ECOLOGICAL STUDY OF SOILS IN THE COASTAL WESTERN HEMLOCK ZONE

by

GYORGY LASZLO LESKO

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Department of Biology + Botany

The University of British Columbia,
Vancouver 8, Canada.

Date May 1, 1961

ABSTRACT

The main purpose of this study was to delineate ecosystem forest types within the forest associations of the Coastal Western Hemlock Zone. This aim was realised through the study of the ecotope of 116 sample plots in fifteen different associations. The study involved examination of topographic position and macroscopic soil properties in all sample plots. Twenty-four soil profiles were analysed for chemical properties.

The forest associations were divided into two or more forest types or kept as a single forest type. This was done by the author and coworker, L. Orloci, primarily on the basis of ecoptopic information.

Results of the study of edaphic factors in relation to plant associations indicate that the moisture regime, soil depth, organic matter/nitrogen ratio and potassium concentration of the soils are the most important factors edaphically differentiating the forest associations.

Soil succession studies included in this work suggest that the climate, the kind of vegetation and water economy of the soil determine the course of soil development. Soil succession may initiate on six essentially different kinds of substrata, in the Coastal Western Hemlock Zone. Soil forming processes contributing to development of soils are podzolization, gleyzation, melanization and peat formation in the study area.

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INTRODUCTION

Available data on the soils and soil site relationships of the Coastal Western Hemlock Zone* in British Columbia are very limited. However, experimental results from neighboring regions may provide important information.

Kelly and Spilsbury (1939) classified the soils of the Lower Fraser Valley on the basis of drainage:

Zonal Soils	Intrazonal Soils	Azonal Soils
Subdrainage	Groundwater Soils	Recent Alluvial Soil
- excessive	Half-Bog	
- restricted	Peat-Bog	
- fair to medium		

Rowles, Farstad, and Laird (1956) recognised Concretionary Reddish Brown, Brown Podzolic, Podzols, Muck, Peat, and Gleysolic soils in the area of the Coastal Western Hemlock Zone.

In the field of soil site relationship Hill, Arnst and Bond (1948) stated that "if the soil is known, production of Douglas-fir can be predicted within narrow limits". The soil units are defined by profile, texture and depth.

Tarrant (1949) studied the chemical properties of Douglas-fir soils in relation to site index. He found no significant relation, and concluded that nutrient content of Douglas-fir soils is too high to constitute a limiting factor in tree growth.

The studies of Krajina and Spilsbury (1953) have thrown light on the importance of the depth and amount of seepage in determining forest associations.

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* Krajina, 1959.

Gessel and Lloyd (1950) found that site index of Douglas-fir increases with change in texture from coarse to medium. Soil depth is an important factor in soils underlain by an impervious layer. Further, they found that site index increased with increasing precipitation up to 40 in., and up to 60 in. on soils underlain by impervious hardpan or bedrock.

McMinn (1957) studied the water relations in the Douglas-fir region and found that "The variation in soil moisture regimes was a most significant factor in the differentiation of sites".

Mueller-Dombois (1959) found correlation between forest associations and chemical properties of the soil such as replaceable calcium and magnesium, organic matter content and soil reaction.

Keser (1960) studied Concretionary Brown and Minimal Podzol soils in relation to site index of Douglas-fir. He found that available water is positively correlated to site index, while chemical and physical properties show no correlation.

The purpose of the present study is fourfold:

1. to provide general information on the soils of the study area;
2. to delineate ecosystem* forest types within the plant associations of the Coastal Western Hemlock Zone of British Columbia;
3. to discuss relationships between plant associations and edaphotopic factors;
4. to suggest possible trends in soil succession.

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* Tansley, 1935.

CHAPTER I. GENERAL DESCRIPTION OF THE STUDY AREA

a. Geography

The Coastal Western Hemlock Zone is located on the western slope of the Coast Mountains, and on Vancouver Island. The study area is a relatively small part of the zone, lying within 122°25' - 123°17' longitude, and 49°18' - 49°53' latitude. Within these borders the sample plots are concentrated in the University Research forest (Haney), Coquitlam Lake Watershed Area, Seymour Mt., Grouse Mt., Seymour Creek Valley, Capilano Valley, Lynn Park, and in the Squamish River floodplain.

b. Geology

The actual study area lies within the Coast Mountains. The steep and high mountains of the area are dissected by deep and wide U-shaped valleys. The Coastal Western Hemlock Zone does not extend higher than 3000 ft. but it is under the influence of high mountain climate.

Valley trend is generally north to south. These large valleys are the main channels of the present drainage system. Rivers are bordered by well developed floodplains and valley walls are generally steep except where they are interrupted by terraces or terrace-like formations.

Mountains are mainly granodiorite, quartzdiorite diorite and monzonite. Volcanic or sedimentary rocks are of minor importance (Geological Map of British Columbia, 1948)*. Bedrock is almost entirely covered by a layer of glacial drift of variable thickness. According to Merril (1966) glacial till in most cases travelled only a short distance. This explains the similarity between composition of glacial till and underlying bedrock. The mantle of glacial drift has been deposited by three major glaciations, viz. Seymour, Semiamu and Vashon. The major pleistocene deposits are described in the following paragraphs, after Armstrong (1956).

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* Canada Dept. of Mines and Resources, Geological Survey of Canada, 1948.

1. The glacial till is a very compact, unsorted deposit, a mixture of clay, silt, and stone. In spite of its coarse texture it is almost or entirely impervious, because of its compact nature. This phenomenon is due to the angular form of fine material and to the great pressure of the ice sheet. In the three consecutive glaciations, three different glacial tills were deposited:

	Sand %	Silt %	Clay %
Surrey till	57	41	2
Semiamu till	47	45	8
Seymour till	44	46	10

2. Glacial outwash is deposited by water from the melting ice.

3. Varved silt and clay is a fine deposit of glacial lakes, with good stratification.

4. Stony, clayey silt is a glacio-marine deposit, composed of about 50% silt, 40% sand and 10% clay.

The distribution of post glacial deposits are very limited. Alluvial deposits and some organic deposits belong to this group.

c. Climate

The proximity of the ocean and the abrupt elevation of the Coastal Mountain from sea level to over 6000 ft. strongly influence the regional climate. The former controls the temperature, not allowing either extreme coldness or heat, where the latter is responsible for the great amount of precipitation. The bulk of the precipitation is winter rainfall or snow (at higher elevations). June, July and August are the driest months, with a monthly mean around 2 inches. The mean annual precipitation - including rain, snow and fog dripping - ranges from 60-70 inches to over 150 inches. The frost-free growing season is around 200 days. The mean annual temperature is 40-45° F. The monthly mean is 20-40° F in January and 56-64° F. in July, according to Chapman, et al. (1956).

CHAPTER II. METHOD OF SAMPLING AND ANALYSIS

a. Selection and anlysis of soil profiles

The study is based on 124 described soil profiles. Soil reaction was determined on 78 profiles; twenty four profiles were analysed for total organic matter content, total cation exchange capacity, exchangeable calcium magnesium and potassium, and available phosphorus, and total nitrogen content was determined in the organic horizon of 22 profiles. On the basis of the obtained data, soils were classified according to the "Outline for the Classification of Canadian Soils as of November 1958"*. The last step was the establishment of ecosystem forest types with the help of edaphic data. Location of soil pits was related to selection of 1/5 acre sample plots for vegetational analysis which were located in areas phytocoenologically uniform. There was no effort to select uniform physiographic conditions, or similar soil profiles in relation to a particular plant community. In other words, the location of soil pits is completely random within a certain plant community.

The first forty fifth acre sample plots used in this work were selected by Dr. V.J. Krajina in the summer of 1958. The other edaphically analysed sample plots were selected by S. Eis, G. Lesko, and L. Orloci. Analysis of a sample plot started with a general description of the plot including physiography, topography, slope, exposure and altitude. Generally one soil profile was exposed in each plot. In cases where the topography was more complex one profile was opened in the convex and one in the concave topography. The entire soil profile was exposed in each case down to the bedrock, impervious hardpan or to the apparently unaltered parent material.

Study of the soil profile included identification of parent material, estimation of stoniness, and drainage. All distinguishable layers were

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* Canadian Soil Survey Committee, 1958.

described separately in each profile, and representative samples were collected from each layer for laboratory analysis. Horizon thickness, color, texture*, structure, consistency, and the nature of boundary between layers were described in the fresh pit. Depth of profile, presence and depth of ground water, and root distribution were also recorded.

Analysis of the vegetation** and forest stand was carried out by L. Orloci and S. Eis.

Chemical analyses of the soils were started in the summer of 1959. They were made on air dried soil material finer than 2 mm. Analyses were carried out for soil reaction, total organic matter content, total base exchange capacity, exchangeable calcium, magnesium and potassium, phosphorus and total nitrogen. For detailed description of the employed analytical methods see appendices.

The total amount of exchangeable calcium, magnesium, potassium and available phosphorus in lb. per acre, total base exchange capacity in equivalents per 100 m^2, and organic matter in tons per acre were calculated in the following way:

Calcium, magnesium, potassium and total base exchange capacity of soils were determined by chemical analysis and expressed in me/100 grams according to horizons and sub-horizons. The analytical results for organic matter content was expressed in per-cent of dry weight and phosphorus in ppm of the dry weight (see Appendices).

For each horizon and sub-horizon its effective thickness was calculated. The proportion representing material coarser than 2 mm was subtracted from the measured thickness.

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* Estimated on the basis of Professor C.F. Shaw's field method given in the Soil Survey Manual 1951. U.S. Dept. Agriculture.

** According to methods employed by Krajina, 1933.

The weight of each horizon and sub-horizon was calculated for a unit area on the basis of assumed bulk density figures:

Horizon	Bulk density	
O	0.2	(Lutz and Chandler, 1946)
A_h	0.9	(Kesen, 1960)
A_e	1.3	(estimated)
B	1.2	(Kesen, 1960)

The amount for the above mentioned chemical properties were calculated separately for each horizon and sub-horizon and added to obtain a value for the whole soil profile. Finally, the values for unit area were converted into lb. per acre, tons per acre and equivalents per 100 m^2 according to the different chemical properties of the soil.

b. Nomenclature of Soil Horizons*

L - Undecomposed litter.

O - Decomposed organic matter with very low mineral content.

A - 1. Surface mineral horizon of maximum organic accumulation.
   2. Surface or subsurface horizons that are lighter in color than the underlaying horizon and which have lost clay minerals, iron, aluminum.
   3. Horizons belonging to both of these categories.

B - 1. An accumulation of clay, iron, aluminum and organic matter.
   2. More or less prismatic or blocky structure, stronger colors than that of the A horizon or the underlying nearly unchanged material.
   3. Horizons characterised by both of these categories.

C - A horizon of unconsolidated material which is little effected by the influence of organisms and presumed to be parent material of the solum.

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* Canadian Soil Survey Committee, 1958.

D - Any substratum underlying the C or B horizon and which is not the parent material.

G - A gley layer of intense reduction, characterised by the presence of ferrous iron and neutral gray color.

Lower case subscription for the identification of soil sub-horizons:

b - A layer characterised by hard irreversible pedogenic concretions.

c - Hard irreversible pedogenic layer.

e - A layer characterised visibly by the removal of clay, iron, aluminum, and/or humus. Usually lighter colored (higher value) than the layers below or above.

f - A layer enriched by hydrated iron.

h - A mineral layer containing sufficient amount of decomposed organic matter to show visible darkness, at least on Munsell unit darker than the layer immediately below.

j - Juvenal - A layer with weakly expressed characters.

m - (mellowed-mitis) A layer characterised by the loss of water-soluble materials only, usually slightly altered by hydrolysis or oxidation. Usually differing in color and structure from the layer immediately above or below.

p - A relic (not currently dynamic) layer. To be used as prefix.

q - (Whitesides) A compact layer that is apparently cemented when dry, brittle when moist.

r - An inherited consolidated layer - used with C.

w - water saturated layer - the apparent water table.

CHAPTER III. SHORT DESCRIPTION AND CLASSIFICATION OF THE SOILS FOUND IN THE COASTAL WESTERN HEMLOCK ZONE

a. Subaqueous Soils

*Dy**. Biologically inert A-C-soil (having only A and C horizons) usually covered by water deeper than 2 meters. It develops over acid rock in lakes surrounded by podzolic soils.

*Eutrophic Gyttja**. A-G-soil (having only A and G horizons) covered by water shallower than 2 meters. Profile is deep and rich in organic matter. Vegetation well developed, mainly *Nuphar* and *Menyanthes*. Occurs in the shallow margins of the lakes and in the oxbows of the flood plains.

b. Organic Soils

Sphagnum Peat (Wilde, 1946). Undecomposed peat of *Sphagnum*, which is saturated with water. *Kalmia polifolia*, *Ledum groenlandicum* and *Sphagnum* mosses are established on it.

*Pitchy Peat Anmoor**. It develops on old *Sphagnum* peat. The peat is decomposed on the surface and converted into black muck humus. The top one foot of the soil is drained in the driest months of the year. It supports forest vegetation.

Spring Line Pitchy Anmoor (n.f.). The top soil is partly waterlogged, mineral-deficient black much thicker than one foot. Humus horizon is underlain by permanently waterlogged, mineral gley horizon. Occurs on slopes where the seepage water rises over the mineral soil surface. These areas are forested.

c. Gleysolic Soils

*Orthic Dark Grey Gleysolic***. Soils with dark colored A_h horizons underlain abruptly by a gleyed layer or layers without distinct illuvial or

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* W.L. Kubiena, 1953. The Soils of Europe. 318 pp.

** Described and classified according to the "Outline for the Classification of Canadian Soils as of November 1958, Canadian Soil Survey Committee" eluvial subhorizons. A thin O horizon (0 to 4 in.) may cover the A_h. Thin forest grows over these soils.

Orthic Gleysol**. Soils with O horizons 1 to 6 in. thick and A_h horizon less than 2 in. thick underlain by strongly gleyed layer or layers without noticeable eluvial or illuvial sub-horizons. These soils are forested.

d. Regosolic Soils

Alluvial Regosol**. Recent alluvial deposits which receive new additional deposits periodically. Profile development is restricted to the formation of an A_h horizon. These soils are covered by dense forests.

Acid Legosol**. Embryonic soils of acid rock outcrops, having a few cm. thick black colored A_h horizon. They support shrubby vegetation.

Eluviated Acid Legosol (n.f.) (synonym. Podzol Ranker, Kubiena, 1953). Soils with O horizon underlain by A_e horizon. The A horizon abruptly underlain by the acid parent rock. No illuviation or very limited in the cracks of the parent rock. These soils are covered by thin forests.

e. Brunisolic Soils

Degraded Concretionary Brown**. Soils have an O horizon, a thin ($\frac{1}{2}$ in. or less) continuous A_e horizon which contains gray concretions and lacks iron coatings, over a dark reddish brown to pale brown B horizon (of low base saturation) which contains concretions and iron coatings. Mottling is absent in the B horizons.

Orthic Brown Podzolic**. Soils with strong to medium acid O horizon (generally of $\frac{1}{2}$ to 2 in. thick) possibly having d, f, or h sub-horizons. The A_h is less than 2 in. thick or lacking, medium to strongly acid and unsaturated. The A_e is generally absent, or, if present, does not exceed $\frac{1}{2}$ in. The B is brown to yellowish brown, medium to strongly acid and

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** Described and classified according to the "Outline for the Classification of Canadian Soils as of November 1958, Canadian Soil Survey Committee" (Mimeographed).

unsaturated, without any noticeable accumulation of clay or sesquioxides, slight mottling may be found in the lower B. The C is acid in reaction.

Modal Acid Dark Brown**. Soils having a distinct dark grayish brown to black A_h horizon low in base saturation (below 50%), underlain by a brownish B horizon low in base saturation and free of mottling.

All soils of the group are forested.

f. Podzolic Soils

Gleyed Podzol**. Podzol soils having an organic (O) horizon, an eluvial (A_e) horizon and illuvial (B) horizon containing accumulations of organic matter and sesquioxides. Gleying indicated by mottling is evident in the upper B or A_e horizons.

Orterde Podzol**. Soils with profile similar to the previous one, but without mottling in the upper B or A_e horizons. The accumulation of organic matter does not reach 10% in the B.

Minimal Podzol**. Podzol soils having an organic (O) surface horizon, a thin (less than one in.) light colored eluvial (A_e) horizon (may be discontinuous) and an illuvial (b) which contains accumulations of organic matter and sesquioxides. Lacks distinct B_h horizons.

Orterde Humic Podzol**. These soils have a moderately thick O horizon, a distinct acid unsaturated A_e horizon and a friable B_h horizon (with 10% or more organic matter) containing iron in addition to organic matter. This is underlain by a friable B_{hf} horizon. B_h horizon thicker than 3 in.

Humic Podzol**. Soils similar to the Orterde Humic Podzols but the B_h horizon thinner than 3 in.

All soils of this group are forested.

** Described and classified according to the "Outline for the Classification of Canadian Soils as of November 1958, Canadian Soil Survey Committee" (Mimeographed).

CHAPTER IV. DESCRIPTION OF SOILS IN CLASSIFIED FOREST TYPES

The classified forest types have been arranged into five groups according to their edaphic nature. The first group (I) includes floodplain communities. These are affected by direct or subsurface flooding. Second (II) are muskeg communities where the organic soil is saturated by water to the surface during the greater part of the year. Seepage communities belong to the third (III) group. Seepage is characteristic for these communities, but it may not be found in all places of the same plant community. On the other hand, seepage is always missing from the soils of dry edaphic communities which belong to the fourth (IV) group. The zonal* communities of the fifth (V) group are characterized by deep soils. Seepage may or may not be present. If present, it is either at such a depth that it does not apparently effect the development of the communities, or it may act temporarily (after heavy rain or melting snow) over the hardpan or bedrock.

FLOODPLAIN COMMUNITIES

Although their area is very small in comparison with the whole area of the Coastal Western Hemlock Zone, floodplains could play an important role in forestry practice. Their significance is due to their high productivity and case of access. Some of the forest types discussed on the following pages are very insignificant in extent and from the point of view of productivity. They are described in order to give a full picture of the floodplains and to aid in the understanding of the succession involved.

Assoc. 1. <u>Populeto</u> - <u>Loniceretum</u>

a. <u>Lonicera</u> - <u>Rubus</u> forest type

This is a young plant community developing on higher well drained

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* Communities controlled by the macroclimate, that develop in various physiographic positions on deep, well drained soils.

locations of river floodplains. According to Orloci (1961) its constant dominant species are:

> *Populus trichocarpa*, *Alnus rubra*, *Rubus spectabilis*, *Lonicera involucrata*, *Cornus occidentalis*, *Picea sitchensis*, *Sambucus pubens*, *Elymus glaucus*, *Maianthemum dilatatum*, *Osmorhiza chilensis*, *Equisetum arvense*, *Smilacina stellata*.

The soil is a young Alluvial Regosol. The profile can be divided into A_h and C_1 horizons. The A_h is a light brown structureless sand about eight inches thick. Its organic matter content is seemingly very low and its chemical properties are probably very similar to the C_1 layer in the *Oplopanax* - *Ribes* forest type described below. The C_1 layer is gray coarse sand without any obvious alteration. Depth of ground water varies from two to six feet.

Roots are distributed mainly in the strongly acid (pH 5,2) A_h horizon. The C_1 layer is moderately acid (pH 5,8).

b. *Elymus glaucus* phase

This pioneer community develops on coarse alluvial material elevated about one to three feet above the average level of the water table. At first the vegetation is very scattered but soon develops into a dense young forest. The tree layer consists of *Alnus rubra*, *Populus trichocarpa* and *Salix sitchensis*. Seedlings of *Picea sitchensis*, *Thuja plicata*, and *Pseudotsuga menziesii* are present in the earliest stage, but their survival is challenged by flooding. Their establishment becomes successful when the other woody vegetation reaches a sufficient density. The shrub and herb layer are very poor in species and abundance.

At first there is essentially no soil development. The coarse sandy stony material is practically free of organic matter. It has an acid reaction (pH 5,3-5,5).

The community is flooded annually, but the sand dries out very quickly after retreat of the water. The texture of the river flood deposit becomes finer each year, after vegetation is established. However soil development, or rather the development of the A_h horizon, starts when vegetation is dense enough to retain the litter produced by the plant community.

This community never reaches the maturity of the forest stand, because within one or two decades the soil surface is elevated sufficiently and enriched by organic material to give place to the formation of different shrub, herb and moss layers.

