty loam, stones as horizon above; weak crumb structure; good porosity; friable; moderate organic matter; frequent fine fibrous roots; moist; diffuse boundary. 14–20″. Dark brown (7·5 YR 3/2) sandy silty loam, stones as horizon above; weak small crumb structure; good porosity; friable; moderate organic matter; few fine fibrous roots; moist; variable depth; over rock.	0–6″. Very dark brown (10 YR 2/2) organic loam, rare stones (Bedded Pyroclastic Series rocks); small crumb structure; moderate porosity; fibrous; peaty fibrous organic matter; abundant fine roots; moist; over rock.

	S.11	S.12
Soil Sub-Group and Parent Material	PEAT RANKER ON BEDDED PYROCLASTIC SERIES OUTCROPS. (XP39)	DEEP PEATY SOIL ON BEDDED PYROCLASTIC SERIES ROCKS. (CL15)
Location	Near base of Clogwyn y Bustach, Nantgwynant. (650534)	By Afon y Ferch, Cwm Merch. (63445237)
Relief	Ledge on very steep cliff. Aspect: 140° Grid.	Slight slope near edge of small basin. Aspect: 320° Grid.
Altitude	600 ft.	1,100 ft.
Drainage	Excessively drained profile in normal site.	Very poorly drained profile in receiving site.
	0–3″. Black (7·5 YR 2/0) organic loam, few small stones (Bedded Pyroclastic Series rocks); small crumb structure; good porosity; fluffy; very high organic matter; abundant roots; moist over rock.	0–8″. Black (10 YR 2/1) organic; weak large crumb structure; moderate porosity; sticky; very high organic matter; abundant fine fibrous roots; wet; diffuse boundary. 8–24″. Black (10 YR 2/1) organic; massive structure; moderate porosity; greasy; peaty; fibrous organic matter; few fine roots; wet; diffuse boundary. 24–30″+. Very dark grey (10 YR 3/1) organic; massive structure; poor porosity; greasy; peaty amorphous organic matter; rare roots; wet.

	S.13	S.14
Soil Sub-Group and Parent Material	BROWN EARTH WITH GLEYING ON BEDDED PYROCLASTIC SERIES ROCKS. (CL19)	PEATY GLEY ON BEDDED PYROCLASTIC SERIES ROCKS. (CL30)
Location	Small depression near ridge above the Miners' Track near Pen-y-pass. (645553)	200 yds. south of farm ruins, Cwm Dyli. (646538)
Relief	Uniform 20° slope. Aspect: 80° Grid.	Small stream hollow, 5° slope. Aspect: 200° Grid.
Altitude	1,500 ft.	1,300 ft.
Drainage	Imperfectly drained profile in normal site.	Poorly drained profile in normal site.
	0–3″. Very dark brown (10 YR 2/2) silty loam, few stones (Bedded Pyroclastic Series rocks); cloddy structure breaking to crumb; good porosity; friable; high organic matter; abundant roots; moist; diffuse boundary. 3–6″. Very grey brown (10 YR 3/2); as above except frequent roots; sharp boundary. 6–11″. Brown (10 YR 5/3) mottled with grey-brown loam, few stones (Bedded Pyroclastic Series rocks, and rhyolite); cloddy structure breaking to strong medium crumb; good porosity; friable; low organic matter; few fine roots; moist; over rock.	0–9″. Black (7·5 YR 2/0) organic; cloddy structure breaking to weak fine crumb; moderate porosity; greasy; peaty amorphous organic matter; abundant fine and few medium roots; wet; merging boundary. 9–11″. Dark reddish brown (5 YR 3/2) clay loam, few large and medium angular stones (Bedded Pyroclastic Series rocks); moderate medium crumb structure; moderate porosity; sticky; moderate organic matter; few medium fibrous roots; moist; merging boundary. 11–19″. Pale brown (10 YR 6/3) with greyer and yellowish mottles, as horizon above except for mod-

erate cloddy structure, low organic matter and diffuse boundary.
19–25″+. Light olive grey (5 Y 6/2) rotted Bedded Pyroclastic Series rock; passing to harder rock below

	S.15	S.16
Soil Sub-Group and Parent Material	PEATY PODZOL ON BEDDED PYROCLASTIC SERIES ROCKS. (XP61)	BROWN EARTH ON SCREE FORMED FROM BEDDED PYROCLASTIC SERIES ROCKS. (CL26)
Location	Above eastern end of Llyn Llydaw, Cwm Dyli. (638552)	Below cliffs west of Cwm Tregalan moraine. (610353)
Relief	5° slope, on ridge crest between rock outcrops. Aspect: 180° Grid.	Uniform 15° colluvial slope. Aspect. 160° Grid.
Altitude	1,750 ft.	1,600 ft.
Drainage	Imperfectly drained profile in shedding site. 0–4″. Very dark brown (10 YR 2/2) organic, rare stones (Bedded Pyroclastic Series rocks); massive structure breaking to cloddy; good porosity; greasy; peaty pseudo-fibrous organic matter; abundant roots; moist; merging boundary. 4–8″. Black (10 YR 2/1) otherwise as horizon above; merging boundary. 8–10″. Very dark brown (10 YR 2/2–3/2) silty loam, stones as horizon above; moderate large cloddy structure; good porosity; greasy; high organic matter; frequent roots; moist; merging boundary. 10–11″. Brown (10 YR 4/3) speckled with orange brown silty loam, few stones (Bedded Pyroclastic Series rocks); moderate large cloddy structure; good porosity; initially compact, breaking to friable; moderate organic matter concentrated in cavities and old root channels; frequent roots; moist; merging boundary. 11–18″. Dark brown (7·5 YR 3/4) lightly mottled with duller grey and brighter yellow brown, and traversed by dark brown humose channels, silty clay loams; frequent small stones (Bedded Pyroclastic Series rocks); moderately massive structure breaking to cloddy; good porosity; initially moderate organic matter; frequent roots; moist. 18″+. Brown weathered shattered rock.	Freely drained profile in normal site. 0–2″. Very dark brown (10 YR 2/2) organic, loam to sandy loam, abundant small to medium stones (Bedded Pyroclastic Series rocks); weak small crumb structure; good porosity; greasy; high organic matter; abundant roots; moist; few small earthworms; merging boundary. 2–14″. Brown (7·5 YR 4/2) loam to silty loam, stones as in horizon above but fewer; moderate medium crumb structure; good porosity; friable; low organic matter; abundant roots; moist; uneven boundary; over rock or boulder scree at variable depth.

	S.17	S.18
Soil Sub-Group and Parent Material	Brown Podzolic Soil on Scree Formed from Bedded Pyroclastic Series Rocks. (CL25)	Peat Ranker on Gwastadnant Grit Outcrops. (CL32)
Location	Above Yr Wyddfa—Y Lliwedd path, near Bwlchysaethau. (615541)	Below Bwlch Maderin, opposite South Snowdon slate tips, Cwm y llan. (607528)
Relief	Broken rocky 25° slope with outcrops, 30 yds. below crest of ridge. Aspect: 200° Grid.	On small ledge of 15° slope on steeper rocky slope. Aspect: 120° Grid.
Altitude	2,600 ft.	1,500 ft.
Drainage	Freely drained profile in normal site	Imperfectly drained profile in shedding site.
	0–2″. Dark grey (7·5 YR 4/0) silty loam, rare small and medium angular stones (Bedded Pyroclastic Series rocks); moderate medium crumb structure; poor porosity; fibrous; friable; moderate organic matter; frequent roots; moist; diffuse boundary. 2–7″. Dark grey (10 YR 4/1) with rusty mottles along root channels, silty loam, few small angular stones (Bedded Pyroclastic Series rocks); strong medium crumb structure; moderate porosity; friable; moderate organic matter; few fine roots; moist: merging boundary. 7–30″+. Yellowish brown (10 YR 5/8) with reddish mottles, sandy loam, rare large and frequent small angular stones (Bedded Pyroclastic Series rocks); weak small crumb structure; moderate porosity; friable; low organic matter; rare fine roots; moist.	0–3″. Black (10 YR 2/1) organic; rare stones (Gwastadnant Grit); weak small crumb structure; moderate porosity; fluffy; peaty fibrous organic matter; abundant fine roots; moist; diffuse boundary. 3–9″. Black (10 YR 2/1) organic, rare stones as horizon above; weak massive structure, breaking to weak small crumb; poor porosity; friable; peaty pseudo-fibrous organic matter; frequent fine roots; moist; over rock.

	S.19	S.20
Soil Sub-Group and Parent Material	Brown Earth (Immature) on Scree Formed from Llandeilo Slate. (CL33)	Peat Ranker on Dolerite Outcrops. (CL20)
Location	North-east of Bwlch Cwmllan. (608525)	Cliff face of Clogwyn Pen-llechen, Cwm Dyli. (64015449)
Relief	Uniform 20° slope. Aspect: 80° Grid.	15° sloping ledge on 70° cliff. Aspect: 180° Grid.
Altitude	1,450 ft.	1,300 ft.
Drainage	Freely drained profile in normal site.	Excessively drained profile in normal site.
	0–2″. Black (10 YR 2/1) silty loam, abundant large, medium and small angular stones (slate); massive structure; moderate porosity; compact fibrous; very high organic matter; abundant fine and few medium roots; wet; diffuse boundary.	0–1″. Very dark brown (10 YR 2/2) organic loam, rare stones (dolerite); weak small crumb structure; good porosity; fluffy; very high organic matter; abundant roots; moist; merging boundary: 1–6″. Dark reddish brown (5 YR 2/2) organic sandy loam, frequent

2–14″+. Dark brown (7·5 YR 3/2) silty loam, abundant large, medium and small angular stones as in horizon above; weak medium crumb structure; moderate porosity; friable; moderate organic matter; frequent fine fibrous roots; moist; continuing with increasing stoniness below.

angular stones (dolerite); strong small crumb structure; good porosity; friable; high organic matter; frequent fine roots; moist; over dolerite.

	S.21	S.22
Soil Sub-Group and Parent Material	Peaty Podzol on Drift Mainly Derived From Rhyolitic Rocks. (CL21)	Peaty Gley on Drift Mainly Derived from Rhyolitic Rocks. (CL22)
Location	Near south shore at northern end of Llyn Llydaw, Cwm Dyli. (637548)	Near south shore at north-eastern end of Llyn Llydaw, Cwm Dyli, 15 yds. N.E. of S.21. (637548)
Relief	Uniform 25° slope. Aspect: 320° Grid.	Uniform 25° slope. Aspect: 320° Grid.
Altitude	1,450 ft.	1,450 ft.
Drainage	Imperfectly drained profile in normal site.	Poorly drained profile in normal site.
	0–3″. Black (10 YR 2/1) organic loam, rare medium to large stones (rhyolite); weak fine crumb structure; moderate porosity; sticky; very high organic matter; abundant fine fibrous roots; moist; merging boundary. 3–5″. Dark brown (7·5 YR 3/2) gritty clay loam, rare medium to large stones (rhyolite); weak small crumb structure; moderate porosity; friable; moderate organic matter; frequent roots; moist; merging boundary, with incipient iron pan. 5–11″. Yellowish red (5 YR 4/8) sandy clay loam, abundant stones as horizon above; weak fine crumb structure; good porosity; friable; low organic matter; rare roots; moist; merging boundary. 11–18″+. Yellowish brown (10 YR 5/6) with occasional greyish mottles, drift of very gritty sandy clay loam, abundant stones as above; weak medium crumb structure; moderate porosity; sticky; low organic matter; rare roots; moist.	0–2″. Black (10 YR 2/1) organic loam, rare stones (rhyolite); massive structure breaking to weak small crumb; poor porosity; sticky; very high organic matter; frequent fine fibrous roots; wet; merging boundary. 2–8″. Very dark brown (10 YR 2/2) as horizon above except lower organic matter and moderate cloddy structure breaking to weak fine crumb. 8–18″. Gray to greyish-brown (10 YR 5/1–5/2) with yellow-brown mottles, drift of gritty loam, abundant stones, dominantly rhyolite; weak medium to large crumb structure; good porosity; slightly sticky; low organic matter; rare roots; wet; over bedrock.