This community is insignificant from the forestry point of view. On the other hand, it is important as a step in the succession of soils and vegetation on the floodplains.

c. *Equisetum arvense* phase

The *Equisetum* phase is another pioneer stage of the *Lonicera* - *Rubus* forest type. It is composed almost exclusively of dense *Alnus rubra* underlain by a dense *Equisetum arvense* herb layer.

The soil is Alluvial Regosol. The deposit is much finer than in the *Elymus* phase. Early development of dense vegetation favors rapid soil development. The darker color of the soil suggests some organic matter accumulation. This community's relation to flooding is similar to that of the previously mentioned *Elymus* phase but the finer soil retains the moisture for a longer time.

Assoc. 2. *Piceeto* - *Oplopanacetum*

(*Oplopanax* - *Ribes* forest type)

An ecologically uniform community, occurring on floodplains only. It is distributed both in the drier and wetter subzones, its water supply being controlled by rivers. In the Coastal Western Hemlock Zone this community occupies those parts of floodplains where the soil surface is high above the average water level of the river.

The forest type is characterised by the following constant dominant species (Orloci, 1961): Picea sitchensis, Tsuga heterophylla, Populus trichocarpa, Ribes bracteosum, Oplopanax horridus, Rubus spectabilis, Sambucus pubens, Viola glabella, Athyrium filix-femina, Maianthemum dilatatum, Streptopus roseus, Osmorhiza chilensis, Tiarella trifoliata, T. unifoliata, Dryopteris austriaca, Gymnocarpium dryopteris, Smilacina stellata, Polystichum munitum, Luzula parviflora, Poa palustris, Mnium insigne, M. punctatum, and Rhytidiadelphus squarrosus.

Soils*:

The soils are Alluvial Regosols, sometimes with several buried A_h horizons. The color of the A_h horizon is dark brown when wet. The C_1 is light- or grayish-brown. The texture of the deeper horizons is coarser than the horizons on the top of the profile. The A_h horizon is fine sand to sandy loam, enriched by organic colloids. The C1 horizon is fine to coarse sand. The A_h is structureless or weak-crumby, while the C_1 is always structureless.

Development of L and O horizons is retarded because of the fast decomposing mixed broadleaf and conifer litter.

Root distribution is not uniform in the profile. However most roots grow in the top one foot of soil; in some profiles they are evenly distributed through the whole profile depth.

Chemical properties**:

The soils are strongly acid with an even distribution of nutrient

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* Described on the basis of 5 profiles.

** On the basis of 3 profiles.

elements. Total base exchange capacity is maintained mainly by organic colloids (see fig. 1). All the important nutrient elements have a definite upward movement in the biogeochemical cycle. They become accumulated in the A_h horizon.

pH - A_h horizon		4.8
C_1 horizon		5.2
Total organic matter in tons per acre:		100
Total cation exchange capacity in equivalents per 100 m^2:		10580
Available P in lb. per acre:		155
Exchangeable cations in lb. per acre:	Ca	1734
	Mg	904
	K	524

(Chemical properties are given for the entire profile, excluding stones and material coarser than 2 mm.)

Percentage distribution of chemical properties by the horizons:

Horizon	A_h	C_1
Organic matter	19.8	80.2
Cation exchange capacity	42.6	57.4
Ca	12.6	87.4
Mg	14.0	86.0
K	11.0	89.0
P	8.2	91.8

Use and Productivity:

The primary use of the Oplopanax - Ribes forest type is commercial wood production.

Site indexes (feet) (S. Eis, 1961):

F* (142), Hw 107, Cr 98, B 95, S 135, Ar 89.

Assoc. 3. Piceeto - Symphoricarpetum

(Symphoricarpos forest type)

This community occupies locations where the surface is raised by sedimentation so that the site is less influenced by subsurface flooding. The surface deposit is rather fine. Other possibilities for its development occur when rivers suddenly change their course and leave the site without further flooding, or when the bed of the river deepens and the site is then too elevated for flooding. In these instances the surface deposit is coarse. Constant dominants are (Orloci 1961): Picea sitchensis, Acer macrophyllum, Populus trichocarpa, Symhoricarpos rivularis, Acer circinatum, Disporum oreganum, Mnium insigne.

Soils:

The soil is very similar to that in the Oplopanax - Ribes forest type but accumulation of litter is more advanced. The fermentation layer is very thin and the decomposed humus is mixed with mineral material. The soil generally is an Alluvial Regosol, having A_h and C_1 layers only. The subsoil is well drained and the whole profile is drier than that in the Piceeto - Oplopanacetum.

While the soils of this association are not adequately studied, the apparent similarity of the profile and the ecological position of the whole community suggest the Symphoricarpos and Oplopanax - Ribes forest types are closely related.

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* F - Douglas-fir, Cr - western red cedar, Hw - western hemlock, B - amabilis fir, S - Sitka spruce, Ar - red alder.

Assoc. 4. Alneto - Ribisetum bracteosi

(Ribes - Lysichitum forest type)

The occurrence of the Ribes - Lysichitum forest type is restricted to special localities on floodplains where drainage is imperfect. The water table is not only high, but very slow moving. This forest type has been found only in two localities, viz. in the upper section of Seymour Creek Valley.

The community is characterised by the following constant dominant species (Orloci, 1961): Alnus rubra, Picea sitchensis, Ribes bracteosum, Sambucus pubens, Rubus spectabilis, Lysichitum americanum, Viola glabella, Maianthemum dilatatum, Dryopteris austriaca, and Mnium punctatum.

Soils:

The community develops on Orthic Dark Gray Gleysols with the total depth of solum being about twelve inches. A 5-16" thick A_h horizon is underlain by a gley horizon rich in organic matter. Depth of the water table was twenty-seven inches late in Spring. Color of the A_h horizon is gray to dark brown, while the gley horizon is dark gray to dark brown. The A_h horizon is crumby structured sandy loam to weak blocky sand. The G horizon is loamy sand with weak blocky structure, or structureless.

Roots are distributed mainly in the A_h horizon.

Chemical properties of soils:

The soils are very strongly acid and well supplied with nutrient elements. The correlation between organic matter and total base exchange capacity suggests a somewhat more important role of mineral colloids, than in the soils of Oplopanax - Ribes forest type. (see fig. 2)

pH - A_h horizon		4.7
C_1 horizon		5.0
Total organic matter in tons per acre:		238*
Total cation exchange capacity in equivalents per 100^2:		11000
Available P in lb. per acre:		71.5
Exchangeable cations in lb. per acre:	Ca	2177
	Mg	522
	K	414

Productivity:

Site indexes in feet: (S. Eis, 1961): Cr 107, Hw 114, S 125, Ar 96.

Assoc. 5. *Nupharetum polysepali*

The *Nuphar polysepalum* association develops in the shallow waters of oxbow lakes of the floodplains. It represents the first step in the succession from open water to terrestrial communities. Its soil is a Eutrophic Gyttja. The A horizon of the soil is rich in organic matter and it may have a considerable thickness. The A horizon is directly underlain by the G layer.

Assoc. 6. *Caricetum retrorsae*

Through further silting the *Nuphar polysepalum* association is replaced by the *Carex retrorsa* - *Equisetum fluviatile* association. In this stage of development the water is several inches deep. The soil is still Eutrophic Gyttja but the A_h horizon attains much greater thickness.

In a more advanced stage *Salix sitchensis* invades the association.

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* All chemical results in this association are based on one analysed soil profile only.

By this time the soil is under water only for a part of the year, and the Lysichitum - Oenanthe forest type begins to develop in the silt-filled oxbow lake.

Assoc. 7. Saliceto - Oenanthetum

(Lysichitum - Oenanthe forest type)

The Lysichitum - Oenanthe forest type occurs in silt-filled oxbow lakes, where the water table is high and stagnant throughout the whole year.

The following constant dominant species are characteristic for the community (Orloci, 1961): Salix lasiandra, Salix sitchensis, Lonicera involucrata, Rubus spectabilis, Cornus occidentalis, Lysichitum americanum, Oenanthe sarmentosa, Glyceria pauciflora, Athyrium filix-femina, and Angelica genuflexa.

Soil*:

The soil is an Orthic Dark Gray Gleysol, consisting of an A_h horizon underlain by a gley horizon. The color of the A_h horizon is gray-brown or dark gray depending on the amount of organic material present. Its texture is clay-loam with sticky consistency and compact structure. The gley horizon is permanently water logged and its physical properties are similar to that of the A_h horizon. The water table fluctuates from about one foot below the soil surface to considerable height above the surface.

Chemical properties:

The pH of the A_h layer is 5.5. Other chemical properties were not studied in this forest type.

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* Described on the basis of 3 profiles.

CORRELATION BETWEEN ORGANIC MATTER CONTENT AND TOTAL CATION EXCHANGE CAPACITY IN FLOODPLAIN SOILS

Fig. 1

Ribes - Oplopanax forest type

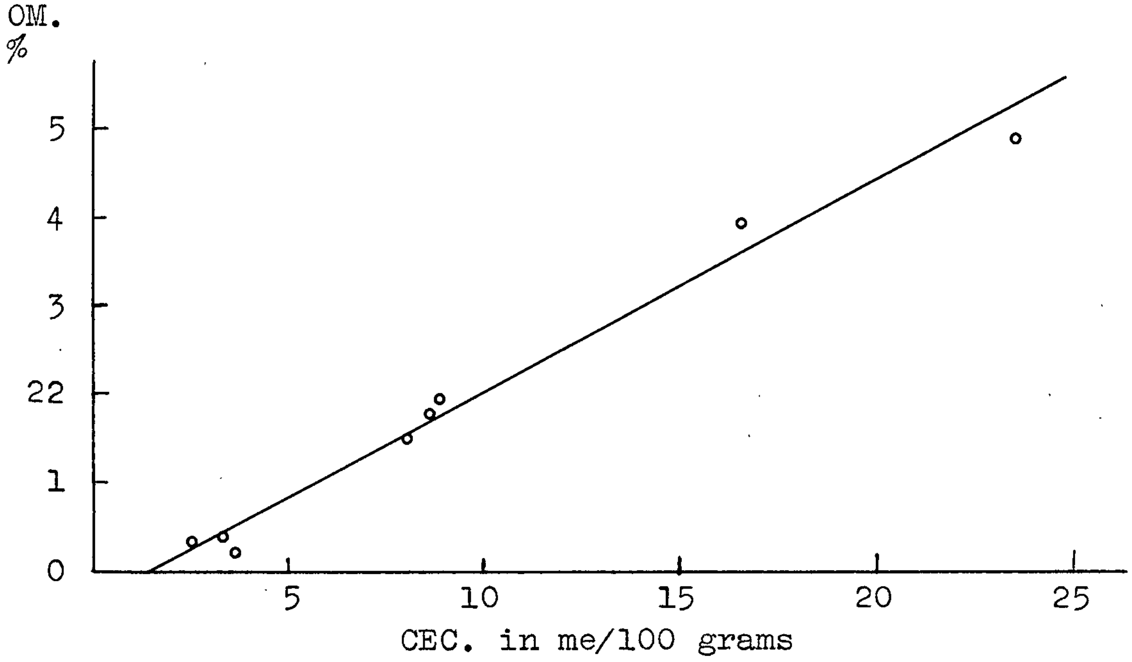

Fig. 2

Ribes - Lysichitum forest type

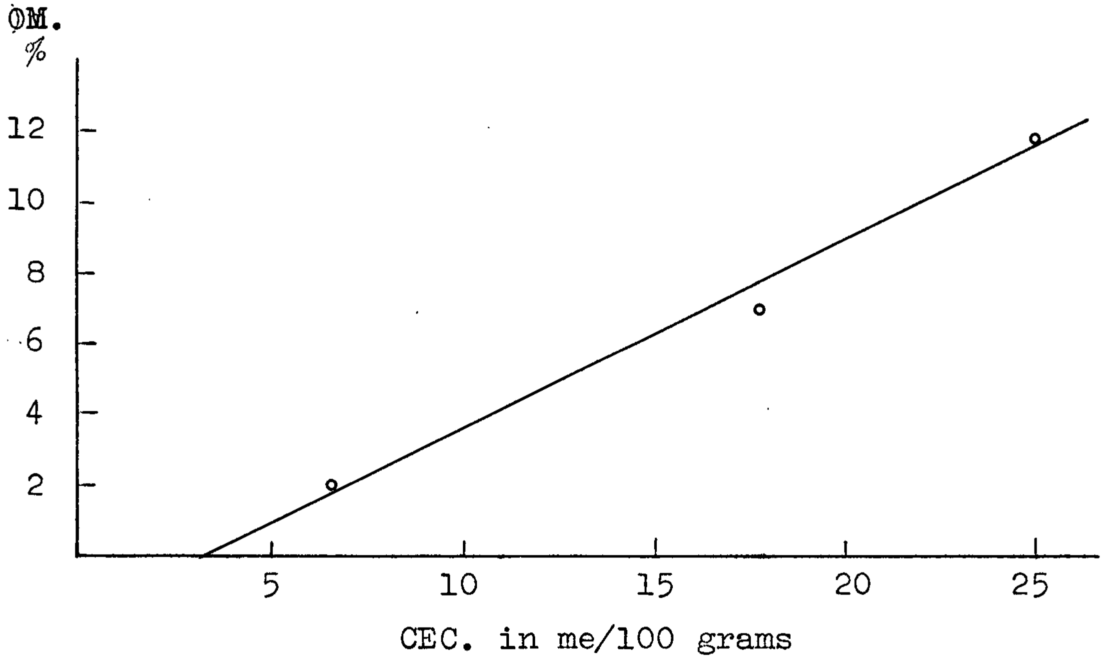

Figure 3, 4

Figure 3. *Oplopanax* - *Ribes* forest type

Figure 4. Alluvial Regosol

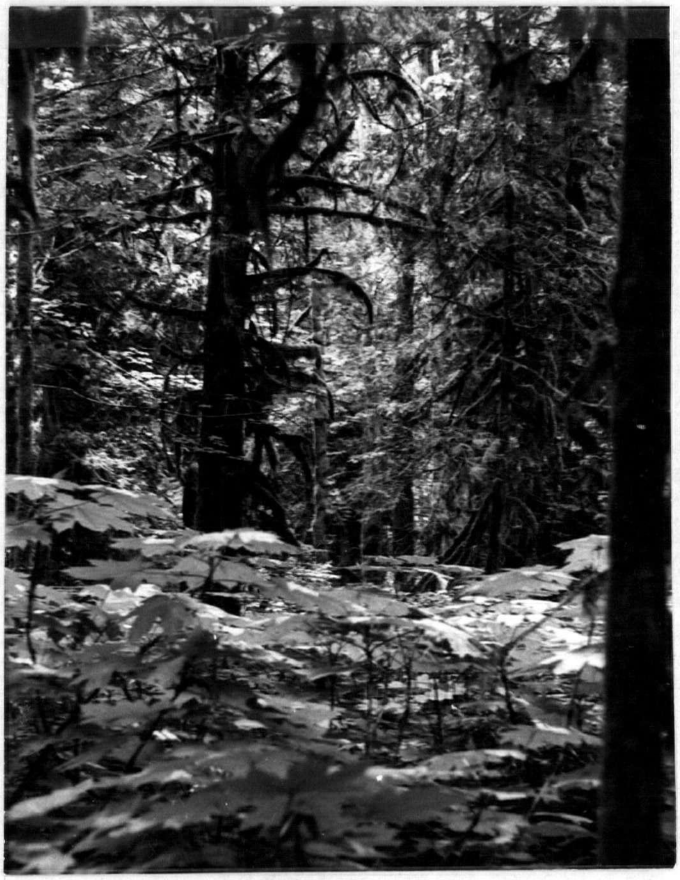

Figure 3.

Figure 4.

Figure 5, 6

Figure 5. <u>Lysichitum</u> - <u>Oenanthe</u> forest type

Figure 6. Orthic Dark Gray Gleysolic soil

Figure 5.

Figure 6.

E. MUSKEG COMMUNITIES

Assoc. 8. *Pineto* - *Ledetum*

(*Ledum* forest type)

This forest type develops on high moors and along the margin of glacial lakes. It is insignificant from a forestry point of view, because of its small extent and low productivity.

Poorly growing *Pinus contorta*, *Chamaecyparis nootkatensis*, and *Thuja plicata* constitute the crown canopy. *Ledum groenlandicum* and *Kalmia polifolia* are characteristic in the shrub layer. The cover of the herb layer is less than fifty percent, and is composed of *Cornus canadensis*, *Linnaea borealis*, and *Habenaria saccata*. The moss layer is strongly developed and dominated by *Sphagnum* species.

This forest type grows on undecomposed living Sphagnum peat. The ground water is stagnant and fills the peat to the surface. The acidity of the peat ranges from pH 3,4 to 4,0.

Assoc. 9. *Thujeto* - *Coptetum*

(*Coptis* - *Lysichitum* forest type)

As the Sphagnum bog becomes old the drainage improves and the *Pineto* - *Ledetum* gives place to the association mentioned above. This has a dense tree layer with *Thuja plicata* and *Tsuga heterophylla* the dominant species. The shrub cover is relatively low, 15 to 20 percent. *Taxus brevifolia*, *Menziesia ferruginea*, *Vaccinium parvifolium* and *Gaultheria shallon* are usually common. *Lysichitum americanum* dominates the herb layer. *Coptis asplenifolia*, *Blechnum spicant*, *Dryopteris austriaca* and *Cornus canadensis* are constant members of the community. The moss layer is well developed with *Mnium punctatum*, *Eurhynchium oreganum*, and *Plagiothecium* undulatum important species, in addition to Sphagnum species.

The surface of the soil, however, may be covered by a thin layer of fresh Sphagnum peat, in which case there is about a one foot thick layer of decomposed muck-like peat in the top soil (Pitchy Peat Anmoor). This mucky layer is underlain by very slightly decomposed Sphagnum peat. The acidity of the peat steadily decreases with increasing depth. The pH is around 3,5 on the surface and reaches the value of 5,5 at thirty inches depth. The average water table is 7 inches below the surface during the summer months.

C. SEEPAGE COMMUNITIES

All forest associations supplied with permanent or temporary seepage water belong to the group of seepage communities. The depth of the seepage below the soil sufrace is an important factor differentiating associations within the seepage communities. If the water table is too high the air supply becomes inadequate and eliminates Douglas-fir from the site or reduces its productivity to a very low value. (See fig. 21)

The seepage communities are composed of four associations:

a) The Thujeto - Polystichetum
b) The Thujeto - Blechnetum
c) The Abieteto - Oplopanacetum
d) The Piceeto - Lysichitetum

Assoc. 10. Thujeto - Polystichetum

(Polystichum forest type)

The Thujeto - Polystichetum occurs mostly in the dry subzone on gentle, lower concave slopes in valley bottoms, on young terraces and on slopes between old terraces. The degree of the slopes range from 3 degrees to 40 degrees.

This association consists of a single forest type that may be called the *Polystichum* forest type. They are characterized by the following constant dominant species (Orloci, 1961): *Thuja plicata*, *Tsuga heterophylla*, *Vaccinium parvifolium*, *Rubus spectabilis*, *Polystichum munitum*, *Dryopteris austriaca*, *Plagiothecium undulatum*, *Mnium punctatum*, *Eurhynchium oreganum*, *Rhytidiadelphus loreus*.

Soils:

The soils are deep and well aerated. Accumulation of unincorporated organic material is restricted. The litter is mixed with a great amount of herbaceous remains. This mixture is soon decomposed and incorporated into the mineral soil forming a mull-like moder (Kubiena, 1953) of various thickness.

Parent material in different plots:	glacial till 52%, alluvial 20%, lacustrine 14%, glacial outwash 14% (of plots)
Physical properties:	
Stoniness	37% (0-80%)*
Depth of solum	39.2 inches (20-58 inches)
Thickness of the O horizon	1.9 inches (0-8 inches)
Thickness of A_h horizon	2.3 inches (0-10 inches)
Thickness of the A_e horizon	0.45 inches (0-1½ inches)
Texture of the A_h horizon	sandy loam to clay loam
Texture of the A_e horizon	sand to sandy loam
Texture of the B horizon	sand to clay
Structure of the A_h horizon	weak granular to crumby
Structure of the A_e horizon	single grain to weak blocky
Structure of the B horizon	single grain to firm blocky

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* Averages and ranges.