	S.23	S.24
Soil Sub-Group and Parent Material	Brown Podzolic Soil on Drift Mainly Derived from Rhyolitic and Bedded Pyroclastic Series Rocks. (CL11)	Deep Peaty Soil on Drift Mainly Derived from Rhyolitic and Bedded Pyroclastic Series Rocks. (CL27)

Location	Cwm Tregalan moraine ridge. (61055320)	Hollow between Cwm Tregalan moraine and scree slope. (611533)
Relief	10° uniform convex slope, near crest of moraine. Aspect: 180° Grid.	Level ground among hummocks of drift.
Altitude	1,600 ft.	1,550 ft.
Drainage	Freely drained profile in shedding site.	Very poorly drained profile in receiving site.
	0–4″. Black (10 YR 2/1) organic silty loam, rare stones (Bedded Pyroclastic Series rocks); strong small crumb structure; poor porosity; friable; high organic matter, abundant fine fibrous roots; moist; merging boundary. (Suggestion of stone concentration at 4″ depth.) 4–7″. Strong brown (7·5 YR 4/5) loam, few small and medium-sized subangular stones (rhyolite and Bedded Pyroclastic Series rocks); weak fine crumb structure; moderate porosity; friable; low organic matter; few fine fibrous roots; moist; merging uneven boundary: 7–14″+. Olive brown (2·5 Y 4/4) drift of gravelly sandy loam, abundant large stones (8″+) (rhyolite and Bedded Pyroclastic Series rocks); single grain structure; good porosity; friable; low organic matter; rare roots; moist.	0–6″. Brown (10 YR 3/3) organic; weak massive structure; poor porosity; fibrous; peaty fibrous organic matter; abundant roots; wet; diffuse boundary. 6–10″. Black (2·5 Y 2/0) organic, weak massive structure; poor porosity; greasy; peaty amorphous organic matter; abundant roots; wet; sharp boundary. (Depth of peat variable, generally 24″+): 10–14″. Grey (10 YR 5/1) silty loam; weak large crumb structure; poor porosity; slightly friable; moderate organic matter; frequent roots; wet; merging boundary. 14–20″. Grey (10 YR 5/1) gleyed relatively stoneless colluvium (not sampled) over rocky drift comparable to S.23, 7–14″+.

	S.25	S.26
Soil Sub-Group and Parent Material	Peaty Gley Podzol on Drift Mainly Derived from Rhyolitic and Bedded Pyroclastic Series Rocks. (CL34)	Peaty Podzol on Drift Mainly Derived from Rhyolitic and Bedded Pyroclastic Series Rocks. (XR29)
Location	300 yds. west of Afon Cwmllan, Upper Cwm y llan. (609528)	Near copper mill, north-western shore of Llyn Llydaw, Cwm Dyli. (627544)
Relief	10° slope near crest of spur. Aspect: 90° Grid.	Bouldery 25° slope. Aspect: 180° Grid.
Altitude	1,300 ft.	1,475 ft.
Drainage	Imperfectly drained profile in normal site.	Imperfectly drained profile in normal site.
	0–4″. Very dark brown (10 YR 3/2) organic, rare stones (rhyolite and Bedded Pyroclastic Series rocks); massive breaking to moderate small crumb structure; moderate porosity; friable; peaty pseudo-fibrous organic matter; abundant fine and few medium roots; moist; sharp boundary. 4–9″. Very dark greyish brown (2·5 Y 3/2) silty loam, few small and rare large, rounded and sub-	0–4″. Black (7·5 YR 2/1) organic; massive structure; poor porosity; greasy; amorphous organic matter; abundant roots; wet; diffuse boundary. 4–10″. As above but slightly less organic and with moderate cloddy structure; sharp boundary. 10–12″. Very dark grey brown (10 YR 3/2) gritty loam, frequent stones (rhyolite); weak small cloddy structure; moderate porosity;

angular stones (rhyolite); weak massive structure, breaking to strong medium crumb; moderate porosity; compact; low organic matter; few fine roots; moist; uneven merging boundary with slight iron pan.
9–13″. Dark greyish brown (10 YR 4/2) loam, frequent small and few large rounded and subangular stones as horizon above; weak fine crumb structure; moderate porosity; friable; low organic matter; rare roots; moist; diffuse boundary.
13–20″+. Olive brown (2·5 Y 4/4) loamy sandy drift; frequent small and medium stones (Bedded Pyroclastic Series rocks); weak fine crumb structure; moderate porosity; friable; very low organic matter; rare roots; moist.

sticky; moderate organic matter; few roots; wet; sharp boundary.
12–15″. Dark yellow-brown (10 YR 5/4–4/4) gritty loam, stones as horizon above; weak small crumb structure; moderate porosity; sticky; low organic matter; few roots; wet; merging boundary.
15–24″+. Light yellowish brown (10 YR 6/4) weakly mottled with grey and yellow brown, drift of loam to sandy clay loam; weak crumb structure; poor porosity; sticky; very low organic matter; soft black (Mn) concretions frequent at 18″+.