Chemical properties*:

pH - O horizon	3.4 (3.2-3.7)
A_h horizon	4.5 (3.7-5.4)
A_e horizon	4.0 (3.5-4.6)
B horizon	5.4 (4.8-5.6)

Organic matter in tons per acre:		184
Total cation exchange capacity in equivalents per 100^2:		14695
Available P in lb. per acre:		112
Exchangeable cations in lb. per acre:	Ca	712
	Mg	542
	K	416

Distribution of chemical properties by horizons in percentage:

Horizon	O	A	B
Organic matter	39	2	59
Cation exchange capacity	13	2	85
Ca	42	18	40
Mg	19	7	74
K	12	3	85
P	4	1	95

Distribution of soil subgroups and site indexes:

Soil subgroups	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr
Modal Acid Dark Brown	9	167	137	119
Orthic Brown Podzolic	6	169	121	114
Minimal Podzol	3	161	132	99
Orterde Humic Podzol	2	156	117	122

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* Three profiles studied.

Figure 7, 8

Figure 7. *Polystichum* forest type

Figure 8. Orthic Brown Podzolic soil with seepage (the length of the ruler is 36 in.)

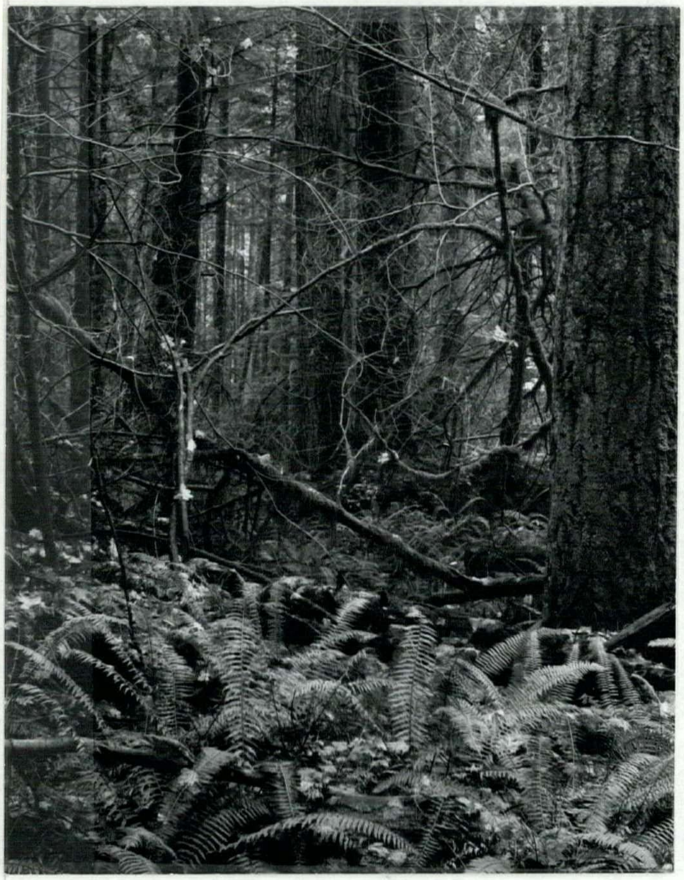

Figure 7.

Figure 8.

The soils are mostly well drained although a few are poorly drained. Almost all the profiles are underlain by an impervious or semi-impervious layer. During the vegetative season, in 38% of the soil pits permanent or temporary seepage moves over this hardpan at an average depth of 35 inches from the mineral soil surface of the profiles. The soils are moist in the upper part of the B horizon and usually wet in the lower portion.

Roots are concentrated in the A_h horizon or in the upper ten inches of the profile. In some profiles the roots are evenly distributed in the A and B horizons.

Assoc. 11. *Thujeto* - *Blechnetum*

The *Thujeto* - *Blechnetum* occurs in the dry and wet subzone on gentle slopes, terraces and valley bottoms. The impervious layer in the soil profile is relatively high and the lower portion of the soil profiles are poorly aerated.

The association is characterized by the following constant dominant species (Orloci, 1961): *Tsuga heterophylla*, *Abies amabilis*, *Vaccinium alaskaense*, *Rubus spectabilis*, *Blechnum spicant*, *Cornus canadensis*, *Tiarella trifoliata*, *Dryopteris austrica*.

The association is divided into four forest types:

a. Orthic *Blechnum* forest type

b. *Blechnum* - *Rubus* forest type

c. Gleysolic *Blechnum* forest type

d. Peaty *Blechnum* forest type

a. The Orthic *Blechnum* forest type

The Orthic *Blechnum* forest type is distributed in the wet subzone, where it occurs on gentle slopes (2 degrees to 10 degrees), terraces and valley bottoms. Its floristic composition is as described for the *Thujeto* - *Blechnetum*.

Soils:

The soils are moderately deep with some excess water supply. A wet, cool microclimate favours accumulation of raw humus. This has a tendency to form firm or hard irreversible aggregates if dried out in room temperatures.

Parent material in different plots:	glacial till 66%, glacial outwash and alluvial 25%, lacustrine 9% (of plots)

Physical properties:

Depth of solum	33 inches (14 to 53 inches)
Stoniness	32% (0 to 60%)
Thickness of the 0 horizon	5.6 inches (1 to 17 inches)
Thickness of A_e horizon	1.3 inches (0 to 3 inches)
Texture of the A_e horizon	sand to sandy loam
Texture of the B horizon	sand to clayey loam
Structure of the A_e horizon	single grain to weak blocky
Structure of the B horizon	single grain to firm blocky, sometimes compact in lower B

Chemical properties[*]:

pH - 0 horizon		3.5 (3.3-4.0)
A_e horizon		3.8 (3.5-4.0)
B horizon		5.0 (4.5-5.2)
Organic matter in tons per acre:		358
Total cation exchange capacity in equivalent per 100 m^2		21306
Available P in lb. per acre:		92
Exchangeable cations in lb. per acre:	Ca	507
	Mg	522
	K	312

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[*] On the basis of three analysed soil profiles. The pH values are averages of nine profiles.

Distribution of chemical properties according to horizons in percentage:

Horizon	O	A	B
Organic matter	63	4	33
Cation exchange capacity	27	2	71
Ca	100	0	0
Mg	40	8	52
K	32	7	61
P	7	4	89

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site Index (Eis, 1961)			
		F	Hw	Cr	B
Orthic Brown Podzolic	3	149	107	127	127
Minimal Podzol	3	145	126	116	120
Orterde Humus Podzol	5	130	116	96	110

These soils are imperfectly or moderately drained. All the profiles are underlain by an impervious or very slowly pervious layer. The degree of drainage is strongly influenced by the depth of this impervious layer and by the amount of seepage water. The A horizon and the upper part of the B horizon is sufficiently aerated throughout the greater part of the year. The average depth of the seepage is thirty inches in the summer time. Seepage occurred in 92% of the profiles studied.

The distribution of roots is related to the extent of drainage within the profile. The bulk of roots is in the O, A and the upper portion of the B horizon. The roots do not penetrate the gleyed part of the B horizon.

b. The Blechnum - Rubus forest type

The Blechnum - Rubus forest type is found in the dry subzone. Its physiographic situation is identical with the previous forest type. Floristically the presence of Rubus vitifolius and the absence of

Clintonia uniflora separate it from the Blechnum forest type.

Soils:

The soil properties are similar to the Blechnum forest type. The depth of solum and the thickness of 0 horizon indicates some difference but the small number of sample plots (three) do not permit any definite conclusions. Seepage exists in all profiles at an average depth of twenty-two inches.

Parent material in different plots:	alluvial deposit and glacial till
Physical properties:	
Depth of solum	29 inches (28 to 31 inches)
Stoniness	25% (15% to 40%)
Thickness of the 0 horizon	1.3 inches (0 to 2 inches)
Thickness of the A_e horizon	2.1 inches (0 to 6 inches)
Chemical properties:	
pH*- 0 horizon	3.9
A_e horizon	4.4
B horizon	5.6

Other chemical properties have not been studied in this forest type.

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	H	Cr
Orthic Brown Podzolic	1	180	180	170
Minimal Podzol	1	157	163	153
Orterde Podzol	1	178	125	128

c. Gleysolic Blechnum forest type

The gleysolic Blechnum forest type has been found only in the wet subzone, but it probably occurs in the dry subzone as well. It occupies

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* Only one profile was studied.

gentle concave slopes (6 degrees to 14 degrees). Floristically the absence of Pseudotsuga menziesii and Polystichum munitum differentiate it from the two former forest types.

Soils:

The soils are shallow and imperfectly drained. Deficient aeration is indicated by gray mottling in the whole B horizon. The accumulation of unincorporated, muck-like organic matter is moderately thick. This organic horizon has a compact but friable nature. Most of the roots are concentrated in this horizon and only few penetrate into the A_e horizon and the top of B horizon. Seepage functions throughout the whole year at an average depth of 17 inches.

Parent material: glacial till

Physical properties:

Stoniness	35% (25% to 50%)
Depth of solum	15.6 inches (7 to 22 inches)
Thickness of the O horizon	6 inches (3 to 8 inches)
Thickness of the A_e horizon	2.1 inches (0 to 5 inches)
Texture of the A_e horizon	sandy loam
Texture of the B_g horizon	sandy loam
Structure of the A_e horizon	weak blocky
Structure of the B_g horizon	blocky to compact

Chemical properties were not studied in this forest type.

The distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) Hw	Cr	B
Gleyed Podzol	2	112	111	116
Orthic gleysol	1	123	-	113

Figure 9, 10

Figure 9. Blechnum forest type

Figure 10. Orthic Brown Podzolic soil with seepage

(The ruler is 18 in. long.)

Figure 9.

Figure 10.

d. Peaty Blechnum forest type

The peaty Blechnum forest type was studied in only one sample plot in the wet subzone. Its floristic composition is identical with the previous forest type, but it is developed on old, decomposed peat.

Soils:

The soil is a mineral deficient peat soil, with very high ground water (10 inches). The top 10 inches of the soil is of well-decomposed peat and litter. It has an amorphous structure in the wet condition and forms very hard, irreversible aggregates if dried at room temperature.

The pH is 4.0 on the top, gradually increasing to pH 5.5 at sixty inches depth.

Roots are restricted to the top 10 inches of the profiles.

Soil subgroup and site index:

Soil subgroup	No. of Profiles	Index site (Eis, 1961) Hw	Cr	B
Pitchy Peat Anmoor	1	104	104	102

Assoc. 12. Abieteto - Oplopanacetum

(Oplopanax - Adiantum forest type)

The Abieteto - Oplopanacetum is an insignificant forest type. Its occurrence is very rare and area small. Its stand consists of Thuja plicata, Tsuga heterophylla and Abies amabilis. Oplopanax horridus is a characteristic species in the shrub layer and Adiantum pedatum in the herb layer.

This community may occur in both subzones on rego-gley soils. Seepage is at the soil surface and always rapidly moving. This moving surface seepage prevents the accumulation of organic matter.

The soil and vegetation have not been studied in detail.

Assoc. 13. *Piceeto* - *Lysichitetum*

The *Piceeto* - *Lysichitetum* is distributed in both subzones in the area studied. Poorly and very poorly drained localities are occupied by this plant community. The topography of these poorly drained areas is concave to flat. The physiographic position may be valley bottom, terrace or basin. It may occur on concave mountain slopes if the impervious layer is very high in the profile and the site supplied by seepage water throughout the whole year.

The floristic composition is represented by the following constant dominant species: *Tsuga heterophylla*, *Vaccinium alaskaense*, *Rubus spectabilis*, *Lysichitum americanum*, *Blechnum spicant*, *Tiarella trifoliata*, *Eurhynchium stokesii*, *Mnium punctatum*, *Conocephallum conicum*, *Pellia species*, *Rhytidiadelphus loreus*, *Hylocomium splendens*, *Sphagnum squarrosum*, *Plagiothecium undulatum*. The constant but only sporadic occurrence of *Picea sitchensis* is also characteristic for the association.

The association is divided into two forest types on the basis of pedological differences. The first is the Gleysolic *Lysichitum* forest type, characterized by gley soils. The second is the peaty *Lysichitum* forest type, occurring on organic soils. Floristic differences have not been established between these two forest types.

a. Gleysolic *Lysichitum* forest type

This forest type has been found on terraces and on very gentle slopes (1 to 5 degrees).

Soils*:

> The soils are very shallow and imperfectly drained. The organic matter accumulation is in the form of black muck. The O horizon is underlain by a B_G horizon. No indication of eluviation has been observed in the profile. The accumulation of organic matter in the B_G horizon is prominent.

Parent material in different plots:	alluvial deposits and glacial till
Physical properties:	
Stoniness	18% (0% to 40%)
Depth of solum	17 inches (7 to 22 inches)
Thickness of the O horizon	9 inches (5 to 12 inches)
Texture of the B_G horizon	sand to loam
Structure of the B_G horizon	blocky to compact
Chemical properties*:	
pH - O horizon	4.4 (3.5-4.9)
B_G horizon	5.0 (4.6-5.5)
Organic matter in tons per acre:	184
Total cation exchange capacity in equivalents per 100 m^2:	4816
Available P in lb. per acre:	4.4
Exchangeable cations in lb. per acre: Ca	2022
Mg	370
K	104

Distribution of soil subgroups and site indexes:

Soil Subgroup	No. of Profiles	Site index (Eis, 1961) Hw	Cr	S	B
Orthic Dark Gray Gleysolic	2	96	120	?	113
Orthic Gleysol	2	96	82	135	70

Root distribution in the profiles is regulated by the water table. Permanent seepage is at the surface of the mineral soil in the Orthic Gleysols while the top 10 inches of the solum in the Orthic Dark Grey

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* The chemical properties are calculated for the O horizon. Nutrients in the B_G horizon are not available for tree growth. All calculations are based on two analysed profiles, one of them from the Peaty Lysichitum type.

Gleysolic soils are above the ground water level. The roots are concentrated in the O horizon and in the top of the A_h horizon respectively.

b. Peaty _Lysichitum_ forest type

The Peaty _Lysichitum_ forest type has a similar distribution to the Gleysolic _Lysichitum_ forest type. Gentle concave slopes, small basins and old _Sphagnum_ bogs may be the physiographic location of the Peaty _Lysichitum_ forest type.

Soils:

Besides the high water table, the great thickness of unincorporated organic material is very characteristic of the soils. The color of the organic layer is black. It is friable or sticky in the natural condition and forms very hard aggregates if dried out at room temperature.

Parent material in different plots:	cumulose deposits
Physical properties:	
Depth of solum:	10 to 12 inches
Thickness of the O horizon:	over 12 inches
Chemical properties:	
pH of the O horizon:	4.5 to 4.8

For other chemical properties see the previous forest type.

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) Hw	Cr	S	B
Pitchy Peat Anmoor	1	91	98	74	?
Spring Line Pitchy Anmoor	2	90	124	140	67

These are very poorly drained soils. The water table is in the organic horizon and about 10 inches from the surface. Occasionally the whole profile is saturated with water. The difference in the water supply between Pitch Peat Anmoor and Spring Line Pitch Anmoor is in the rate of movement of the seepage. The water is semi-stagnant in the former and relatively rapidly moving in the latter. The oxygen supply is much better in moving water than in stagnant or semi-stagnant water. Root distribution is restricted to the top of the organic layer. Small hummocks allow establishment of tree seedlings, while depressions are devoid of trees.

D. DRY EDAPHIC COMMUNITIES

Dry edaphic communities are distributed in both the dry and wet subzones. They are restricted to localities which are supplied only by water from precipitation. The soils are shallow or very coarse textured. The prevailing humus type is the raw humus (mor).

Assoc. 14. *Pseudotsugetum menziesii*

The *Pseudotsugetum* occurs in the drier subzone on hill-tops or upper slopes. This association is divided into three forest types on the basis of floristic and pedologic differences.

a. Orthic *Gaultheria* forest type

The Orthic *Gaultheria* forest type occurs on convex hillsides. The steepness of the slopes range from 5 degrees to 18 degrees. The constant dominant species of this type are the following (Orloci, 1961): *Pseudotsuga menziesii*, *Thuja plicata*, *Tsuga heterophylla*, *Gaultheria shallon*, *Vaccinium parvifolium*, *Pteridium aquilinum*, *Eurhynchium oreganum*, *Hylocomium splendens*, *Plagiothecium undulatum*.

Soils:

Parent material	glacial till

Physical properties:

Stoniness	35% (20% to 60%)
Depth of solum	22.0 inches (11 to 34 inches)
Thickness of the O horizon	3.6 inches (1 to 9 inches)
Thickness of the A_e horizon	2 inches (thin broken to 5 inches)
Texture of the A_e horizon	sand
Texture of the B horizon	sand to loamy sand
Structure of A_e horizon	single grain to weak blocky
Structure of B horizon	single grain to firm blocky

Chemical properties*:

pH - O horizon	3.9 (3.4-4.5)
A_e horizon	4.0 (3.7-4.3)
B horizon	5.2 (5.0-5.4)
Organic matter in tons per acre:	75
Total cation exchange capacity in equivalents per 100 m^2	4468
Available P in lb. per acre:	85
Exchangeable cations in lb. per acre: Ca	195
Mg	100
K	123

Distribution of chemical properties by horizons in percentage:

Horizon	O	Ae	B
Organic matter	52	½	47½
Cation exchange capacity	20	2	78
Ca	99	1	0
Mg	51	1	48
K	59	1	40
P	5.4	0.2	94.4

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* On the basis of one analysed profile, except for pH values which are averages of five profiles.

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr
Degraded Concretionary Brown	2	111	110	78
Orterde Podzol	1	122	87	90
Orterde Humic Podzol	1	117	93	77

b. Legosolic Gaultheria forest type

The Legosolic Gaultheria forest type occurs mostly on hill-tops or on steep slopes. The contours are always convex. The slopes are between 30 degrees to 40 degrees on hillsides and under 20 degrees on hill-tops. The plant community is identical with the Gaultheria forest type except that Calliergonella schreberi, missing from the latter, is present here.

Soils:

Parent material	granitic bedrock
Physical properties:	
Stoniness (above bedrock):	0
Depth of solum	3.3 inches (1 to 10 inches)
Thickness of the O horizon	2.9 inches (1.5 to 2 inches)
Thickness of the Ae horizon	2.4 inches (1 to 6 inches)
Texture of Ae horizon	sand to sandy loam
Structure of the A_e horizon	single grain to weak blocky
Chemical properties:	
pH - O horizon	3.8 (3.5-4.1)
A_e horizon	3.8 (3.5-4.1)

The other chemical properties have not been studied in this forest type. Chemical data on Eluviated Acid Legosol are presented in the Vaccinium - Gaultheria forest type.

Soil subgroup and site index:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr
Eluviated Acid Legosol	5	85	86	73

c. Gaultheria - Mahonia forest type

The Gaultheria - Mahonia forest type occurs on steep convex hillsides. The slope is 30 degrees to 35 degrees and exposed to the south. Floristically Mahonia nervosa separates this forest type from the previous two. It is a constant dominant in the Gaultheria - Mahonia forest type and only accidental in the two others.

Soils:

Parent material in different plots:	glacial drift
Physical properties:	
Stoniness	60% (40% to 80%)
Depth of solum	43.5 inches (39 to 48 inches)
Thickness of the O horizon	3 inches
Thickness of the A_e horizon	2 inches
Texture of the A_e horizon	sand
Texture of the B horizon	sand to loamy sand
Structure of the A_e horizon	single grain to weak blocky
Structure of the B horizon	single grain to firm blocky
Chemical properties*:	
pH - O horizon	4.1
A_e horizon	4.4
B horizon	5.7
Organic matter in tons per acre:	76
Total cation exchange capacity in equivalents per 100m^2:	3343

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* On the basis of one analysed profile.

Available P in lb. per acre:		33
Exchangeable cations in lb. per acre:	Ca	232
	Mg	110
	K	123

Distribution of the chemical properties according to horizons in percentage:

Horizon	O	Ae	B
Organic matter	48	3	49
Cation exchange capacity	32	1	67
Ca	88	2	10
Mg	33	6	61
K	59	4	37
P	14	9	77

Soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr
Minimal Podzol	2	99	90	75

Assoc. 15. Tsugeto - Gaultherietum

The Tsugeto - Gaultherietum occurs only in the wet subzone. This edaphically extremely dry community is located on hilltops, ridges and on convex slopes close to hilltops. The association is divided into two forest types. One of them is characterized by podzolic soils and the other by legosols.

a. Orthic Vaccinium - Gaultheria forest type

The Orthic Vaccinium - Gaultheria forest type is characterized by the following constant dominant species (Orloci, 1961): Tsuga heterophylla, Thuja plicata, Vaccinium alaskaense, Gaultheria shallon, Hylocomium splendens, Rhytidiadelphus loreus, Plagiothecium undulatum, Rhytidiopsis robusta.

The sporadic occurrence of Chamaecyparis nootkatensis and Pinus monticola is very important in the recognition of this forest type.