	S.27	S.28
Soil Sub-Group and Parent Material	BROWN PODZOLIC SOIL ON DRIFT MAINLY DERIVED FROM RHYOLITIC ROCKS AND DOLERITE. (XD18)	BROWN PODZOLIC SOIL/RANKER INTERGRADE ON DRIFT MAINLY DERIVED FROM RHYOLITIC ROCKS AND DOLERITE. (XD16)
Location	Southern slope of Craig Aderyn, Cwm Dyli. (639542)	Southern slope of Craig Aderyn, Cwm Dyli. (638543)
Relief	Concave 25° slope below rocky crest. Aspect: 200° Grid.	Near crest of 25° concave slope. Aspect: 180° Grid.
Altitude	1,225 ft.	1,250 ft.
Drainage	Freely drained profile in normal site.	Freely drained profile in normal site.
	0–1½″. Dark brown (7·5 YR 3/2) organic loam; few large stones (rhyolite, Bedded Pyroclastic Series rocks and dolerite); moderate crumb structure; moderate porosity; friable; high organic matter; abundant roots; moist; merging boundary. 1½–7″. Brown (7·5 YR 4/2) loam, frequent stones and few boulders as above; moderate crumb structure; good porosity; friable; moderate organic matter; abundant roots; moist; sharp boundary. 7–18″. Strong Brown to yellowish-red (7·5 YR 5/6–5 YR 5/6) loam to silty loam, abundant boulders (dolerite); weak large crumb structure; moderate porosity; weakly compact; low organic matter; frequent roots; moist; over boulders.	0–1½″. Black (10 YR 2/1) organic loam, frequent small stones (rhyolite, Bedded Pyroclastic Series rocks and dolerite); small to medium crumb structure; good porosity; moderately compact; very high organic matter; abundant roots; moist; merging boundary. 1½–3″. Very dark brown (10 YR 2/2) loam, frequent small stones as above; moderate cloddy structure; good porosity; slightly compact; high organic matter; abundant roots; moist; merging boundary. 3–12″. Brown (7·5 YR 4/4) loam, frequent small stones as above among large stones and boulders, dominantly dolerite; weak small crumb structure; good porosity; friable; low organic matter; frequent roots on boulder surfaces; moist.

	S.29	S.30
Soil Sub-Group and Parent Material	Brown Podzolic Soil/Brown Earth Intergrade on Drift Mainly Derived from Rhyolitic Rocks, Bedded Pyroclastic Series Rocks and Slate. (CLRG1)	Peaty Podzol on Drift Mainly Derived from Rhyolitic Rocks, Bedded Pyroclastic Series Rocks and Slate. (CL9)
Location	Above Plascwmllan, above field wall near mine, Cwm y llan. (622522)	Near slate quarry dressing shed, Cwm y llan. (611524)
Relief	25° uniform slope. Aspect: 200° Grid.	25° uniform slope. Aspect: 100° Grid.
Altitude	1,050 ft.	1,125 ft.
Drainage	Freely drained profile in normal site.	Freely drained profile in normal site.
	0–$1\frac{1}{2}$″. Litter mat, not supplied. $1\frac{1}{2}$–3″. Very dark grey brown (10 YR 3/2) organic; few stones (rhyolite and slate); strong small crumb structure; good porosity; friable; peaty fibrous organic matter; abundant roots; wet; sharp boundary: 3–10″. Brown-dark brown (7·5 YR 4/4) loam to sandy loam; drift with rhyolite and slate; moderate medium crumb structure; good porosity; friable; low organic matter; frequent roots; wet; continuing as stony drift below.	0–7″. Black (10 YR 2/1) organic, few large stones (grit); strong medium crumb structure; moderate porosity; friable; peaty amorphous organic matter; abundant fine fibrous roots; moist; merging boundary. 7–9″. Very dark brown (10 YR 2/2) coarse sandy loam, abundant small subangular stones (rhyolite, slate and grit); weak crumb structure; moderate porosity; friable; moderate organic matter; frequent fine fibrous roots; moist; merging boundary. 9–13″. Dark yellowish brown (10 YR 3/4) sandy loam; abundant small rounded and subangular stones, as horizon above; weak small crumb structure; moderate porosity; friable; low organic matter; frequent fine fibrous roots; moist; diffuse boundary. 13–19″. Dark yellowish brown (10 YR 3/4) gravelly sandy loam, as above but good porosity and few roots; merging boundary. 19–30″+. Olive (5 Y 4/3) gravelly sandy loamy drift; abundant small and rare large stones as above; good porosity; friable; no organic matter.

	S.31	S.32
Soil Sub-Group and Parent Material	Peaty Gley on Drift Mainly Derived from Rhyolitic Rocks, Bedded Pyroclastic Series Rocks and Slate. (CL10)	Gley on Bedded Pyroclastic Series Rocks. (CL42)
Location	Between quarry and former tramway, Cwm y llan. (61315222)	East of site of Hafod, Cwm Dyli. (647539)
Relief	15° uniform slope. Aspect: 40° Grid.	On 10° slope at foot of steeper slope. Aspect: 0° Grid.
Altitude	1,100 ft.	1,125 ft.