Soils:

Parent material	glacial till or granitic bedrock
Physical properties:	
Stoniness	7% (5% to 10%)
Depth of solum	8.6 inches (6 to 12 inches)
Thickness of the 0 horizon	5.3 inches (5 to 6 inches)
Thickness of the A_e horizon	3 inches (2 to 4 inches)
Texture of the A_e horizon	sand to loamy sand
Texture of the B horizon	loamy sand to sandy loam
Structure of the A_e horizon	single grain to granular
Structure of the B horizon	granular to blocky
Chemical properties:	
pH - 0 horizon	3.1 (3.05-3.1)
A_e horizon	3.4 (3.4-3.49)
B horizon	4.3 (4.0-4.6)

Other chemical properties have not been studied in this forest type, but probably they are very similar to the soils of the Gaultheria forest type.

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961)				
		F	Hw	Cr	Cy	B
Orterde Humic Podzol	3	74	61	77	59	44

b. Legosolic Vaccinium - Gaultheria forest type

Floristically mainly the presence of Calliergonella schreberi separates this forest type from the previous one.

Soils:

Parent material	granitic bedrock
Physical properties:	
Stoniness	2% (0% to 10%)
Depth of solum	4.0 inches (2 to 6 inches)
Thickness of the 0 horizon	5.2 inches (1 to 11 inches)
Thickness of the A_e horizon	3.8 inches (2 to 6 inches)
Texture of the A_e horizon	fine sand
Structure of the A_e horizon	granular
Chemical Properties*:	
pH - 0 horizon	3.6 (3.4-3.8)
A_e horizon	3.5 (3.4-3.7)
Organic matter in tons per acre:	64
Total cation exchange capacity in equivalents per $100m^2$:	1794
Available P in lb. per acre:	10.7
Exchangeable cations in lb. per acre: Ca	170
Mg	90
K	187

Distribution of chemical properties by horizons in percentage:

Horizon	0	A_e
Organic Matter	70	30
Cation exchange capacity	48	52
Ca	53	47
Mg	52	48
K	68	32
P	45	55

---

* On the basis of one analysed profile. The pH values are averages for

Figure 11, 12, and 13

Figure 11. Orthic *Gaultheria* forest type

Figure 12. Degraded Concretionary Brown soil

Figure 13. Eluviated Acid Legosol soil from legosolic *Vaccinium* - *Gaultheria* forest type

Figure 11.

Figure 12.

Figure 13.

Soil subgroup and site index:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr	Cy	B
Eluviated Acid Legosol	6	69	55	53	63	40

E. ZONAL COMMUNITIES

There is one zonal association in each subzone. The Tsugetum heterophyllae plagiothecietosum undulati is zonal in the dry subzone and the Abieteto - Tsugetum heterophyllae in the wet subzone. Zonal communities occur in a wide range of topographic conditions, but always on deep, well drained soils.

Assoc. 16. Tsugetum heterophyllae plagiothecietosum undulati

The Tsugetum heterophyllae plagiothecietosum undulati is divided into two forest types. One is the Orthic Plagiothecium forest type, which is characterized by a very poorly developed shrub layer. The other is the Plagiothecium - Mahonia forest type characterized by a well developed shrub layer. Both forest types occur on terraces, gentle slopes (0 degrees to 25 degrees), or on flat hill-tops.

a. The Orthic Plagiothecium forest type

The Orthic Plagiothecium forest type has a dense tree layer but very poorly developed shrub and herb layers. The moss layer is usually well developed. The constant dominant species of the forest type are the following (Orloci, 1961): Tsuga heterophylla, Psedotsuga menziesii, Thuja plicata, Acer circinatum, Pteridium aquilinum, Plagiothecium undulatum, Eurhynchium oreganum, Hylocomium splendens, Rhytidiadelphus loreus.

Soils:

The soils are mostly coarse textured but deep. The solum is covered with a thin or moderately thick layer of decomposed and partly decomposed organic matter. This organic layer is black or very dark reddish-brown mor.

Parent material	glacial till and outwash
Physical properties:	
Stoniness	39% (5% to 60%)
Depth of solum	39 inches (30 to 55 inches)
Thickness of the O horizon	2.6 inches (0.5 to 6 inches)
Thickness of the A_e horizon	1.2 inches (0 to 3 inches)
Texture of the A_e horizon	sand to loamy sand
Texture of the B horizon	sand to sandy loam
Structure of the A_e horizon	single grain to weak blocky
Structure of the B horizon	single grain to firm blocky
Chemical properties*:	
pH - O horizon	3.8 (3.4-4.1)
A_e horizon	4.0 (3.7-4.2)
B horizon	5.6 (5.3-6.0)
Organic matter in tons per acre:	143
Total cation exchange capacity in equivalents per $100m^2$	11200
Available P in lb. per acre:	79
Exchangeable cations in lb. per acre: Ca	210
Mg	340
K	206

---

* On the basis of three analysed profiles. The pH values are averages of six profiles.

Distribution of chemical properties by horizons in percentage:

Horizon	O	A_e	B
Organic matter	23	2	75
Cation exchange capacity	8	2	90
Ca	94	4	2
Mg	10	7	83
K	23	5	72
P	6	4	90

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr
Minimal Podzol	5	138	105	86
Orterde Podzol	1	144	113	88
Orterde Humic Podzol	2	151	128	100

All are well-drained, coarse textured soils. The roots are evenly distributed in some of the profiles but mostly they are concentrated in the O horizon and in the upper part of the solum proper. All soil profiles with one exception are underlain by hardpan. In 33% of the profiles temporary or permanent seepage is evident at an average depth of forty-one inches. The moisture conditions are fair in the whole profile.

b. The Plagiothecium - Mahonia forest type

The forest in this community is just as dense as in the previous forest type, the only difference between the two is the well developed shrub layer of the Plagiothecium - Mahonia type. In the shrub layer Mahonia nervosa is the dominant species.

Soils:

The general soil properties are very similar to those of the Plagiothecium forest type. There is, however, a difference in parent material and in stoniness.

Figure 14, 15

Figure 14. Orthic *Plagiothecium* forest type

Figure 15. Orthic Brown Podzolic soil

Figure 14.

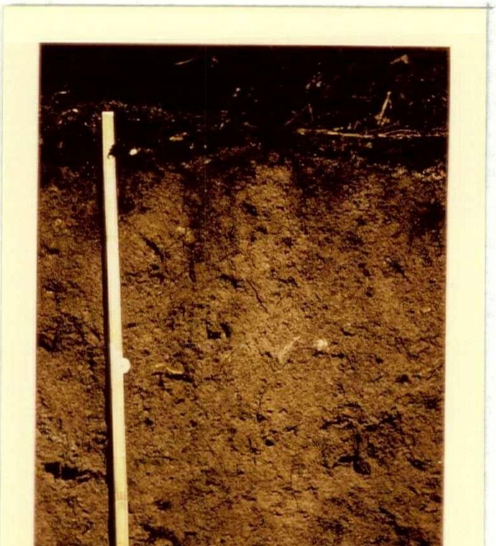

Figure 15.

Parent material is mostly alluvial deposits.

Physical properties:

Stoniness ranges from 2% to 50% with a 26% average.

Chemical properties:

pH values* -	O horizon	3.9 (3.8-4.0)
	A_e horizon	4.0 (4.0-4.1)
	B horizon	5.4 (5.0-5.6)

For other chemical properties see the Plagiothecium forest type.

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr
Orthic Brown Podzolic	1	121	95	90
Minimal Podzol	1	117	120	114
Orterde Podzol	1	155	99	88
Orterde Humic Podzol	1	161	132	85

These profiles are well- or excessively-drained. Root distribution is even throughout the whole profile. There is no indication of seepage in any of the profiles.

Assoc. 17. Abieteto - Tsugetum heterophyllae

The Abieteto - Tsugetum heterophyllae is the zonal association of the wet subzone. The ecotopic conditions of this association are similar to that of the Tsugetum heterophyllae plagiothecietosum undulati. The differences are mainly climatic characterizing the wet subzone, i.e. the amount of precipitation, amount of snow fall and temperature. The association is divided into two forest types:

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[*] Two profiles were studied for pH.

a. *Vaccinium* - *Plagiothecium* - *Clintonia* forest type

This forest type occurs on terraces, hillsides (slope 5 to 30 degrees) or on flat hilltops. Its species composition is characterized by the following constant dominant species (Orloci, 1961): *Tsuga heterophylla*, *Thuja plicata*, *Abies amabilis*, *Vaccinium alaskaense*, *Blechnum spicant*, *Plagiothecium undulatum*, *Rhytidiadelphus loreus*, *Mnium punctatum*, *Hylocomium splendens*.

Floristically the presence of *Clintonia uniflora* and the absence of *Acer circinatum* distinguish this community from the *Vaccinium* - *Plagiothecium* - *Acer* forest types.

Soils:

The deep soils are covered by a thick layer of decomposed organic matter. This accumulated decomposed organic matter is black or very dark reddish brown mor. In two out of seven profiles the collected humus sample formed very hard irreversible aggregates when dried at room temperature.

Parent material in different plots:	glacial till 70%, glacial outwash 30% (of plots)
Physical properties:	
Stoniness	47% (20% to 80%)
Depth of solum	34.7 inches (19 to 58 inches)
Thickness of the O horizon	7.5 inches (3 to 12 inches)
Thickness of the A_e horizon	0.9 inches (0 to 3 inches)
Texture of the A_e horizon	sand to sandy loam
Texture of the B horizon	sand to loam
Structure of the A_e horizon	single grain to weak blocky
Structure of the B horizon	single grain to firm blocky

Chemical properties*:

pH -	O horizon	3.6 (3.3-4.3)
	A_e horizon	3.9 (3.8-4.0)
	B horizon	5.3 (5.0-5.9)
Organic matter in tons per acre		195
Total cation exchange capacity in equivalents per 100m2		8440
Available P in lb. per acre		28.6
Exchangeable cations in lb. per acre:	Ca	840
	Mg	287
	K	173

Distribution of chemical properties by horizons in percentage:

Horizon	O	A	B
Organic matter	58	1	41
Cation exchange capacity	34	5	61
Ca	97.5	2.5	0
Mg	54	4	44
K	54	8	38
P	30	2	68

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site index (Eis, 1961) F	Hw	Cr	B
Orthic Brown Podzolic	1	119	107	113	117
Minimal Podzol	4	108	114	98	93

All soils are well drained in the top two feet of their profiles, but some are imperfectly drained in the lower portion of the B layer.

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* The data for chemical properties are the average of three profiles including one from the Vaccinium - Plagiothecium - Acer forest type. The pH values are averages for the Vaccinium - Plagiothecium - Clintonia forest type.

The major portion of the roots is located in the O horizon. Indication of temporary or permanent seepage has been found in 36% of the sample plots at an average depth of 35 inches. Plots with permanent seepage could be considered as highly degraded *Blechnum* forest types, which by their ecosystems and advanced primary succession may be considered as parts of this zonal plant association.

b. *Vaccinium* - *Plagiothecium* - *Acer* forest type

The *Vaccinium* - *Plagiothecium* - *Acer* forest type has altitudinally a lower position on the mountain slopes relative to the previous forest type. It may be found on gentle lower slopes (5 to 20 degrees) and river or lake terraces. Its floristic composition is identical with the *Vaccinium* - *Plagiothecium* - *Clintonia* forest type except for the presence of *Acer circinatum* and the absence of *Clintonia uniflora*.

Soils:

The quality of the accumulated organic matter is similar to that of the previous forest type.

Parent material in different soils:	glacial outwash, lacustrine deposit 60%, glacial till 40% (of plots)
Physical properties:	
Stoniness	16% (0% to 50%)
Depth of solum	39.1 inches (16 to 52 inches)
Thickness of the O horizon	5.3 inches (1 to 13 inches)
Thickness of the A_e horizon	0.1 inch (0 to 2 inches)
Texture of the A_e horizon	sand to loamy sand
Texture of the B horizon	sand to clayey loam
Structure of the A_e horizon	weak granular to weak blocky
Structure of the B horizon	weak granular to firm blocky

Chemical properties:

pH -	O horizon	3.3 (2.9-3.6)
	A_e horizon	3.7 (3.4-4.6)
	B horizon	5.2 (5.0-5.7)

For other chemical properties see the *Vaccinium* - *Plagiothecium* - *Clintonia* forest type.

Distribution of soil subgroups and site indexes:

Soil subgroup	No. of Profiles	Site indexes (Eis, 1961) F	Hw	Cr	B
Minimal podzol	8	114	102	108	92
Orterde Humic Podzol	2	135	108	85	107
Orthic Brown Podzolic	1	122	104	113	94

The drainage of soils is excessive to poor. Roots are located mostly in the O horizon but a few penetrate down to the impervious layer. In the poorly drained profiles the lower portion of the B horizon is without any roots. Seepage exists in 18% of the profiles at an average depth of 32 inches. Those plots, where seepage is observable, could be considered again as highly degraded *Blechnum* forest types. (Zonal forest type, which developed from *Blechnum* forest type in the course of primary succession.)

Figure 16 and 17

Figure 16. *Vaccinium* - *Plagiothecium* forest type

Figure 17. Orterde Humic Podzol

(The ruler is 18 in. long.)

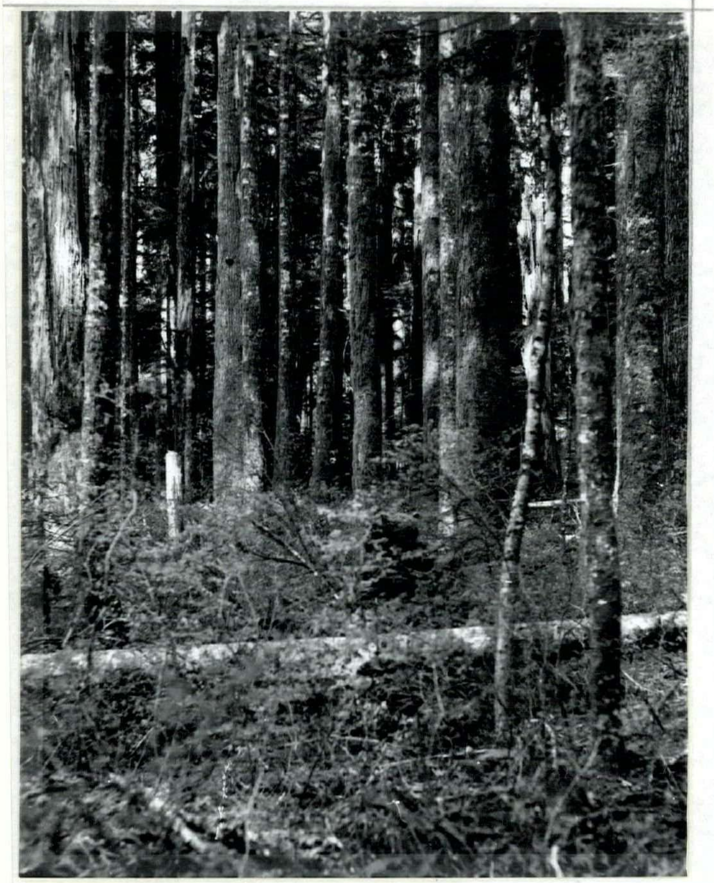

Figure 16.

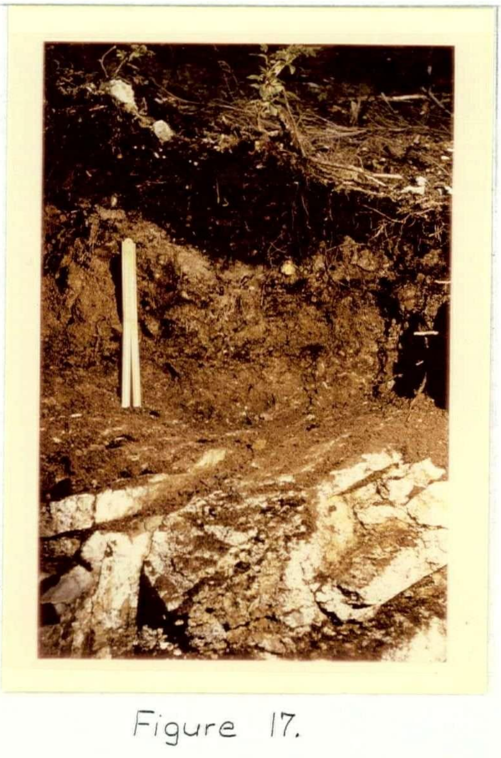

Figure 17.

CHAPTER V. COMPARISON OF ECOTOPIC CHARACTERISTICS OF ASSOCIATIONS AND FOREST TYPES

Altitude and exposure

It is very difficult to draw sound conclusions from the general distribution of association and forest types according to altitude and exposure in the study area. The evaluation would be more realistic if the study area were divided up into geographical units with similar climates. Three such units were separated in the present study. Area number one includes Seymour Mountain, Lynn Park, Cypress Creek area and Grouse Mountain. Area number two includes Seymour Creek Valley and Coquitlam Lake area. Area number three is the University Forest at Haney. The associations of the dry and wet subzone are very sharply separated from each other within these geographic units. (See fig. 18, 19, 20). The altitudinal differences are especially sharp between the dry edaphic and zonal communities of the subzones, because they are controlled mainly by the climate. Overlapping is considerably wide in the case of seepage communities, because of the significant role of this edaphic factor.

The following table shows the altitudinal distribution of sample plots compared by associations in the three geographic groupings.

Area	Range of altitude of sample plots in feet*					
	T	AT	G	VG	P	B
No. 1	430- 950	1100-2730	600- 960	?	500-1360	460-3000
No. 2	-	550- 880	600- 650	590-1000	430- 700	570- 920
No. 3	1010-1050	1620-2600	900-1400	1450-2000	750-1500	1450-1680

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* T - Tsugetum heterophyllae plagiothecietosum undulati
AT - Abieteto - Tsugetum heterophyllae
G - Pseudotsugetum menziesii
VG - Tsugeto - Gaultherietum
P - Thujeto - Polystichetum
B - Thujeto - Blechnetum

These data suggest that the wet subzone begins at the altitude of 1400-1500 feet in the number three area, 900-1000 feet in the number one area and 500-600 feet in the number two area.

Associations and soil subgroups

The distribution of soil subgroups in the associations is far from being random. (See fig. 20/a) There is a definite relationship between forest association and soil subgroup. The correlation is the greatest in the association of extreme edaphic position. The *Ribes - Lysichitum*, *Lysichitum - Oenanthe*, *Oplopanax - Ribes*, *Coptis - Lysichitum* and *Ledum* forest types are confined to particular soil subgroups. In the dry edaphic communities the Eluviated Legosol is most common. The Minimal Podzol is the prevalent soil subgroup in the zonal associations. A series of different degrees of podzolization may be followed in these associations, from the Orthic Brown Podzolic to the Humic Podzol subgroup. Podzolization reaches the most advanced stage in the *Abieteto - Tsugetum heterophyllae* in the wet subzone while the *Thujeto - Polystichetum* is distributed mainly on Brunisolic soils. Podzolization is retarded in the latter community probably as a result of its species composition which does not support raw humus accumulation. The greatest soil variation is in the *Thujeto - Blechnetum*. This variation is partly due to the fact that the wettest section of the *Thujeto - Blechnetum* is associated with gleysolic soils. The participation of podzolic soils is considerably smaller in this plant association than in the dry edaphic or zonal communities. The accumulation of raw humus is great enough to promote the process of podzolization, but in the imperfectly drained places the high water table restricts downward migration of organic matter and sequioxides.

The *Piceeto - Lysichitetum* is more uniform from the point of view of soils than is indicated in fig. 20/a. All four of these soils are poorly

Fig.18. Altitude And Exposure Distribution Of The Dry Edaphic Communities

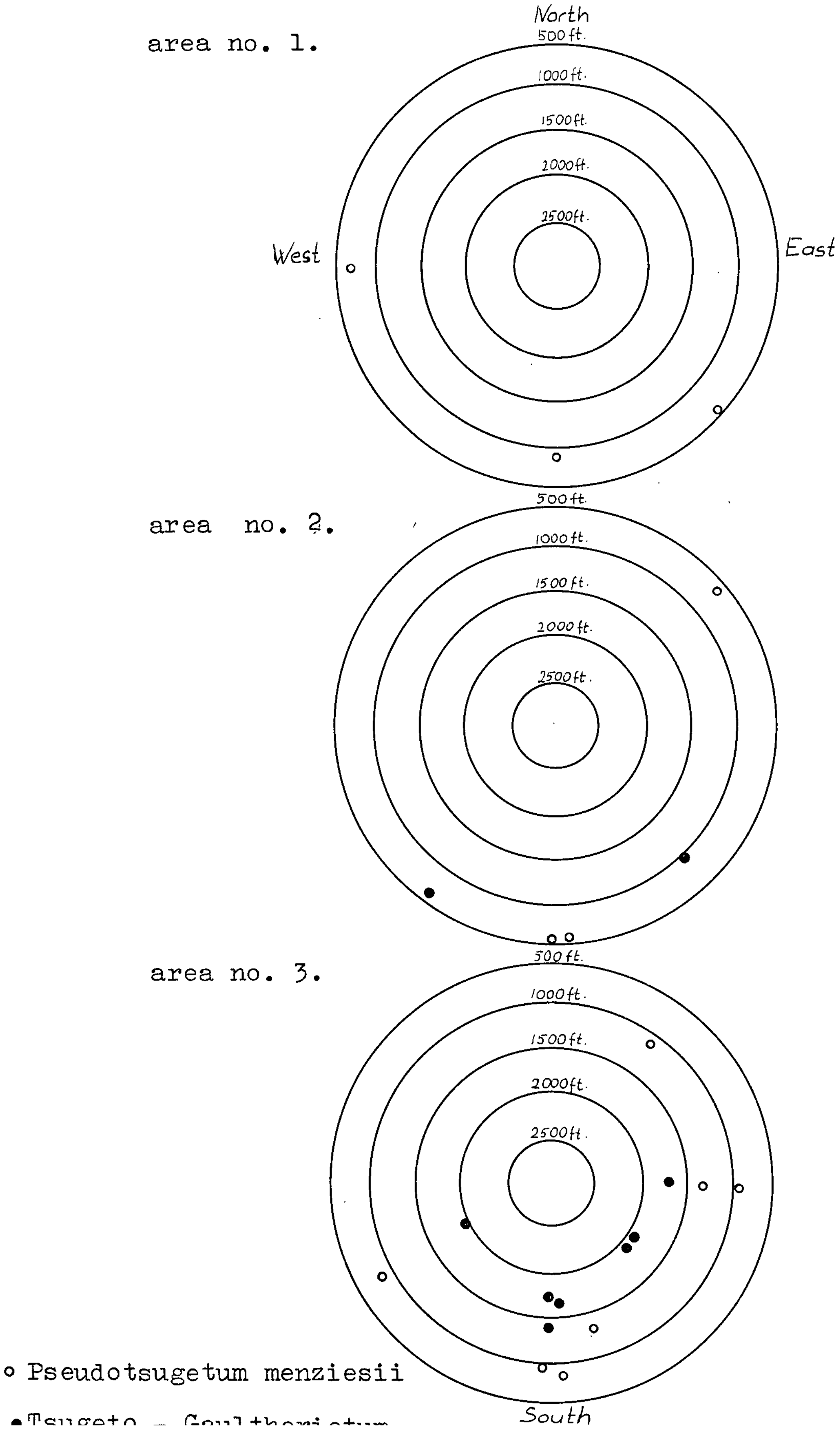
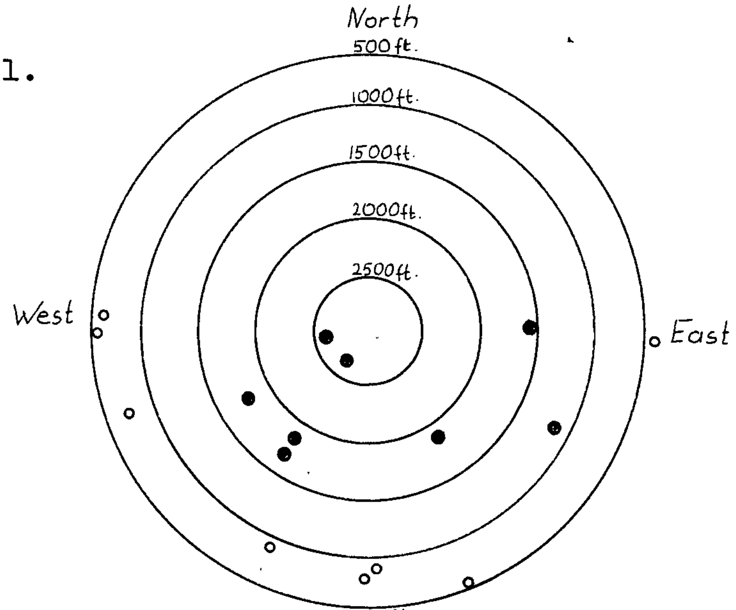
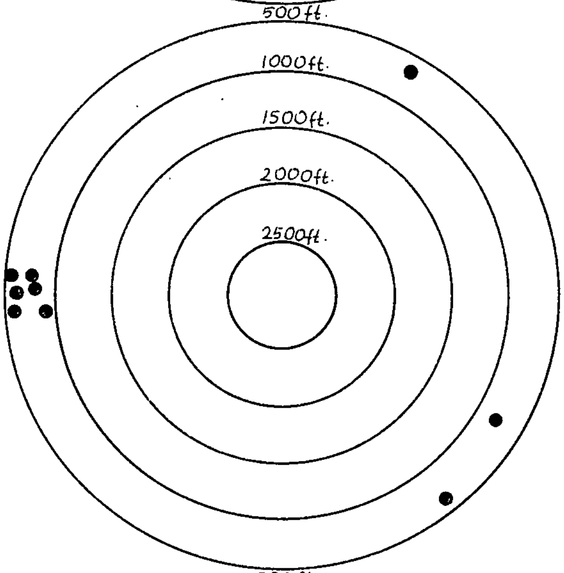


Fig.19. Altitude And Exposure Distribution Of The Zonal Associations

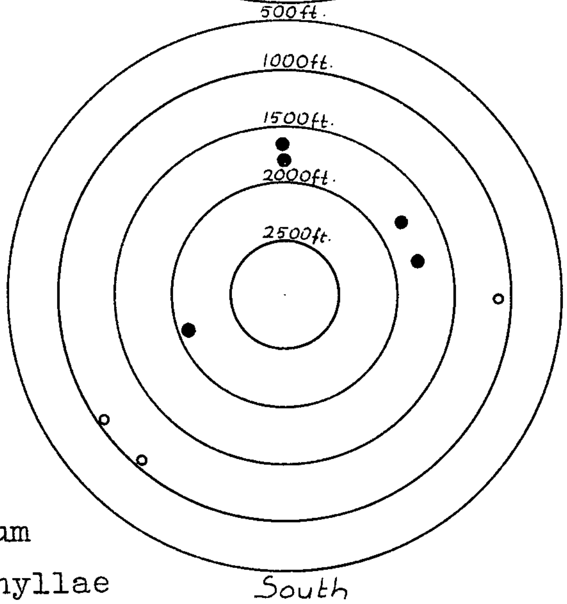
area no. 1.



area no. 2.



area no. 3.



● Abieteto - Tsugetum
○ Tsugetum heterophyllae

Fig. 20. Altitude And Exposure Distribution Of Seepage Associations

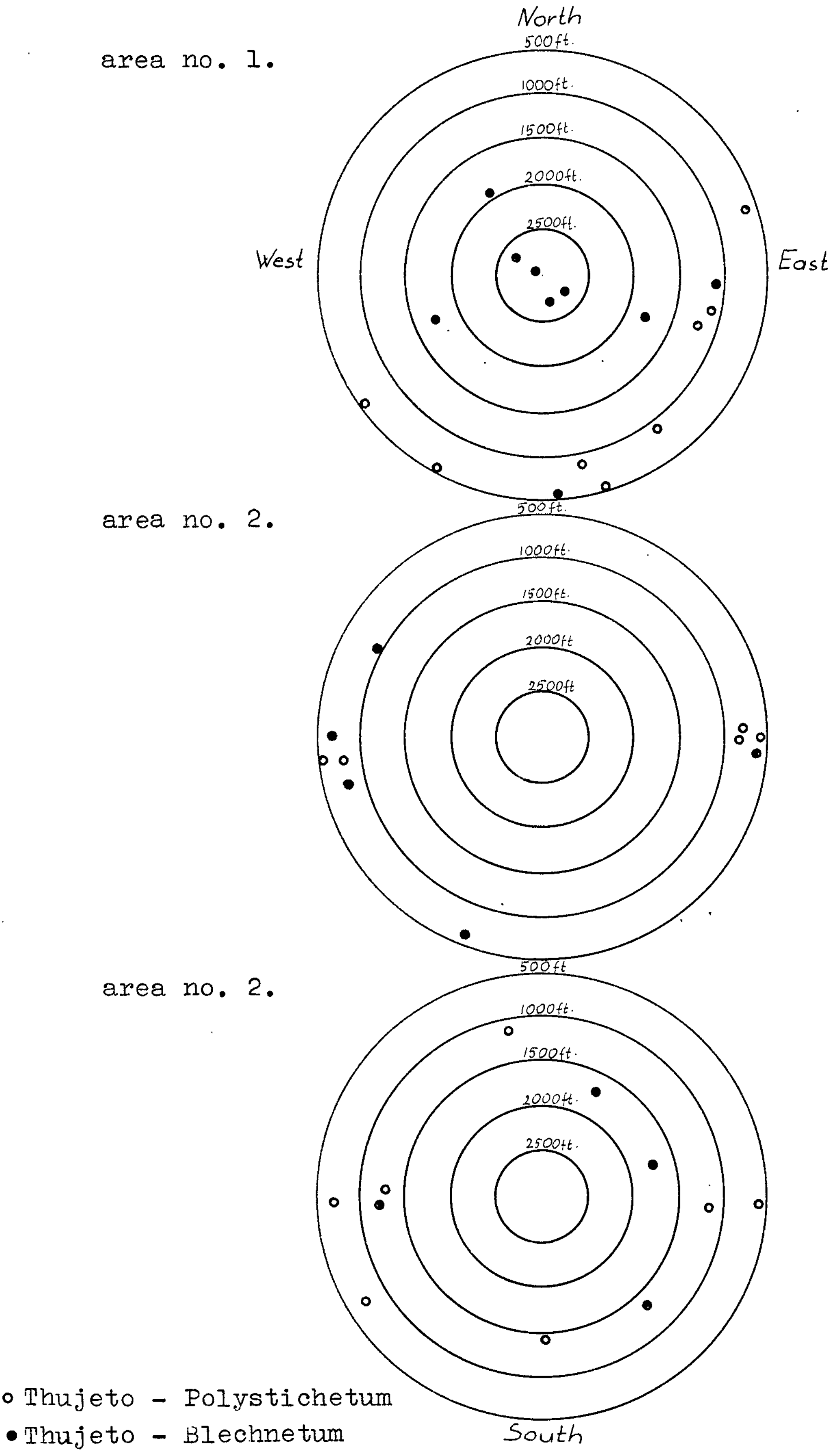


Figure 20/a

Figure 20/a. Distribution of Soil Subgroups in the Associations

The width of the dark area in the diagramm is proportional with the frequency of a certain soil subgroup in different associations. Its value varies from 0 to 100%.

Abbreviations:

RO - Piceeto - Oplopanacetum
RL - Alneto - Ribisetum bracteosi
OL - Saliceto - Oenanthetum
L - Pineto - Ledetum
CL - Thujeto - Coptetum
VL - Piceeto - Lysichitetum
B - Thujeto - Blechnetum
P - Thujeto - Polystichetum
TA - Abieteto - Tsugetum heterophyllae
Th - Tsugetum heterophyllae plagiothecietosum
PG - Pseudotsugetum menziesii
TG - Tsugeto - Gaultherietum
EAL - Eluviated Acid Legosol
DCB - Degraded Concretionary Brown
OP - Orterde Podzol
OHP - Orterde Humic Podzol
HP - Humic Podzol
MP - Minimal Podzol
OBP - Orthic Brown Podzolic
MA - Modal Acid Dark Brown Forest
GP - Gleyed Podzol
OG - Orthic Gleysol
OD - Orthic Dark Gray Gleysolic
SPA - Springline Pitchy Anmoor
PP - Pitchy Peat Anmoor
SP - Sphagnum Peat
AR - Alluvial Regosol

DISTRIBUTION OF SOIL SUBGROUPS IN THE ASSOCIATIONS

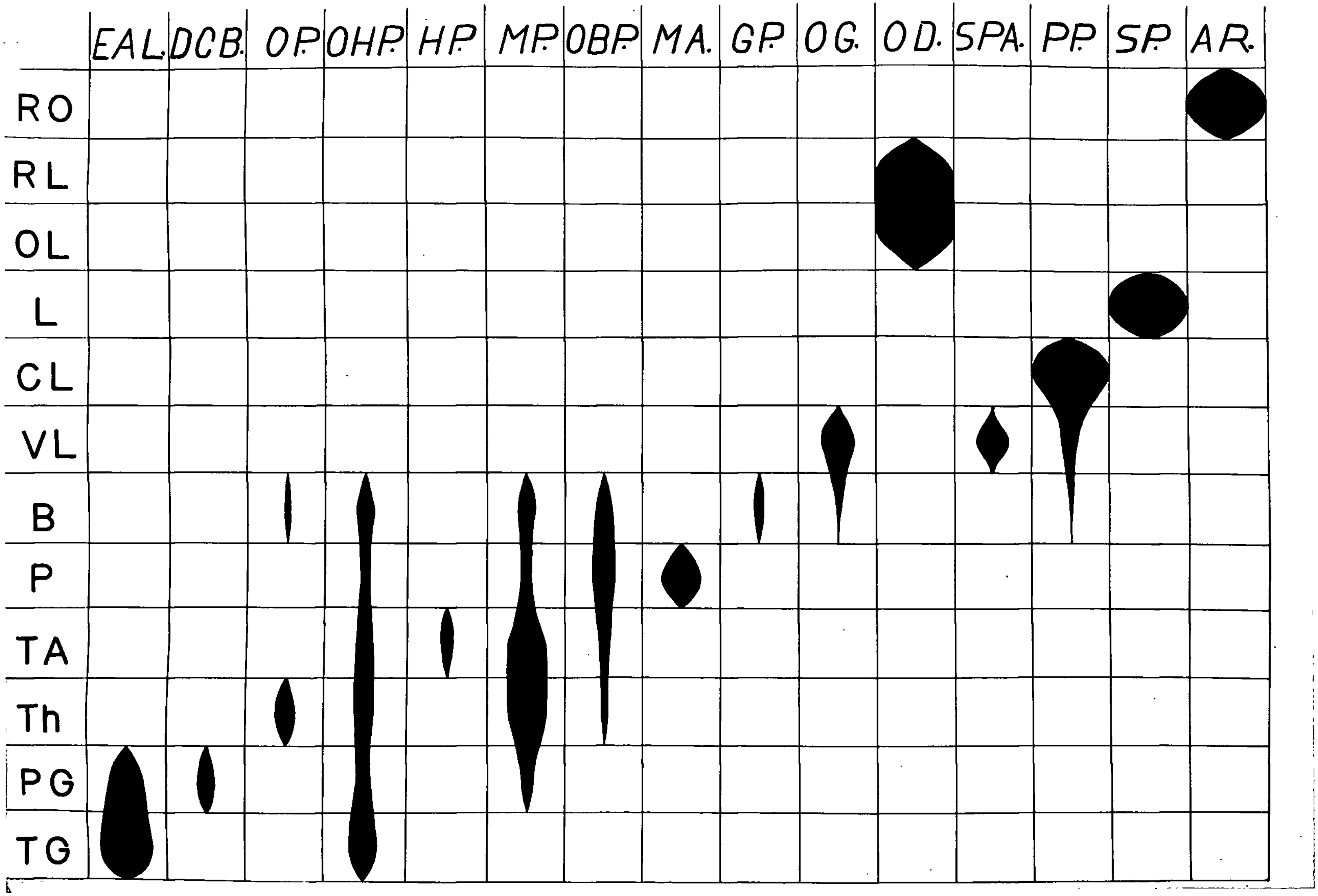


Figure 20/a

drained and characterized by reduction. The only real difference is in the thickness of accumulated organic matter and the speed of water movement.

There are four soil subgroups most widely distributed in the Coastal Western Hemlock Zone. These are the Orthic Brown Podzolic, Minimal Podzol, Orterde Podzol and Orterde Humic Podzol. All four occur in three or more different plant associations on well drained soils. All other soil subgroups are restricted to a particular plant association or occur on extremely wet or dry habitats.

Depth of solum

The depths of sola are compared only in those forest types where the soil depth is an important factor determining site quality. Forest types in which the water table is high and permanent regardless of the depth of the impervious layer are not included.

Solum depths are compared separately in the dry and wet subzone. The following data are means and standard deviations.

Dry subzone:

Legosolic *Gaultheria*	3.3 ± 1.5
------------------------------	----------
Orthic *Gaultheria*	22.0 ± 9.1
------------------------------	----------
Gaultheria - *Mahonia*	43.5 ± 6.4
Plagiothecium - *Mahonia*	35.5 ±13.2
Orthic *Plagiothecium*	39.0 ± 9.2
Polystichum	39.2 ±10.1
Blechnum - *Rubus*	29.0 ± 1.7

The dotted lines separate populations which are significantly different from one another at the one percent level, in both subzones.

Wet subzone:

Legosolic *Vaccinium* - *Gaultheria*	4.0 ± 1.7
Orthic *Vaccinium* - *Gaultheria*	8.6 ± 3.0
Vaccinium - *Plagiothecium* - *Clintonia*	34.7 ± 12.6
Vaccinium - *Plagiothecium* - *Acer*	39.1 ± 11.6
Orthic *Blechnum*	33.0 ± 10.1
Gleysolic *Blechnum*	15.6 ± 7.7

The Gleysolic *Blechnum* forest type differs significantly from the *Vaccinium* - *Plagiothecium* and Orthic *Blechnum* forest types at the five percent level.

The forest types are arranged in the order of increasing wetness in both subzones. This arrangement indicates that the extremeness of the site decreases with increasing soil depth as the shallow soils are either dry or wet. Consequently, the wet shallow soils must have additional water supply which is not direct precipitation. This additional water supply is seepage or ground water. The configuration of the topography determines if the site will collect or rapidly drain off the precipitation water. However, the topography alone never determines the wetness of the site. The reason for this is that if the impermeable layer is high in a concave area the site is likely to be wet; on the other hand a site with the same topography may be moderately dry if the impervious layer is very deep under the solum. In the same way convex topography can represent extremely dry sites if the soil is shallow, or deep but coarse; the same convex sites develop mesic sites, if the soil is deep and relatively fine.

Consequently the mutual evaluation of soil depth (depth of the impervious layer) and topography can serve as a useful tool in the estimation of site quality. But, as it was mentioned in the beginning of this chapter, the level of ground water or the depth of seepage is often far from being equal to the depth of impervious layer. Hence, the sites need to be examined also from this point of view.

Depth of seepage and ground water

The following table summarizes the abundance and average depth of seepage or ground water in the forest types. The depths are measured from the surface of the organic horizon.

Forest type	Percentage of Occurrence	Depth in inches
Vaccinium - Plagiothecium A.	18	32
Orthic Plagiothecium	33	41
Vaccinium - Plagiothecium C.	36	35
Polystichum	38	35
Orthic Blechnum	92	30
Blechnum - Rubus	100	22
Gleysolic Blechnum	100	17
Peaty Blechnum	100	10
Vaccinium - Lysichitum	100	7
Coptis - Lysichitum	100	7
Ledum	100	5

The depth of ground water in the coarse textured floodplain forest types depends on the water level of the river. If we assume that the first colonies of vegetation appear on sediments just above the average level of the river, the positions of floodplain forest types relative to this level are the following:

Ribes - Lysichitum - 1 to 3 feet
Lonicera - Rubus - 2 to 6 feet
Oplopanax - Ribes - 5 to 10 feet
Symphoricarpos - 10 feet and onward

The water level in the Lysichitum - Oenanthe forest type does not follow the fluctuation of water in the river. The fine sediment of this habitat does not permit drainage of the water but keeps it at a high level (one foot or higher) throughout the whole year.

In fig. 21 the site indexes for F, Hw, and Cr as well as soil depth and seepage are summarized according to forest types. The communities are arranged in the order of increasing wetness from left to right. The forest types are separated according to subzone and the types occurring in both subzones are placed into a third group. In the dry subzone the site index gradually increases with wetness of the site up to the Blechnum - Rubus forest type, where the average depth of seepage is 22 inches. From this point the productivity decreases with increasing wetness. The example of Gaultheria - Mahonia forest type demonstrates a case where the deep soil (43 inches) and corase texture results in a much drier habitat than the 22 inch deep soil in the Orthic Gaultheria forest type. Both habitats occur on convex topography but the relatively high impervious layer in the Orthic Gaultheria forest type is more effective in retaining available water for plant growth than the deep, coarse profile of the Gaultheria - Mahonia type.