Drainage	Poorly drained profile in normal site. 0–3″. Black (10 YR 2/1) organic, rare stones (slate and rhyolite); moderate crumb structure; poor porosity; sticky; peaty, amorphous organic matter; abundant fine fibrous roots; wet; sharp boundary. 8–14″. Greyish brown (10 YR 5/2) clay loam, few angular stones (rotted slates); small crumb structure; poor porosity; sticky; very low organic matter; few fine fibrous roots; wet; diffuse boundary. 14–36″+. Olive (5 Y 5/3) gravelly sandy loamy drift; abundant small subangular stones (slate, rhyolite and quartz); weak crumb structure; moderate porosity; sticky; no organic matter; rare roots; wet.	Poorly drained profile in normal site. 0–10″. Dark grey (10 YR 4/1) loam to silty loam, rare stones; moderate medium crumb structure; moderate porosity; greasy; high organic matter; abundant roots; wet; few earthworms; sharp boundary. 10–20″+. Light olive brown (2·5 Y 5/4) loam to silty loam, frequent large and small subangular stones (Bedded Pyroclastic Series rocks); cloddy; moderate porosity; friable; low organic matter; frequent roots; wet.
	S.33	S.34
Soil Sub-Group and Parent Material	GLEY ON DRIFT MAINLY DERIVED FROM RHYOLITIC AND BEDDED PYROCLASTIC SERIES ROCKS. (CL41)	DEEP PEATY SOIL ON DRIFT MAINLY DERIVED FROM RHYOLITIC ROCKS. (CL40)
Location	South of Afon Glaslyn, near site of Hafod, Cwm Dyli. (644539)	Near southern shore of Llyn Llydaw. (633544)
Relief	10° slope near crest of drift mound. Aspect: 315° Grid.	Basin site on level ground.
Altitude	1,125 ft.	1,420 ft.
Drainage	Poorly drained profile in normal site. 0–5″. Dark greyish brown (10 YR 4/2) with small orange mottles along root channels; silty loam, few small stones (rhyolite and Bedded Pyroclastic Series rocks); massive, breaking to weak small crumb structure; moderate porosity; sticky; moderate organic matter; abundant roots; wet; few earthworms; merging boundary. 5–12″. Light olive brown (2·5 Y 5/4) with strong brown (7·5 YR 5/8) mottles, sandy loam, frequent small and large stones as above; cloddy, breaking to weak medium crumb structure; moderate porosity; weakly friable; low organic matter; few roots; wet; merging boundary. 12–20″+. Light yellowish brown (10 YR 6/3–6/4) with olive mottles, sandy loamy drift; frequent stones as above; massive structure; poor porosity; sticky; low organic matter; rare roots; wet.	Very poorly drained profile in receiving site. 0–8″. Black (5 YR 2/1) organic, rare stones; poor porosity; greasy; peaty fibrous organic matter; abundant roots; wet; merging boundary. 8–20″+. Very dark brown (10 YR 2/2) organic; rare stones; poor porosity; greasy; peaty amorphous organic matter; abundant roots; wet.

CLASSIFICATION ACCORDING TO SUB-GROUP AND PARENT MATERIAL OF THE DESCRIBED SOIL PROFILES

Soil Sub-Group	Parent Material	Profile Number
Brown Earth of Low Base Status ..	Bedded Pyroclastic Series	S.6, 7, 8
Brown Earth of Low Base Status ..	Bedded Pyroclastic Series scree	S.16
Brown Earth of Low Base Status ..	Llandeilo slate scree	S.19
Brown Earth with Gleying	Bedded Pyroclastic Series	S.13
Brown Earth with Gleying	Drift mainly derived from rhyolitic and Bedded Pyroclastic Series rocks	—
Brown Podzolic Soil	Rhyolitic Series	—
Brown Podzolic Soil	Bedded Pyroclastic Series	S.9
Brown Podzolic Soil	Bedded Pyroclastic Series scree	S.17
Brown Podzolic Soil	Llandeilo slate and Gwastadnant grit	—
Brown Podzolic Soil	Llandeilo slate scree	—
Brown Podzolic Soil	Drift mainly derived from rhyolitic and Bedded Pyroclastic Series Rocks	S.23
Brown Podzolic Soil	Drift mainly derived from rhyolitic rocks and dolerite	S.27, 28
Brown Podzolic Soil	Drift mainly derived from rhyolitic rocks, Bedded Pyroclastic Series rocks and slate	S.29
Peaty Podzol	Bedded Pyroclastic Series	S.15
Peaty Podzol	Drift mainly derived from rhyolitic rocks	S.21
Peaty Podzol	Drift mainly derived from rhyolitic and Bedded Pyroclastic Series rocks	S.25, 26
Peaty Podzol	Drift mainly derived from rhyolitic rocks, Bedded Pyroclastic Series rocks and slate	S.30
Gley	Bedded Pyroclastic Series	S.32
Gley	Drift mainly derived from rhyolitic and Bedded Pyroclastic Series rocks	S.33
Peaty Gley	Bedded Pyroclastic Series	S.14
Peaty Gley	Drift mainly derived from rhyolitic rocks	S.22
Peaty Gley	Drift mainly derived from rhyolitic rocks, Bedded Pyroclastic Series rocks and slate	S.31
Peat Ranker	Rhyolitic Series	S.4, 5
Peat Ranker	Rhyolitic Series scree	S.35
Peat Ranker	Bedded Pyroclastic Series	S.10, 11
Peat Ranker	Llandeilo slate and Gwastadnant grit	S.18
Peat Ranker	Dolerite	S.20
Deep Peaty Soil	Bedded Pyroclastic Series	S.12
Deep Peaty Soil	Drift mainly derived from rhyolitic rocks	S.34
Deep Peaty Soil	Drift mainly derived from rhyolitic and Bedded Pyroclastic Series rocks	S.24
Deep Peaty Soil	Drift mainly derived from rhyolitic rocks, Bedded Pyroclastic Series rocks and slate	S.36
Basin Peat	—	S.3