With the exception of Legosolic Vaccinium - Gaultheria and Orthic Vaccinium - Gaultheria forest types all communities in the wet subzone are well supplied with water, regardless of the presence of seepage. In other words, if the soil is sufficiently deep, precipitation water satisfies the needs of vegetation, and the site quality is more or less indifferent to the additional water supply. The high water table in the Gleysolic and Peaty Blechnum forest types affects the site indirectly causing an air deficiency in the soil. These poorly aerated sites will not support Douglas-fir. The climatic differences of the two subzones are also indicated by the difference of ground water level corresponding to the best site for Douglas-fir. The

Figure 21

Figure 21. Relationship Between Forest Type, Soil Depth, Seepage Depth and Site Indexes

a. dry subzone

b. wet subzone

c. forest types occurring in both subzones.

The vertical lines in the graphs indicate the depth of seepage from the surface of organic horizon. The soil depths are indicated by the continuous line in the graph.

Symbols:

Df - Douglas-fir
Hw - Western hemlock
Cr - red cedar
LG - Legosolic Gaultheria forest type
MG - Gaultheria Mahonia forest type
G - Orthic Gaultheria forest type
MT - Plagiothecium Mahonia forest type
T - Orthic Plagiothecium forest type
P - Polystichum forest type
RB - Blechnum rubus forest type
LTG - Legosolic Vaccinium Gaultheria forest type
TG - Orthic Vaccinium Gaultheria forest type
VPl.C - Vaccinium Plagiothecium Clintonia forest type
VPl.A - Vaccinium Plagiothecium Acer forest type
B - Orthic Blechnum forest type
GB - Gleysolic Blechnum forest type
PB - Peaty Blechnum forest type
VL - forest types of Piceeto - Lysichitetum
CL - Coptis Lysichitum forest type
L - Ledum forest type

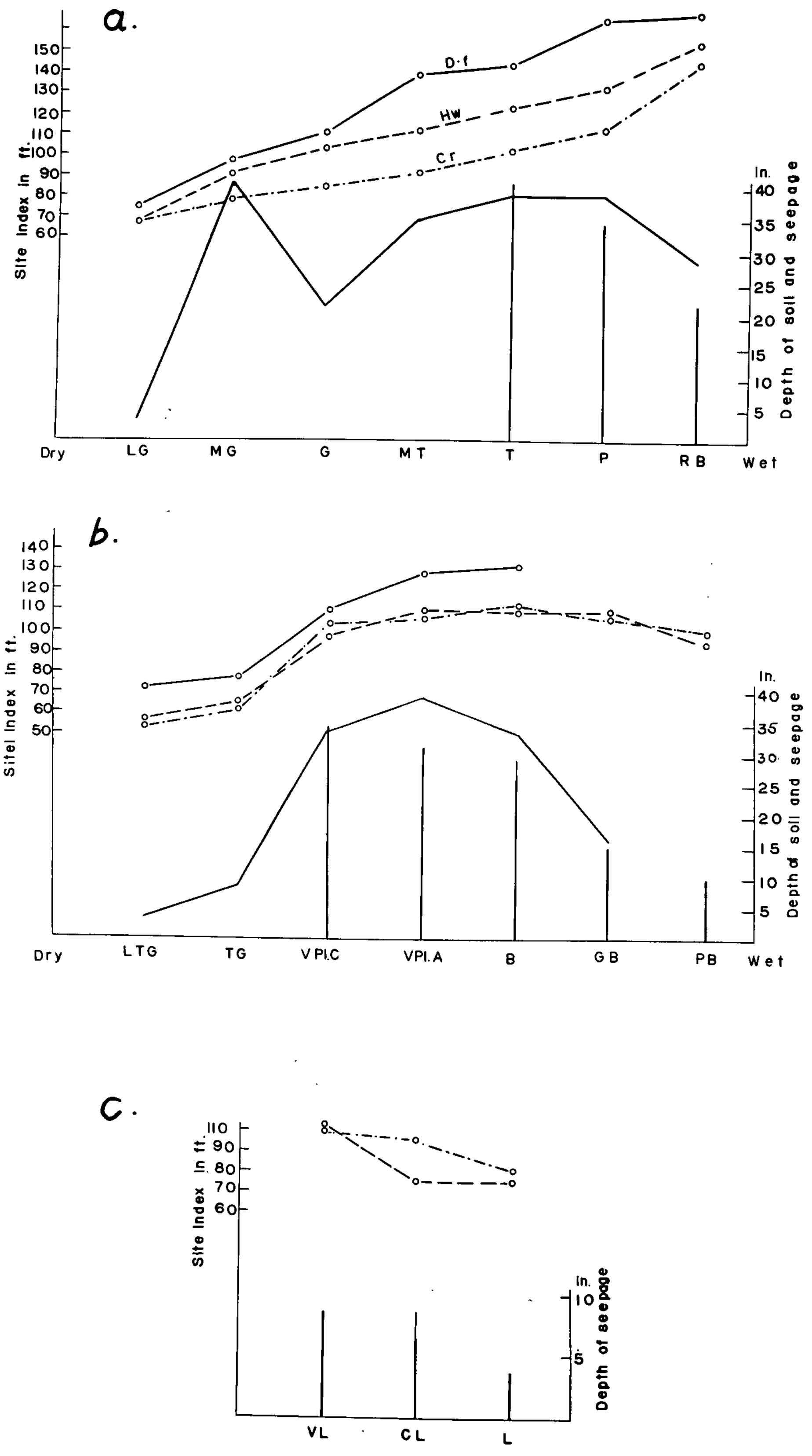

a.
Site Index in ft.
60
70
80
90
100
110
120
130
140
150
D·f
Hw
Cr
In.
5
10
15
20
25
30
35
40
Depth of soil and seepage
Dry
LG
MG
G
MT
T
P
RB
Wet
b.
Sitel Index in ft.
50
60
70
80
90
100
110
120
130
140
In.
5
10
15
20
25
30
35
40
Depth of soil and seepage
Dry
LTG
TG
VPl.C
VPl.A
B
GB
PB
Wet
c.
Site Index in ft.
60
70
80
90
110
In.
5
10
Depth of seepage
VL
CL
L

Figure 21.

seepage in the Blechnum - Rubus forest type of the dry subzone (22 inches) is considerably higher than in the Orthic Blechnum (30 inches) in the wet subzone. Generally, the productivity of the dry subzone is higher than that of the wet subzone.

Comparison of Chemical Characteristics

Statistical analysis has been carried out at the associaton level for the chemical properties of soils. The associations of dry edaphic communities and those for the Lysichitum associations were combined to form one unit each for statistical analysis. By this simplification seven groups have been compared.

1. Dry edaphic communities (De)
2. Tsugetum heterophyllae plagiothecietosum undulati (T)
3. Abieteto - Tsugetum heterophyllae (AT)
4. Thujeto - Polystichetum hylocomietosum splendentis (P)
5. Thujeto - Blechnetum (B)
6. Piceeto - Oplopanacetum (O)
7. Lysichitum communities (Ly)

Analysis of variance was carried out for the total amounts and for the concentration of chemical properties. Significant differences were established by Tukey's Studentized Range Test.* (For tables of analysis of variance see Appendices.)

1. Total Organic Matter

The accumulation of organic matter takes place in two different ways in the soils of the Western Hemlock Zone. One is the accumulation of organic matter formed in situ, on the surface of the mineral soil. The other way is the lateral translocation of incorporated humus which eventually accumulates in seepage soils above the impervious layer. (See the chemical

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* Snedecore, 1957.

properties of plot number 44, 110.) The accumulated organic matter is stored partly in the O horizon and partly in the solum as incorporated humus. The amount of this accumulated organic matter varies according to association.

Organic Matter in t / Acre

De	O	T	AT	P	Ly	B
72	100	143	195	184	211	358

De, O and T are significantly lower than B at the 5% level. There is no other significant difference among associations. Actually the greatest organic matter accumulation takes place in the *Lysichitum* communities where sometimes several yards thick of peat layer occur. In this study, however, only that part of the soil which can be utilized by plants is considered.

If the *Piceeto* - *Oplopanacetum* is not considered - representing very young regosols only - the pattern indicates that the amount of accumulated organic matter increases with the wetness of the site.

The amount of organic matter in the soil is an important factor determining site quality. Its action is mainly indirect through its cation exchange and waterholding capacity.

The O and B horizons are significantly higher than the A horizon in the amount of stored Organic matter.

2. Total cation exchange capacity

The total values of cation exchange capacity for the whole soil profile are compared in the following table.

Cation exchange capacity in e/100 square meter

De	Ly	AT	T	O	P	B
3202	5202	8440	11200	10580	14695	21306

The analysis of variance does not indicate significant differences between associations.

Individual mean compared by Tukey's Studentized Range Test show significant difference between B, De, communities. The vertical distribution of cation exchange capacity is similar to the distribution of organic matter. The O and B horizons are significantly higher than the A horizon.

3. Amount of exchangeable Calcium

Most of the exchangeable Ca is stored in the O layer of the soils in the Coastal Western Hemlock Zone. This suggests that the Ca which participates in the biogeochemical cycle is retained in the soil and the exchangeable Ca not utilized by the vegetation is easily removed by drainage water. This phenomenon is due to the very high degree of mobility of exchangeable Ca (Lutz & Chandler, 1946). The regosolic soils of the Oplopanax forest type are relatively rich in Ca throughout the whole mineral profile. On the other hand the B horizon of the older podzolized soils are extremely poor in exchangeable Ca.

The amount of exchangeable calcium by associations in lb. per acre

De	AT	T	Ly	B	P	O
199	840	211	2022	507	712	1734

The total amount of calcium in Ly is significantly larger than in De, T and B communities. Similarly O is significantly higher than De and T communities. The Ca content of the O horizon is significantly higher than that of the A and B horizons.

4. Amount of exchangeable Magnesium

The total amount of exchangeable Mg is about one half the amount of Ca.

Exchangeable Magnesium by associations in lb. per acre

De	AT	T	Ly	B	P	O
100	287	340	446	522	542	904

The difference between O and De is significant. The vertical distribution of Mg is different from that of Ca. While Ca is concentrated mainly in the O horizon, the greater part of Mg is stored in the B horizon. The amount of Mg in the B horizon is significantly greater than in the O or A horizon.

The over-all ratio of exchangeable Ca and Mg is very close to 2:1. (The over-all average of calcium is 889 lb./acre and 448 lb./acre is of magnesium.) The vertical distribution of the two elements shows a remarkable difference. Over 80% of the total exchangeable Ca is concentrated in the O horizon. On the other hand, the Mg is stored mostly in the B horizon of the soils. This phenomenon seems to be explained by the different uptake of these two nutrients by the vegetation.

According to Tarrant, Isaac and Chandler (1951) the three leading tree species of the Coastal Western Hemlock Zone return the following amount of Ca and Mg to the soil annually in the form of litter.

	Ca	Mg
	lbs./acre	
Western red cedar	42.8	0.8
Douglas-fir, 100-year old	8.0	0.2
Western Hemlock	5.6	0.6

(The translocation of Mg^{++} - Meyer and Anderson (1952) - may be one reason for the smaller amount of magnesium in the litter.)

If we assume an average stand composed of 50% Western Hemlock, 30% Western red cedar, and 20% Douglas-fir the annually returned amount of Ca would be 17.2 lbs/acre. The returned amount of Mg is only 0.58 lbs/acre annually. The grand average amount of exchangeable Ca in the soils (including the O horizon) is 900 lbs/acre. Consequently a full rotation of Ca in the biogeochemical cycle takes about 50 years. On the other hand a full rotation of Mg requires about 800 years assuming a grand average of 450 lbs/acre.

5. Amount of exchangeable Potassium

The total amount of exchangeable Potassium by associations in lbs/acre:

De	T	AT	P	B	Ly	O
144	206	173	416	312	259	524

The total amount of exchangeable potassium is significantly larger in the O association than in De, T and AT associations.

The potassium content of the B horizon is significantly higher than that of A and O horizons.

6. Total available Phosphorus

The total amount of available Phosphorus in lbs/acre by associations:

De	T	AT	P	B	Ly	O
46	79	28.6	112	92	37.9	155

The total amount of phosphorus in the O association is significantly larger than in AT and Ly associations.

Phosphorus content of the B horizon is significantly higher than that of the A and O horizons.

7. Concentration of organic material

In percent of dry weight

Horizon	De	T	AT	P	B	Ly	O
O	76.6	72.6	85.0	76.0	85.7	74.0	0
A	5.0	2.6	0.6	9.6	2.6	7.0	3.6
B	10.0	9.0	10.3	8.1	7.0	12.0	1.3

The concentration of organic matter in the Oplopanax - Ribes forest type is signficantly lower than on all other associations.

The concentration of organic matter in the O horizon is significantly higher than in A and B horizons.

8. Concentration of Cation Exchange Capacity

In me/100 grams

Horizon	De	T	AT	P	B	Ly	O
O	84.6	88.6	96	97.6	95	95	0
A	13.6	8.6	8.5	39.0	9	17	16.6
B	36.5	31.6	26.6	26.3	29.3	26	6.6

The concentration of cation exchange capacity of Oplopanax - Ribes forest type is significantly lower than all other associations.

The concentration of cation exchange capacity of the O horizon is significantly higher than the A and B horizon.

9. Calcium concentration

Concentration of exchangeable calcium in me/100 grams:

Horizon	De	T	AT	P	B	Ly	O
O	8.11	11.72	15.43	8.78	4.60	14.99	-
A	0.46	0.61	0.25	8.07	0.0	0.79	1.27
B	0.15	0.19	0.0	0.23	0.0	0.77	0.55

The concentration of Ca in the O horizon of Abieteto - Tsugetum is significantly higher than that of the Thujeto - Blechnetum.

The concentration of exchangeable Ca in P and Ly communities is significantly higher than in O and B associations.

The concentration of Ca in the O horizon is very highly significantly higher than in the A and B horizons.

10. Magnesium concentration

Concentration of exchangeable Magnesium in me/100 grams:

Horizon	De	T	AT	P	B	Ly	O
O	3.71	3.78	5.98	4.43	3.20	6.28	-
A	0.57	0.68	0.21	4.63	0.65	0.84	0.96
B	0.52	0.83	0.72	1.81	0.47	0.28	0.58

The concentration of exchangeable magnesium in the P association is significantly higher than in the O association.

The concentration of Mg in the O horizon is significantly higher than in the A and B horizons.

11. Potassium concentration

Concentration of exchangeable Potassium in me/100 grams:

Horizon	De	T	AT	P	B	Ly	O
O	2.38	1.46	0.95	0.76	0.54	0.37	-
A	0.19	0.11	0.09	0.27	0.08	0.15	0.14
B	0.13	0.13	0.11	0.16	0.11	0.12	0.11

The concentration of exchangeable K in the O horizon of Dry Edaphic communities is significantly higher than that of all other associations. Similarly the Tsugetum heterophyllae is significantly higher than the B, O, Ly and AT associations.

The concentration of exchangeable K steadily decreases with increasing wetness of the association.

The concentration of K in the O horizons is significantly higher than in the A and B horizons.

12. Phosphorus concentration

Concentration of available Phosphorus in ppm

Horizon	De	T	AT	P	B	Ly	O
O	46.0	62.0	31.6	24.0	14.6	10.5	-
A	16.3	15.0	15.0	9.0	6.6	12.3	13.3
B	47.0	19.6	13.3	20.0	25.6	14.3	11.3

The concentration of P in the Dry Edaphic and Tsugetum heterophyllae is significantly higher than that of all other associations. P concentration in the O horizon of the Tsuga heterophylla association is significantly higher than in the O horizon of the Tujeto - Blechnetum.

Similar to K, the distribution of P concentration decreases with increasing wetness of the site. Poorly drained soils are prone to suffer considerable removal of phosphate by leaching (McGregor, 1953).

13. Saturation of Ca, Mg, and K

Saturation of Ca, Mg, and K in % of total cation exchange capacity:

Horizon	De	T	AT	P	B	Ly	O
O	16	19	23	15	9	36	-
A	9	14	4	24	19	10	17
B	4	14	3	9	3	18	25

There is no significant difference in the base saturation of soils.

14. Nitrogen content of humus horizons

Nitrogen content of humus horizon in % of dry weight:

De	T	AT	P	B	Ly	O
1·2	1·3	1·4	1·4	1·3	1·3	0·2

The nitrogen % of the Oplopanax - Ribes forest type is significantly smaller than all other associations except Lysichitum, at the one per cent level. Significant differences are established by Student's test. (Moroney, 1958, Wilde, 1959).

Ratio of total organic matter to total nitrogen content in humus horizons.

15. Ratio of Total Organic Matter and Nitrogen (OM/N):

De	T	AT	B	:	Ly	P	:	O
65	61	60	66	:	43	46	:	25

The vertical line separates the populations which are significantly different from each other at the five percent level.

These differences of organic matter/nitrogen ratio indicate the differences in the intensity of biological activity in each association. The high biological activity in the Oplopanax - Ribes forest type is due to the loose sandy soil and the vegetation composition. The Piceeto - Lysichitetum and Thujeto - Polystichetum possess better biological conditions in the top soil than the Dry Edaphic and Zonal communities or Tujeto - Blechnetum.

Significant differences are summarized in table 1. There is one row and one column for each association or association group in the table. In the square, where the column of an association intersects the row of another association, those chemical properties are indicated in which those two associations are significantly different. The differences in the total amounts of chemical properties are indicated in the upper lefthand section of the table and the differences in concentrations in the lower righthand section. The arrows beside the symbols of chemical properties point in the direction of the association which is richer in that chemical property.

Table 1. Significant differences in chemical properties between associations by total amount and concentration

Total amounts

De	T	AT	P	B	Ly	O	
Ca → Mg → K →	Ca → K →	K → P →		↑ OM ↑ CEC	P →		O
Ca →	Ca →			Ca →		OM → CEC → Ca → ↑ OM/N	Ly
OM →	OM →				↑ Ca ↑ OM/N	OM → CEC → N → ↑ OM/N	B
				Ca → ↑ OM/N →		OM → CEC → Ca → Mg → N → ↑ OM/N	P
			↑ OM/N	Ca →	↑ OM/N	OM → CEC → N → ↑ OM/N	AT
		K → P →	P → ↑ OM/N	K → P →	K → P → ↑ OM/N	OM → CEC → K → P → N → ↑ OM/N	T
	K →	K → P →	K → P → ↑ OM/N	K → P →	K → P → ↑ OM/N	OM → CEC → K → P → N → ↑ OM/N	De

Concentration

Legend:

Ca - Calcium
Mg - Magnesium
K - Potassium
OM - Organic matter
P - Phosphorus
CEC - Cation exchange capacity
N - Nitrogen
OM/N- Organic matter/Nitrogen ratio

CHAPTER VI. PROPOSED TRENDS IN SOIL SUCCESSION

The climate, water-economy and vegetation are the main forces altering the parent material to form soil at any given place in the Coastal Western Hemlock Zone.

The role of climate is both direct and indirect. Its indirect action lies in determining the kind of vegetation. Its direct effect is the weathering and transportation of soluble material in response to gravity.

The water-economy controls the vegetation. On the other hand, vegetation also influences the water-economy by the accumulation of organic matter or by Sphagnum bog formation.

The main effect of vegetation on soils is the transportation of plant nutrient elements to the surface of the soil through the biogeochemical cycle. This action is demonstrated by the translocation of Ca and Mg from the B horizon to the O horizon in the course of soil development. (See figures 22, 23) The greater loss of bases from the B horizon is also due to the behaviour of hydrogen ions in soils of different reactions. As was pointed out by Bear (1955), "The efficiency of H^+ in replacing plant nutrients may decrease with falling pH. The higher the neutralization, the stronger the replacing power of H^+".

The combined effect of these three forces contribute to the processes of podzolization, gleyzation or peat formation, depending on the nature and topographic position of parent material. There are six main groups of substrata on which soil development may start:

1. Well drained glacial drift,
2. Alluvial deposits,
3. Bedrock,
4. Poorly drained glacial drift,

Distribution of Exchangeable Calcium and Magnesium in Different Soil Subgroups in the O and B Horizons

Fig.22

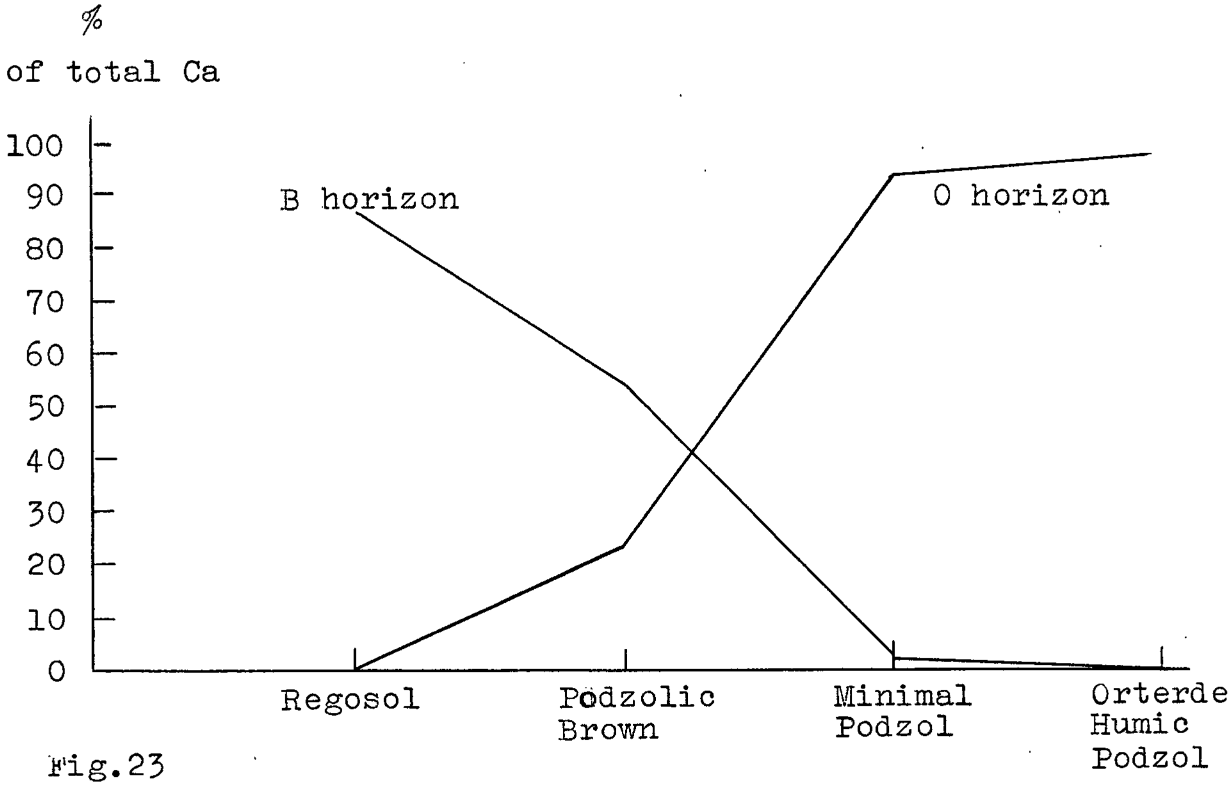
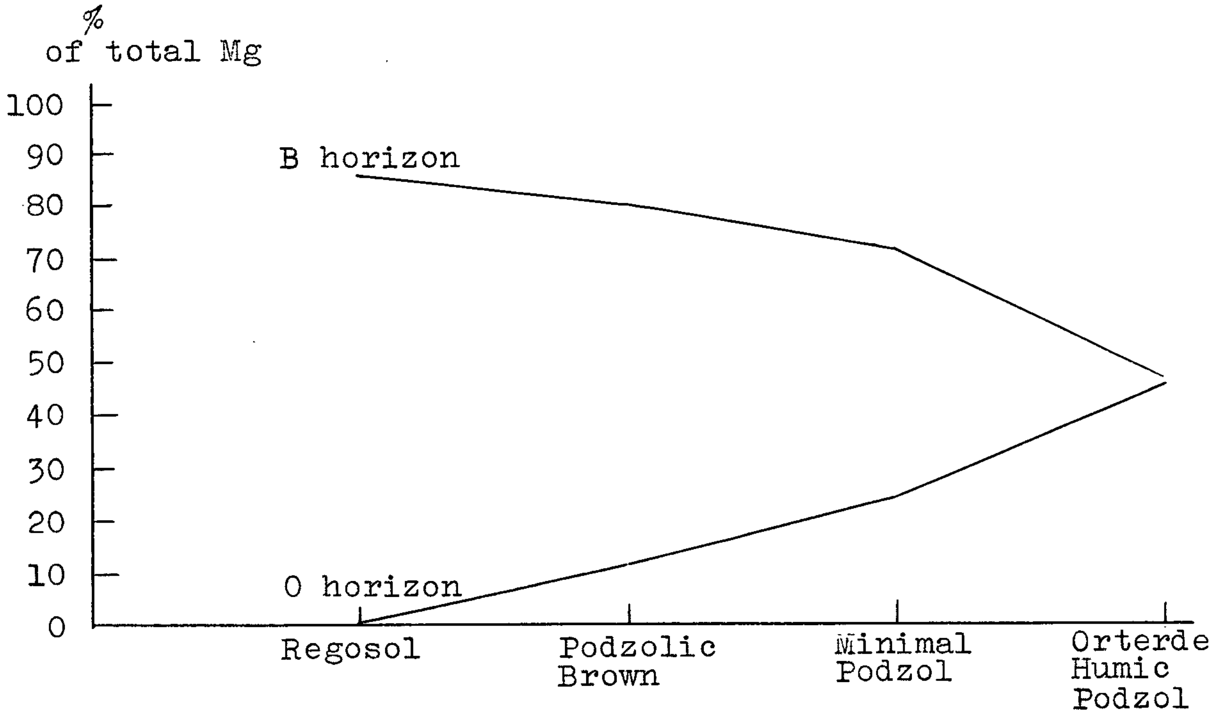


Fig.23



5. Periodically flooded oxbow lakes,
6. Other lakes.

The development of soil on the above substrata will be discussed separately.

1. Well drained glacial drift

Fresh, well drained glacial drift is colonized by alder. In this stage the soil is an acid Regosol. The decomposed remains of the vegetation slowly build up an A_h horizon while weathering action transforms the parent material into a B horizon. The soil is called Modal Acid Dark Brown at this stage of succession. The increasing proportion of conifer species in the stand promotes the formation of raw humus over the A_h layer. Through the effect of raw humus (increased acidity of soil solution), the initial signs of podzolization appear in the profile. This soil is called Orthic Brown Podzolic. Further development of the soil follows continued podzolization. Minimal Podzol, Orterde Podzol, and Orterde Humic Podzol follow each other as the accumulation of sequioxides and organic matter increases in the B horizon. When there are no more sesquioxides to be leached out from the top soil, organic matter alone accumulates in the B horizon. This is the most advanced stage of soil development in the Coastal Western Hemlock Zone, and is called Humus Podzol.

Depending on the water-economy and vegetation, the period of time for any stage of this development will vary. The soils of the Coastal Western Hemlock Zone are relatively young and most of them have not developed beyond the stage of Minimal Podzol.

Soils developed from glacial outwash are usually in a less advanced stage of development. This is due to their finer texture and topographic position.

Shallow glacial till regosols may develop into Concretionery Brown soils if subjected to periodic wetting and drying. These soils will develop into Orterde Podzols through degradation. From this point development follows the pattern described in the first paragraph.

2. Alluvial Deposits

Soil development on alluvial deposits follows the same sequences as on well drained glacial drift. Concretionary Brown soils do not develop from Alluvial Regosols. Their location in the valley bottom does not favour the periodic wetting and drying necessary for the formation of Concretionary Brown soils, and so these are absent.

3. Bedrock

Soil development on exposed bedrock starts with the activity of a moss and/or lichen vegetation. The first product of this vegetation is a thin Acid Legosol. Further accumulation of organic material creates favourable conditions for establishment of shrubs and tree seedlings. Weathering products very slowly accumulate under the protection of the vegetation and organic layer. The high precipitation causes leaching of this mineral layer as quickly as it is formed. Therefore, instead of the development of a B or A_h layer an A_e layer is formed. The soil is an Eluviated Acid Legosol in this stage of development. This is the most advanced stage of soil development on rock-outcrops in the Coastal Western Hemlock Zone.

4. Poorly drained glacial drift

On poorly drained glacial drift the Rego-Gley soil is the starting point. These soils are colonized by Lysichitum or by Oplopanax - Adiantum communities depending on the nature of seepage. By the accumulation of an organic horizon, the Rego-Gley develops into Orthic Gley then Springline Pitchy Anmoor. If the impervious layer is lowered gradually by weathering processes, the top of the mineral horizon will be drained and the soils become Podzolic Gleysol. If the drained part of the soil becomes increasingly deeper, the soil will develop towards Humus Podzol through the steps of Gleyed Podzol, and Orterde Humic Podzol.

5. Oxbow lakes

Soil development in the oxbow lakes starts with the underwater Gyttja soil. The mutual action of organic accumulation and fine alluvial deposits soon fills up the basin of the shallow oxbow lake. The first semi-terrestrial soil is the Orthic Dark Grey Gleysolic. The insufficient number of observations does not show clearly the further development of this peculiar habitat.

6. Other lakes

The development of lakes without periodic flooding differs sharply from that of the oxbow lakes. Here cumulose deposits alone fill up the lake basin. In the deep waters, the zoogenous "dy" soil marks the starting point of soil succession. When the water is shallow enough for the establishment of Nuphar and Menyanthes communities the Dy develops into Gyttja soil. When the accumulated organic material reaches the surface of the water, the peat-forming Sphagnum mosses establish on the Gyttja. The soil develops into Sphagnum peat. If the Sphagnum peat rises higher than the permanent water table it will decompose at the surface giving place to the Pitchy Peat Anmoor. There has not been found any evidence showing the further development of this soil.

The full scheme of soil succession is demonstrated in figure 24. The solid lines in the scheme indicate successional trends that actually can be followed in nature. Further possible developments are indicated by a broken line.

Figure 24

Figure 24. Trends of soil succession

TRENDS OF SOIL SUCCESSION

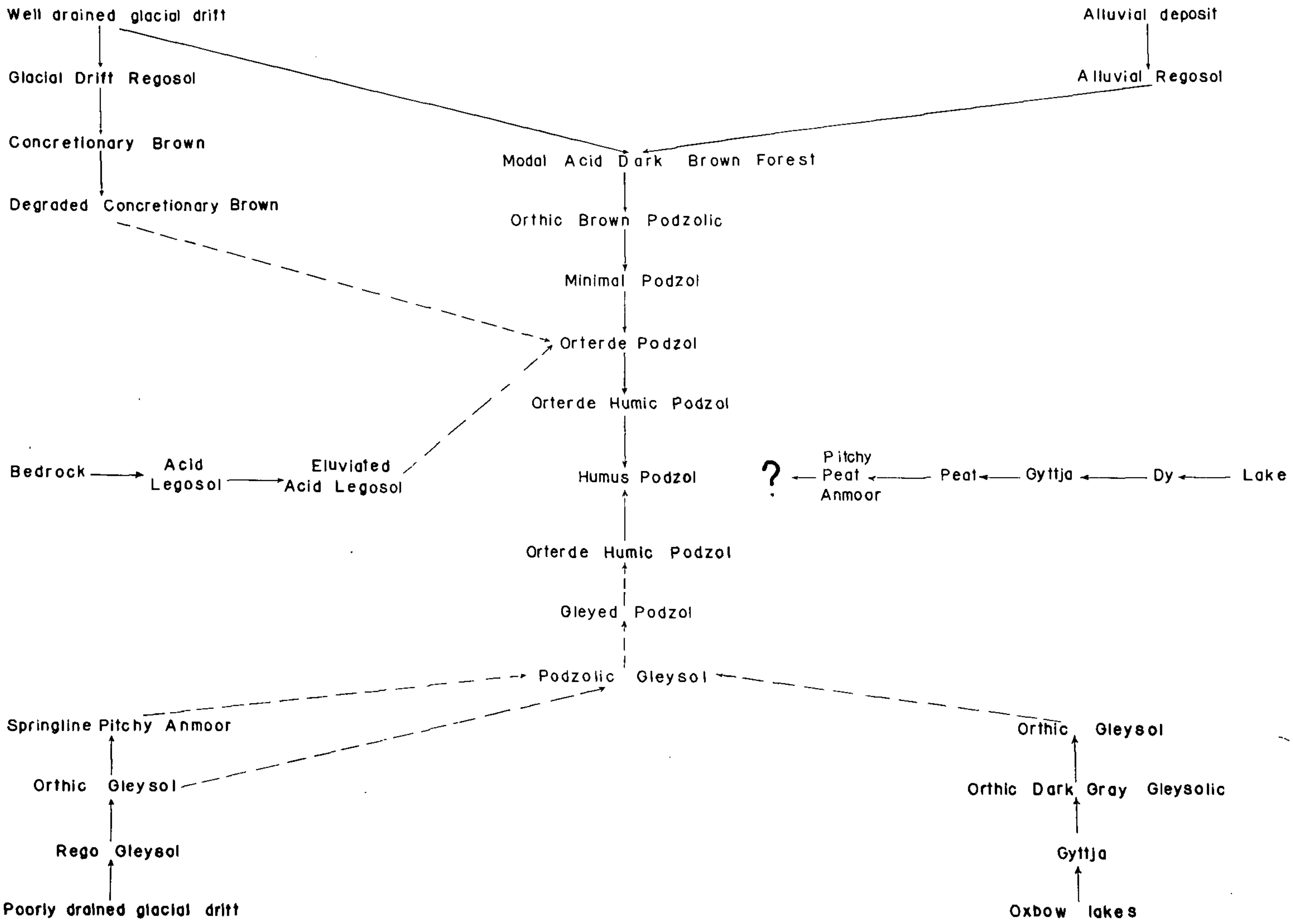


Figure 24

CONCLUSION

1. The soils of the Coastal Western Hemlock Zone are very acid. The pH ranges from 2.9 to 4.9 in the O horizons, 3.5 to 4.6 in A_e horizons, 3.7 to 5.4 in A_h horizon and 4.0 to 6.0 in B horizons.

2. The forest associations and forest types are separated from each other by edaphic differences besides their floristical structure. Differences in soil morphology, in moisture-regime, in soil depth and in chemical properties play roles in the delineation of forest types.

   Organic matter/nitrogen ratio, the concentration of potassium and phosphorus seems to be the most important chemical properties differentiating associations from each other.

3. The lesser vegetation appears to be more sensitive to changes in ecological factors than the commercial tree species of the Coastal Western Hemlock Zone. Significant differences in soil depth moisture-regime and in chemical properties that are not indicated by the composition of tree species are clearly shown by the changes in the lesser vegetation.

4. In the course of podzolization the accumulation of calcium, magnesium and potassium does not take place in the B horizon of the soils. These elements apparently accumulate in the humus horizon on the top of the soil profile, or are entirely removed from the soil by seepage water. This phenomenon is due to the great amount of precipitation and to impervious layers that underly the great majority of soils. The high precipitation promotes the leaching and lateral transportion of these elements over the impervious layer.

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APPENDIX

SHORT DESCRIPTION OF THE CHEMICALLY ANALYSED SOIL PROFILE

Piceeto - Oplopanacetum

Plot No. 79 Alluvial Regosol

Horizon	Depth in.	Color (dry)	Description
A_h	0-5	2.5 Y 5/2*	Dark brown weak crumby sandy loam.
C	5-19	5 Y 6/1	Light brown loose sand.
A_{hp}	19-28	2.5 Y 6/2	Brown weak blocky loamy sand.
C	28-43	5 Y 6/1	Light grayish brown loose sand. Coarse sand under water table.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
A_h	4.8	4.90	23.62	0.769	1.186	0.164	8.97	0.176	16.1
C	5.2	0.26	3.47	0.210	0.279	0.074	16.74	-	8.5
A_{hp}	5.3	1.77	8.57	0.322	0.254	0.086	7.72	-	13.0
C	5.2	0.33	2.56	0.442	0.191	0.077	27.73	-	11.0

* Munsell notation of color.

Plot No. 80 Alluvial Regosol

Horizon	Depth in.	Color (dry)	Description
C	0-1½	5 Y 6/1	Brownish gray loose sand.
A_{hp}	1½-30	5 Y 5/1	Dark brownish gray loose loamy sand.
D	30 +		Stony gravel.

Ground water 40 in.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
C	5.3	0.40	3.13	0.601	0.493	0.103	38.24	-	5.0
Ahp	5.0	1.94	8.85	1.265	0.737	0.136	24.15	-	11.0

(Footnote) pH - soil reaction; OM - total organic matter content; CEC - cation exchange capacity; Ca, Mg, K - exchangeable calcium, magnesium and potassium; BS - saturation of calcium, magnesium and potassium.

Plot No. 82 Alluvial Regosol

Horizon	Depth in.	Color (dry)	Description
A_h	0-4	10 YR 4/1	Dark brown crumby structured loamy sand.
C	4-60	2,5 Y 6/2	Light brown loose sand.

Ground water 6 feet.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
A_h	4.8	3.9	16.69	1.780	1.196	0.160	18.78	0.169	13.0
C	5.1	1.5	7.91	0.632	0.722	0.116	18.58	-	15.7

Alneto - Ribisetum bracteosi

Plot No. 76 Orthic Dark Gray Gleysolic

Horizon	Depth in.	Color (dry)	Description
A_h	0-5	10 YR 5/2	Dark brown weak crumby sandy loam.
C	5-16	2,5 YR 6/2	Light gray weak blocky sand.
A_{hpg}	16-25	10 YR 4/1	Dark gray structureless loamy sand.
D	25+		Gravel.

Soil developed on flood plain, parent material alluvial sand; ground water 25 inches.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
A_h	4.6	6.90	17.34	0.794	0.839	0.151	10.28	0.169	37.0
C	4.8	1.97	6.47	0.769	0.281	0.118	18.05	-	11.6
A_{hpg}	5.0	12.00	25.68	3.268	1.094	0.213	17.81	-	21.7

Thujeto - Polystichetum

Plot No. 22/a Minimal Podzol

Horizon	Depth in.	Color (dry)	Description
L	8-7		Undecomposed litter of Alnus and Polystichum.
O	7-0	5 Y 2/2	Well decomposed and partly decomposed organic matter; high proportion of decaying wood; dark reddish gray.
A_e	0-½	2,5 Y 6/2	Light gray, weak crumby structured sand.
B_{hj}	½-17	10 YR 6/5	Brown, mottled reddish brown and dark brown; coarse loamy sand; weak structure; gray concretions.
B_{hjb}	17-24	10 YR 6/4	Light brown, mottled yellow and reddish brown; slightly compacted stony loamy sand; many gray and brown concretions.
Cr	24 +		Light gray, mottled reddish; firmly cemented loamy sand.

Soil developed on gentle slope; parent material glacial till; stoniness 40%.

	pH	OM %	CEC	Ca me/100 grams	Mg	K	BS %	N %	P ppm
L	4.8								
O	3.7	82.9	93.52	8.228	4.976	0.595	14.56	1.94	34.5
A_e	4.2	7.24	17.34	0.696	0.643	0.116	8.39	-	6.1
B_{hj}	5.3	7.16	24.62	t	1.852	0.164	8.18	-	9.5
B_{hjb}	5.6	7.16	21.06	0.012	0.833	0.105	4.51	-	26.2
C	5.9	0.85	5.95	t	0.554	0.075	10.57	-	24.8

Plot No. 42 Modal Acid Dark Brown

Horizon	Depth in.	Color (dry)	Description
L	1-½		Undecomposed litter of conifers and <u>Polystichum</u>.
O	½-0	10 YR 3/1	Black, decomposed organic matter; friable blocky.
A_h	0-3½	10 YR 4/1	Brown, mottled gray; friable granular structured loam with soft brown concretions.
B_{fj}	3½-16	10 YR 6/3	Reddish brown, blocky structured sand.
B_{mj}	16-24	10 YR 6/3	Brown, mottled grayish and reddish; friable blocky fine sand.
B_c	24-47	5 Y 7-2	Brownish reddish gray; hard, cemented upper portion, softer in the lower part; compacted sand.
C	47+		Stratified fine and coarse sand.