	S.35	S.36
Soil Sub-Group and Parent Material	PEAT RANKER ON SCREE FORMED FROM RHYOLITIC ROCKS. (CL43)	DEEP PEATY SOIL ON DRIFT MAINLY DERIVED FROM RHYOLITIC ROCKS, BEDDED PYROCLASTIC SERIES ROCKS AND SLATE. (CL44)
Location	On edge of erosion gully below Craig-ddu, Cwm y llan. (619525)	Near former tramway opposite the south end of the slate tips, Cwm y llan. (613521)

Relief	35° slope below cliff. Aspect: 180° Grid.	10° slope close to edge of basin site. Aspect: 45° Grid.
Altitude	1,100 ft.	1,175 ft.
Drainage	Excessively drained profile in shedding site.	Poorly drained profile in receiving site.
	0–6″. Very dark brown to very dark greyish brown (10 YR 3/1–3/2) organic; abundant angular stones (rhyolite); moderate small crumb structure; high porosity; fluffy; high organic matter; abundant roots; moist; over scree.	0–3″. Fibrous *Sphagnum* mat; not sampled. 3–14″. Very dark brown to very dark greyish brown (10 YR 3/1–3/2) organic; rare stones; amorphous; very poor porosity; greasy; high organic matter; abundant roots; wet; merging boundary: 14–18″+. Black (10 YR 2/1) organic, as above but frequent roots; over drift.

APPENDIX (2)

CHEMICAL ANALYSIS TECHNIQUES

(a) pH

A suspension of 10 g. field-moist soil in 25 ml. distilled water was prepared with thorough mixing. After allowing the suspension to stand for 30 minutes, the pH was measured using a meter.

Other analytical data are given on a weight basis on that part of the soil which passes a 2 mm. sieve after air-drying (35° C.) and light grinding.

(b) Loss-on-ignition.

Loss-on-ignition was determined as the percentage weight loss of oven-dry (105° C.) soil after ignition for 16 hours at 375° C. This is a measure of total organic matter from which organic carbon can be calculated (Ball, 1964). Organic carbon $=0 \cdot 458 \times$ loss-on-ignition $-0 \cdot 4$.

(c) Total Nitrogen.

Total nitrogen was determined on oven-dry (105° C.) soil on a weight percentage basis.

(d) Carbon/Nitrogen Ratio.

The carbon/nitrogen ratio is expressed as a weight ratio of organic carbon, calculated from the loss-on-ignition figure, to total nitrogen.

(e) Exchangeable Cations.

Exchangeable cations were extracted by shaking 5 g. soil with 200 ml. neutral N ammonium acetate for one hour, then filtering the extract for analysis. Individual cations were determined as follows: calcium, magnesium and manganese by atomic-absorption spectrophotometry (Ca and Mg by the procedure of Macphee and Ball, 1967); potassium and sodium by flame photometry.

The quantities are quoted as milli-equivalents per 100 g. air-dry (35° C.) soil. These values can be converted to mg. of oxide/100 g. by multiplying by the following factors: CaO : X28, MgO : X20, K_2O : X47, Na_2O : X31, and MnO : X35·5.

(f) Extractable Phosphate.

Phosphate was extracted by shaking 5 g. soil with 200 ml. N/2 acetic acid for one hour, then filtering the extract for analysis. Phosphate was determined by the molybdate blue colorimetric method. The quantities are quoted as mg. P_2O_5/100 g. air-dry soil.

(g) Approximate conversions to a volume basis.

Conversion of exchangeable cations and extractable phosphate from an equal weight to an equal volume basis can be made for air-dry fine earth using the following approximate conversion factors:

Loss-on-Ignition range %	Approximate Conversion Factor
0–5	me/100 g. × 1·0 = me/100 ml.
6–10	me/100 g. × 0·9 = me/100 ml.
11–20	me/100 g. × 0·8 = me/100 ml.
21–30	me/100 g. × 0·7 = me/100 ml.
31–50	me/100 g. × 0·6 = me/100 ml.
51–70	me/100 g. × 0·5 = me/100 ml.
71–90	me/100 g. × 0·4 = me/100 ml.
91–100	me/100 g. × 0·3 = me/100 ml.

Chemical Data For Soil Profiles

Profile Number	pH	Loss-on-Ignition % W/W	Total Nitrogen % W/W	Carbon/Nitrogen Ratio W/W	Exchangeable Cations (me/100 g. Air-Dry Soil)					Extractable P_2O_5 (mg./100 g. Air-Dry Soil)
					Ca	Mg	K	Na	Mn^{II}	
S.1/ 0–6″ ..	4·6	6·0	0·25	9·5	0·6	0·1	0·08	0·38	0·15	0·3
6–12″ ..	4·5	7·5	0·32	9·5	0·6	0·1	0·07	0·38	0·19	0·3
S.2/ 0–8″ ..	4·4	6·0	0·22	11·5	0·3	0·1	0·07	0·38	0·06	<0·06
S.3/ 0–6″ ..	4·1	92·0	1·9	22·0	1·7	3·1	0·45	1·2	0·04	3·0
6–24″ ..	4·1	93·0	1·3	33·0	0·5	0·7	0·06	0·90	0·01	0·5
S.4/ 2–7″ ..	4·1	37·0	1·5	11·0	0·6	0·6	0·30	0·66	0·01	2·3
S.5/ 0–6″ ..	4·4	41·5	1·4	13·5	0·8	1·3	0·32	0·56	0·12	2·0
S.6/ 0–6″ ..	5·2	12·0	0·59	8·5	1·1	1·0	0·38	0·38	0·22	1·0
6–12″ ..	5·3	7·0	0·37	7·0	0·6	0·3	0·06?	0·35	0·04	0·1
12–16″ ..	5·4	4·0	0·20	6·5	0·4	0·2	0·02	0·28	0·01	<0·06
16–24″ ..	5·1	5·0	0·21	8·5	0·4	0·1	0·01	0·28	0·01	<0·06
S.7/ 0–4″ ..	4·8	17·0	0·66	11·5	0·4	0·9	0·24	0·49	0·39	2·5
4–12″ ..	4·9	11·0	0·40	11·5	0·4	0·4	0·08	0·42	0·22	1·0
S.8/ ½–18″ ..	5·8	20·5	0·84	10·5	4·8	3·5	0·33	0·52	0·76	1·5
S.9/ 0–7″ ..	4·6	26·5	1·0	11·0	0·6	0·6	0·26	0·56	0·04	1·0
7–14″ ..	4·6	12·0	0·42	12·0	0·5	0·2	0·08	0·49	0·03	0·3
14–20″ ..	4·6	13·0	0·33	16·5	0·7	0·8	0·03	0·42	0·01	0·7
S.10/ 0–6″ ..	3·9	21·0	0·71	12·5	0·2	0·1	0·18	0·49	0·05	3·5
S.11/ 0–3″ ..	6·5	67·5	2·8	11·0	60 (free $CaCO_3$)	7·4	1·1	1·1	0·59	2·5
S.12/ 0–8″ ..	4·4	68·0	2·4	12·5	0·5	0·1	0·36	0·80	0·04	2·7
8–24″ ..	4·6	36·5	1·3	12·0	0·4	0·5	0·05	0·56	0·03	0·8
24–30″ ..	4·8	20·5	0·78	11·5	0·3	0·2	0·02	0·49	0·03	0·3
S.13/ 0–3″ ..	4·8	26·5	1·1	16·5	0·8	0·6	0·60	2·8	0·07	2·1
3–6″ ..	4·6	18·0	0·74	10·5	0·6	0·5	0·18	0·59	0·01	0·7
6–11″ ..	4·8	7·0	0·20	14·0	0·5	0·3	0·03	0·45	0·00	0·06
S.14/ 0–9″ ..	4·3	74·5	2·5	13·5	0·7	1·2	0·93	1·0	0·04	4·7
9–11″ ..	4·4	19·0	0·53	15·5	0·3	0·1	0·04	0·45	0·01	0·7
11–19″ ..	4·7	9·5	0·23	17·0	0·4	0·1	0·05	0·52	0·01	0·3
19–25″ ..	4·8	3·5	0·11	11·0	0·3	0·0	0·02	0·42	0·01	7·1
S.15/ 0–4″ ..	3·9	82·5	2·4	14·5	2·3	4·7	1·9	0·84	0·14	16·2
4–8″ ..	4·1	78·0	1·5	21·5	0·7	1·2	0·34	0·63	0·02	0·8
8–10″ ..	4·3	27·0	0·84	15·0	0·5	0·6	0·19	0·49	0·02	0·6
10–11″ ..	4·3	14·5	0·31	19·5	0·3	0·6	0·20	0·52	0·02	0·3
11–18″ ..	4·4	12·5	0·23	22·0	0·3	0·4	0·11	0·45	0·02	0·7
18–24″ ..	4·4	5·5	0·10	16·5	0·3	0·3	0·10	0·45	0·02	8·3
S.16/ 0–2″ ..	4·7	22·0	0·99	10·0	1·0	1·2	0·70	0·66	1·64	2·5
2–14″ ..	4·9	7·5	0·23	13·0	0·4	0·1	0·05	0·45	0·25	0·06
S.17/ 0–2″ ..	4·2	16·5	0·65	11·0	0·2	0·5	0·16	0·56	0·01	0·7
2–7″ ..	4·2	12·0	0·50	10·0	0·3	0·3	0·07	0·49	0·01	0·5
7–30″ ..	4·5	3·0	0·09	11·0	0·2	0·1	0·04	0·42	0·21	0·1

Chemical Data For Soil Profiles—*Continued*

Profile Number	pH	Loss-on-Ignition % W/W	Total Nitrogen % W/W	Carbon/Nitrogen Ratio W/W	Exchangeable Cations (me/100 g. Air-Dry Soil)					Extractable P_2O_5 (mg/100 g. Air-Dry Soil)
					Ca	Mg	K	Na	Mn^{II}	
S.18/ 0–3″ ..	4·5	54·0	2·5	9·5	0·5	0·5	0·83	0·70	0·09	3·1
3–9″ ..	4·6	43·0	1·5	13·0	0·5	0·4	0·36	0·63	0·06	1·1
S.19/ 0–2″ ..	4·5	65·0	2·4	12·0	0·6	0·6	1·2	0·80	0·06	4·6
2–14″ ..	4·6	18·5	0·78	10·5	0·4	0·3	0·34	0·52	0·19	1·1
S.20/ 0–1″ ..	4·2	42·5	1·5	12·5	1·3	1·6	1·7	0·84	0·12	6·3
1–6″ ..	4·4	29·5	1·0	12·5	0·6	0·5	0·12	0·59	0·06	1·7
S.21/ 0–3″ ..	4·3	46·5	1·6	12·5	0·7	1·0	0·78	0·84	0·01	7·2
3–5″ ..	4·6	10·0	0·35	12·0	0·4	0·2	0·06	0·49	0·01	0·8
5–11″ ..	4·5	7·5	0·17	17·5	0·3	0·2	0·03	0·45	0·01	0·2
11–18″ ..	4·7	2·5	0·04	20·0	0·3	0·1	0·02	0·42	0·01	<0·06
S.22/ 0–2″ ..	4·3	56·0	1·8	14·5	0·3	0·8	0·80	0·84	0·04	4·1
2–0″ ..	4·6	28·5	1·1	11·5	0·7	0·3	0·12	0·59	0·01	1·1
8–18″ ..	4·8	3·5	0·11	10·0	0·5	0·1	0·04	0·42	0·04	0·2
S.23/ 0–4″ ..	4·2	23·0	0·96	10·5	0·5	0·3	0·09	0·49	0·09	5·0
4–7″ ..	4·7	8·0	0·16	20·5	0·5	0·5	0·03	0·42	0·04	1·0
7–14″ ..	4·9	2·5	0·04	17·5	0·3	0·1	0·04	0·42	0·01	1·3
S.24/ 0–6″ ..	4·5	89·5	1·2	32·0	1·7	1·4	1·5	1·57	0·23	4·0
6–10″ ..	4·6	66·0	2·2	14·0	1·0	0·9	0·53	1·11	0·86	3·2
10–14″ ..	4·7	8·0	0·27	12·5	0·9	0·5	0·14	0·66	0·11	0·4
S.25/ 0–4″ ..	4·2	43·5	1·7	11·5	0·7	0·7	0·51	0·73	0·86	4·1
4–9″ ..	4·5	8·0	0·31	10·5	0·4	0·1	0·05	0·49	0·04	0·8
9–13″ ..	4·7	6·0	0·12	20·0	0·3	0·1	0·04	0·42	0·01	0·3
13–20″ ..	4·8	2·0	0·05	10·0	0·3	0·0	0·03	0·38	0·01	0·2
S.26/ 0–4″ ..	4·6	74·5	2·9	11·5	1·0	2·5	0·88	0·63	0·11	0·5
4–10″ ..	5·0	50·0	1·8	12·5	0·5	0·6	0·23	0·49	0·06	0·2
10–12″ ..	5·2	11·5	0·35	14·0	0·3	0·1	0·08	0·42	0·02	0·1
12–15″ ..	5·2	7·0	0·20	14·5	0·6	0·1	0·05	0·42	0·00	0·1
15–24″ ..	5·2	2·5	0·09	10·0	0·6	0·1	0·05	0·38	0·00	<0·06
S.27/ 0–1½″ ..	4·7	26·5	1·0	11·5	0·8	2·0	0·53	0·52	0·04	2·0
1½–7″ ..	4·7	15·5	0·64	10·5	0·4	0·5	0·24	0·42	0·39	1·0
7–18″ ..	4·8	6·0	0·22	10·0	0·3	0·0	0·09	0·38	0·06	N.D.
S.28/ 0–1½″ ..	4·6	58·0	1·9	13·5	0·5	1·4	0·74	0·56	0·09	1·5
1½–3″ ..	4·7	21·5	0·84	11·5	0·3	0·5	0·24	0·45	0·06	N.D.
3–12″ ..	4·7	12·0	0·42	12·0	0·3	0·3	0·11	0·45	0·06	0·6
S.29/1½–3″ ..	4·2	44·5	1·4	14·0	0·7	0·6	0·47	0·73	0·07	4·7
3–10″ ..	4·7	14·5	0·38	16·0	2·9	3·0	0·08	0·45	0·07	0·8
S.30/ 0–7″ ..	4·1	29·0	0·93	14·0	0·5	0·4	0·05	0·42	0·03	1·1
7–9″ ..	4·5	8·0	0·30	11·0	0·4	0·2	0·06	0·38	0·01	0·6
9–13″ ..	4·6	8·5	0·19	18·5	0·3	0·2	0·04	0·35	0·09	0·8
13–19″ ..	4·7	5·0	0·10	20·0	0·3	0·2	0·04	0·35	0·03	1·2
19–30″ ..	4·9	1·5	0·04	7·5	0·3	0·1	0·04	0·35	0·03	2·8
S.31/ 0–8″ ..	4·2	61·5	2·1	13·0	0·7	0·9	0·44	0·77	0·01	2·8
8–14″ ..	4·7	3·5	0·07	14·5	0·3	0·1	0·04	0·35	0·01	1·0
14–36″ ..	4·9	2·0	0·04	12·5	0·5	0·6	0·05	0·42	0·07	1·4
S.32/ 0–10″ ..	5·2	18·5	0·75	10·5	2·0	0·7	0·27	0·64	1·23	2·8
10–20″ ..	5·3	8·0	0·31	11·0	0·8	0·3	0·07	0·54	0·15	0·7
S.33/ 0–5″ ..	5·1	28·0	1·1	11·0	2·5	1·1	0·62	0·73	0·65	2·3
5–12″ ..	5·2	7·0	0·20	14·5	0·4	0·2	0·07	0·49	0·15	0·9
12–20″ ..	5·4	4·5	0·12	13·0	0·3	0·1	0·31	0·52	0·15	1·7
S.34/ 0–8″ ..	4·0	92·0	1·4	29·0	1·6	4·5	1·2	2·19	0·51	4·6
8–20″ ..	4·1	55·5	1·5	16·5	0·1	0·9	0·19	0·82	0·00	3·4
S.35/ 0–6″ ..	4·8	18·5	0·56	14·5	0·0	0·3	0·29	0·59	0·32	1·1
S.36/ 3–14″ ..	4·5	89·0	N.D.	N.D.	0·9	2·1	0·18	1·32	0·32	1·9
14–18″ ..	4·8	62·5	2·0	14·5	0·6	1·5	0·11	1·29	0·32	3·1