Soil developed on valley bottom, parent material glacial outwash; seepage at 50 inches.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.6								
O	4.1	66.0	97.24	13.471	2.569	1.047	17.57	1.48	16.1
A_h	4.6	22.4	61.75	15.444	8.630	0.427	39.67	-	12.5
Bfj	5.2	5.26	27.74	t	0.598	0.114	2.56	-	1.0
B_{mj}	5.6	1.68	18.70	t	0.554	0,078	3.37	-	5.0
B_c	5.5	1.18	11.80	0.320	0.526	0.085	7.88	-	12.5

Plot No. 110 Modal Acid Dark Brown

Horizon	Depth in.	Color (dry)	Description
L	½-0		Dry remains of conifers and lesser vegetation.
A_h	0-5	5 Y 3/1	Grayish black, structureless loamy sand.
B_f	5-11	10 YR 5/3	Reddish brown, mottled black; friable blocky structured sand with few concretions.
B_{fj}	11-44	5 Y 6/3	Grayish, reddish brown, friable blocky sand.
B_h	44-46	5 YR 3/4	Blackish dark brown, friable blocky loam
C_r	46 +		Light brownish gray, compacted and cemented glacial till.

Soil developed on a U shaped valley bottom; parent material glacial till; stoniness 35%.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
A_h	4.15	24.4	69.26	2.787	1.623	0.408	6.95	0.79	11.2
B_f	5.35	1.34	25.48	t	0.846	0.919	6.92	-	15.0
B_{fj}	5.60	3.28	16.23	0	0	0.072	0.44	-	5.5
B_h	5.30	32.8	60.82	t	0.437	0.157	0.97	-	14.0

Plot No. 96 Orthic Brown Podzolic

Horizon	Depth in.	Color (dry)	Description
O	3-0	10 YR 2/1	Dark gray, black brown; friable crumby and blocky structured decomposed organic matter.
A_{hj}			In small patches only.
Bh	0-5	10 YR 6/4	Reddish brown, friable blocky structured clay with few concretions.
B_{mj}	5-55	2,5 Y 7/2	Light brown friable blocks mixed with undecomposed varved clay.
C	55+		Grayish brown, hard varved clay.

Soil developed on steep slope between two terraces; parent material varved clay; seepage at 58 inches.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
O	3.7	79.0	102.56	4.645	5.763	0.656	10.78	1.6	22.5
Bh	5.3	14.4	27.53	0.384	2.971	0.223	12.98	-	12.8
B_{mj}	5.4	2.95	15.82	0.320	0.263	0.154	4.65	-	22.00

Thujeto - Blechnetum

Plot No. 91 Minimal Podzol

Located on terrace; relief simple; parent material varved silt.

Horizon	Depth in.	Color (dry)	Description
L	7-6		Undecomposed conifer litter.
O	6-0	10 YR 2/2	Reddish black decomposed organic matter; structure weak blocky; irregular; moist.
A_e		10 YR 6/1	Well defined patches of gray sand.
B_j	0-17	10 YR 7/4	Yellowish brown, mottled reddish; firm blocky sandy loam; very few concretions; diffuse irregular boundaries; moist.
B_f	17-29	10 YR 6/4	Pinkish red layer with diffuse boundaries; clayey loam; compact; plastic.
B_j	29-42	5 Y 7/3	Brownish gray, mottled red; clayey loam; compact plastic; boundary diffuse; transition to C.
C	42+	5 Y 7/1	Brownish gray, loamy sand; compact, hard; almost impervious.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.1								
O	3.5	83.3	94.48	0.995	2.933	0.561	4.75	1.62	18.5
A_e	3.8	3.39	8.62	t	0.460	0.074	6.20	-	6.1
B_j	5.0	2.6	17.67	t	0.393	0.069	2.61	-	24.6
B_f	5.2	5.21	30.10	0	0.262	0.078	1.12	-	2.5
B_j	5.2	4.34	26.09	t	0.671	0.137	3.09	-	11.3
C	5.2	1.04	8.42	t	1.632	0.108	29.24	-	15.0

Plot No. 101 Orterde Humic Podzol

Horizon	Depth in.	Color (dry)	Description
L			Undecomposed litter, in patches only.
O	20–0	2.5 YR 2/2	Reddish black decomposed organic matter mixed with decaying wood; moist.
A_e	0–5	5 Y 6/1	Sharply bordered irregular layer of gray sand; friable, weak blocky; moist.
B_{fhj}	2–19	10 YR 4/4	Reddish brown, mottled black; blocky textured friable sand; lower boundary diffused; the lower portion saturated by ground water.
B_q	10–28	10 YR 7/4	Grayish brown cemented layer of coarse sand; compact hard; slowly pervious; boundaries diffuse; seepage above.
C	28 +	5 Y 6/3	Brownish gray gravely coarse sand; loose.

Located on terrace at an elevation of 690 feet; parent material alluvial sand; topography flat.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.3								
O	3.8	95.7	95.44	4.778	3.834	0.397	9.43	1.37	10.0
A_e	3.9	1.58	5.02	t	0.158	0.067	4.45	-	0
B_{fhj}	5.2	6.55	34.42	0	0.379	0.078	1.32	-	11.0
B_q	5.6	1.44	8.94	0	0.379	0.066	4.97	-	2.5

Plot No. 49 Orterde Humic Podzol

Located on mountain side with simple concave relief; parent material glacial till; stoniness 30%; bedrock is the impervious layer.

Horizon	Depth in.	Color (dry)	Description
L	12-10		Conifer litter with white and yellow mycelium.
O	10-0	5 YR 2/1	Black to reddish brown OM mixed with decaying wood; friable, moist.
A_{e1}	0-3	5 Y 6/1	Gray, friable granular structured silty sand; upper boundary sharp, lower diffuse.
A_{e2}	3-8	2.5 YR 5/2	Dark gray, mottled brown; loamy sand with blocky structure; sharp boundary to B.
B_h	8-12	10 YR 5/3	Dark reddish brown, mottled brown and red; sand with angular blocky structure; moist; few concretions.
B_{hg}	12-14	5 Y 6/3	Grayish, mottled brown and yellow; compacted sandy loam; the layer of seepage.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.1								
O	3.6	79.4	96.29	8.026	2.852	0.673	11.99	1.02	16.0
A_{e1}	4.0	3.29	3.19	t	1.440	0.113	48.68	-	14.5
A_{e2}	4.3	3.29	13.97	0	0	0.082	0.59	-	44.0
B_{hj}	4.6	8.86	24.13	0	0.203	0.105	1.27	-	41.0
B_{hjg}	4.9	7.84	21.06	0	0.379	0.107	2.30	-	13.5

Piceeto - Lysichitetum

Plot No. 43 Pitchy Peat Anmoor

Horizon	Depth in.	Color (dry)	Description
O_1	0-12	10 YR 2/2	Amorphous black muck.
O_2	12-60	10 YR 2/2	Peaty black muck.
O_3	60	10 YR 3/1	Undecomposed peat.

Soil developed in a depression of a valley bottom; ground water from one foot up to the surface.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
O_1	4.5	82.3	109.590	30.526	6.490	0.238	33.99	1.52	11.60
O_2	4.8	83.6	96.290	20.572	5.536	0.076	27.19	-	3.40
O_3	4.6	83.6	89.370	26.544	5.637	0.136	36.16	-	1.00

Plot No. 95 Orthic Gleysol

Horizon	Depth in.	Color (dry)	Description
O_1	0-7	10 YR 3/1	Black, mucky organic matter.
O_2	7-0	10 YR 3/2	Light brown undecomposed peat.
B_{hg}	0-11	10 YR 3/2	Dark brown compacted loamy sand.
C	11	5 Y 4/1	Grayish brown sand; structureless.

Soil developed on a flat terrace; parent material alluvial sand; seepage at 10 inches from the surface; strong reduction in B_h.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
O_1	4.5	66.4	65.960	14.466	6.081	0.890	32.50	1.83	9.2
O_2	4.9	76.16	81.500	13.803	5.687	0.551	24.55	-	5.0
B_{hg}	4.7	16.70	60.43	2.307	0.905	0.101	5.47	-	21.4
C	5.1	3.15	11.30	1.986	0.567	0.078	23.28	-	56.0

Abieteto - Tsugetum heterophyllae

Plot No. 18 Orterde Humic Podzol

Soil developed on a mountain slope at the altitude of 1730 ft. Slope is exposed to SW. Parent material is glacial till with 25% stoniness.

Horizon	Depth in.	Color (dry)	Field Description
L	6½-6		Undecomposed conifer litter.
O	6-0	10 YR 2/2	Partly decomposed and decomposed organic matter mixed with decaying wood.
A_e	0-2	10 YR 6/1	Well developed light gray podzol layer with sharp boundaries on both sides. Texture is sandy loam, structure single grain.
B_{hi}	2-20	10 YR 4/3	Rusty brown, mottled by very bright stripes of gray and dark brown. Texture is sandy loam, structure blocky.
C	20 +		Light brown-gray compacted sand.

	pH	OM %	CEC	Ca	Mg	K	BS %	N %	P ppm
			me/100 grams						
L	4.0								
O	3.7	88.0	87.64	13.604	3.922	1.224	21.39	1.37	35.0
A_e	3.9	0.13	4.31	0	0	0.095	2.2	-	3.0
Bhi	4.5	9.47	15.18	t	0.496	0.137	4.16	-	25.5

Plot No. 32 Orterde Humic Podzol

Horizon	Depth in.	Color (dry)	Description
L	$7\frac{1}{2}$-7		Undecomposed litter of mostly <u>Tsuga</u> and <u>Abies</u>.
O	7-0	10 YR 2/1	Very dark reddish brown; mostly amorphous decaying wood; smaller amount of friable crumby humus.
A_e	0-2	10 YR 6/1	Light gray, friable granular sand; irregular sharply bordered.
B_{fh}	2-15	10 YR 5/6	Dark rusty brown, mottled dark brown and reddish brown; slightly compacted blocky structured clayey loam; some concretions.
D	15 +		Light brown compacted stony sand; slowly pervious.

Soil developed on gentle lower slope; parent material glacial outwash.

	pH	OM %	CEC	Ca	Mg	K	BS %	N %	P ppm
			me/100 grams						
L	4.5								
O	3.9	87.2	100.44	17.780	9.174	0.442	27.27	1.57	35.2
A_e	4.0	1.24	15.44	0.501	0.421	0.097	6.59	-	t
B_{fh}	5.0	12.8	40.10	t	1.488	0.072	3.89	-	11.0

Plot No. 118 Orthic Brown Podzolic

Soil pit located on slightly concave hillside; parent material is local outwash overlying glacial till; stoniness 5%; seepage at 34".

Horizon	Depth in.	Color (dry)	Description
L	1¼-1		Mostly undecomposed <u>Thuja</u> twigs.
O	1-0	10 YR 4/2	Friable, black decomposed organic matter; sharp boundary with the mineral horizon.
B_{fj}	0-14	10 YR 7/4	Reddish brown, mottled yellow; friable blocky loamy sand; distinct lower boundary.
B_{fhj}	14-33	10 YR 5/6	Dark reddish brown, mottled yellow; friable blocky sand; distinct lower boundary; few concretions.
B_g	33-54	10 YR 5/6	Light grayish brown, mottled reddish; sticky clayey sandy loam.
D	54+		Cemented till.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.6								
O	4.4	65.9	112.57	16.457	3.660	0.755	18.54	1.55	21.0
B_{fj}	5.9	3.94	15.79	0.045	0.100	0.092	1.5	-	6.2
B_{fhj}	5.5	6.9	22.84	t	0.904	0.118	4.47	-	2.0
B_g	6.1	0.15	6.66	t	0.510	0.082	8.88	-	7.0

Plot No. 108 Humus Podzol

Pit 1 Soil developed on concave hillside; parent material glacial till; stoniness 20%; seepage is 30 inches from the surface.

Horizon	Depth in.	Color (dry)	Description
L	16-14		Wet litter of conifers.
O	14-0	5 YR 2/1	Reddish black compact layer of decomposed organic matter.
B_h	0-2	5 YR 3/4	Dark gray, firm blocky loam.
B_{hg}	2-19	10 YR 5/4	Dark brown, mottled black; firm blocky loam; developed under seepage influence.
C_r	19 +		Light gray compacted, cemented sandy loam; impervious.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.5								
O	4.3	41.4	84.87	8.096	4.988	0.925	16.5	-	11.0
B_h	5.15	24.3	54.56	t	0.480	0.180	1.2	-	13.0
B_{hg}	5.5	13.35	48.44	0	0.175	0.131	0.63	-	7.5

Plot No. 108 Minimal Podzol

Pit 2 Soil developed on convex slope; parent material glacial till; stoniness 80%.

Horizon	Depth in.	Color (dry)	Description
L	7-6		Undecomposed litter with yellow and white mycelia.
O	6-0	5 YR 2/1	Black amorphous decomposed organic matter.
A_{ej}	0-1		Only in patches; light gray sand.
B_f	1-50	10 YR 5/6	Reddish brown, very irregular layer; firm blocky loamy sand with concretions.
B_{hj}	1-58	10 YR 5/4	Brown, very irregular layer of loose loamy sand.
C_r	58 +		Light gray, cemented, hard, impervious.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.3								
O	3.9	80.0	100.44	14.931	4.861	1.200	20.90	1.6	24.7
A_{ej}	-	-	-	-	-	-	-	-	
B_f	5.9	3.7	20.25	t	0.058	0.115	0.85	-	1.0
B_{hj}	5.5	9.3	24.61	t	0.175	0.137	1.26	-	3.6

Tsugetum heterophyllae plagiothecietosum

Plot No. 46 Minimal Podzol

Parent material is coarse glacial drift with 5% stones. Elevation is 1010'.

Horizon	Depth in.	Color (dry)	Description
L	1-3/4		Undecomposed litter of conifers with white and yellow mycelium.
O	3/4-0	5 YR 2/2	Reddish black layer of decomposed organic matter. It contains yellow mycelium.
A_e	0-½	10 YR 6/1	Thin but regular layer of gray sand; it has a very weak granular structure.
B_{mj}	½-16	10 YR 6/3	Light brown, mottled gray and reddish brown; structure is very weak granular, texture sandy loam; contains a few rocks and numerous brown concretions.
B_j	16-27	5 YR 6/2	Grayish brown, mottled reddish brown and dark brown; loose sand with scattered subangular blocks.
C_m	27-30	5 Y 6/1	Gray, mottled reddish brown; compacted sand; lower limit of root penetration.
C	30+	5 Y 7/1	Gray slowly permeable compacted sand.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.54								
O	4.0	70.0	86.26	9.820	4.986	1.162	18.51	1.09	71.0
A_e	4.2	2.5	8.52	0.543	0.811	0.103	17.1	-	17.5
B_{mj}	5.4	2.3	9.20	t	0.787	0.108	9.72	-	32.7
B_j	5.4	0.95	2.58	t	0.554	0.095	25.15	-	19.9
C_m	5.5	0.52	2.87	t	0.802	0.068	30.31	-	23.0

Plot No. 107 Orterde Humic Podzol

Horizon	Depth in.	Color (dry)	Description
L	5-4		Undecomposed litter.
O	4-0	10 R 2/1	Black, friable, decomposed organic material.
A_e	0-5	10 YR 6/1	Irregular layer of gray sandy loam; friable weak blocky.
B_f		5 YR 4/6	Pinkish red patches of loam up to 2" thick; structureless.
B_{fhj}	2-21	10 YR 6/3	Reddish brown loamy sand; friable weak blocky.
B_{fh}	21-31	10 YR 7/4	Dark reddish brown; firm blocky loamy sand.
B_f	31-55	10 YR 6/3	Rusty brown; hard blocky; loamy sand; wet.

Soil pit located on hillside; parent material glacial till; 60% stoniness; seepage at 43 inches.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.4								
O	4.1	72.6	88.47	10.352	5.028	1.258	18.8	1.2	43.5
A_e	4.2	1.51	6.47	t	0.849	0.100	14.66	-	9.5
B_f	5.1	3.3	16.50	0.557	1.047	0.160	10.69	-	37.0
B_{fhj}	5.3	7.21	18.75	t	1.021	0.111	6.03	-	13.5
B_{fh}	5.2	15.7	45.74	t	0.554	0.144	1.52	-	9.7
B_f	5.5	6.17	34.85	0.013	0.162	0.078	0.72	-	2.5

Plot No. 44

Pit 1 Soil pit located on the lower third of a hillside; parent material glacial till; stoniness 40%; seepage is active in the greater part of the year.

Horizon	Depth in.	Color (dry)	Description
L	1-3/4		Undecomposed litter with white and yellow mycelium.
O	3/4-0	10 YR 2/2	Reddish black decomposed organic matter with yellow and white mycelium.
A_e	0-½	10 YR 6/1	An irregular and broken layer of light gray sand.
B_{bj1}	½-13	10 YR 5/6	Light brown, loose sandy loam; with many brown concretions.
B_{bj2}	13-28	10 YR 7/4	Gray mottled light brown; loose sandy loam with many brown and gray concretions.
B_h	28-30	10 YR 6/3	Light brown, loose sandy loam; with gray concretions; penetrated by many roots developed under seepage condition.
C_r	30+	5 Y 6/2	Olive gray cemented sandy loam, very slowly permeable.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.5								
O	4.1	75.11	92.41	14.997	1.320	1.972	19.8	1.23	72.0
A_e	4.0	4.2	12.5	0.689	0.391	0.129	9.67	-	19.5
B_{bj1}	5.6	4.28	18.16	0.019	0.156	0.108	1.55	-	9.9
B_{bj2}	5.7	2.62	11.71	0	0	0.101	0.85	-	12.7
B_h	5.5	9.48	39.86	t	0.656	0.131	1.97	-	7.4
C_r	5.7	1.05	11.22	0.410	0.377	0.101	7.91	-	12.4

Pseudotsugetum menziesii

Plot No. 104 Degraded Concretionary Brown

Soil pit is on the upper convex portion of the hillside; parent material is shallow glacial till on solid rock; stoniness 20%; elevation 1025 ft.

Horizon	Depth in.	Color (dry)	Description
L	3½-3		Undecomposed litter of conifers and salal.
O	3-0	10 YR 2/1	Black, well decomposed friable organic material.
A_e	0-3	10 YR 6/2	Gray, mottled black; irregular; soft blocky structured sand.
B_{bfj}	3-11	10 YR 5/4	Reddish brown, weak blocky structured sandy loam; brown concretions.
D	11+		Solid bed rock.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.5								
O	4.5	69.0	84.13	8.494	3.744	1.632	16.48	1.18	40.0
A_e	4.0	2.5	9.08	0.272	0.304	0.081	7.23		6.0
B_{bfj}	5.1	5.25	14.72	t	0.291	0.095	2.62		59.0

Plot No. 105 Minimal Podzol

Elevation 900 feet; steep hillside; topography simple; parent material glacial till; stoniness 80%; (seepage at 40").

Horizon	Depth in.	Color (dry)	Description
L	4-3		Partly decomposed and undecomposed organic material with mycelium.
O	3-0	10 YR 2/1	Black, well decomposed organic material with little decaying wood.
A_e	0-3	10 YR 7/1	Gray, weak blocky, friable sand.
B_{mj}	3-35	2.5 Y 6/2	Grayish brown, single grain stony sand.
B_{fh}	35-48	10 YR 5/4	Reddish brown, firm blocky stony sandy loam; developed under seepage effect.
D	48+		Solid bedrock.

	pH	OM	CEC	Ca	Mg	K	BS	N	P
		%	me/100 grams				%	%	ppm
L	4.4								
O	4.1	77.5	86.48	10.810	3.230	1.960	18.5	1.2	47.0
A_e	4.4	4.47	11.68	0.316	0.605	0.136	9.04		29.6
B_{mj}	5.5	3.6	14.26	t	0.633	0.129	5.34		35.0
B_{fh}	5.7	15.0	57.99	0.314	0.751	0.170	2.12		28.0

Tsugeto - Gaultherietum

Plot No. 52 Eluviated Acid Legosol

Soil developed on exposed hilltop; elevation 1800 feet; parent material quartz diorite; stoniness 0.

Horizon	Depth in.	Color (dry)	Description
L	3.5-2		Laminated undecomposed and partly decomposed litter; many yellow mycelia.
O	2-0	5 Y 3/1	Dark gray, friable, crumby; well decomposed OM; very densely penetrated by roots.
A_{ej}	0-1.5	5 Y 5/1	Ashy gray, granular structured fine sand.
C	1.5+		Solid bedrock.

	pH	OM %	CEC	Ca	Mg	K	BS %	N %	P ppm
			me/100 grams						
L	3.7								
O	3.6	84.2	84.48	5.016	4.170	3.571	15.1	1.2	51.0
A_{ej}	3.7	8.8	19.08	0.911	0.817	0.356	10.9	-	13.0

METHODS OF CHEMICAL ANALYSIS

Determination of pH

1. pH-measurements were taken on material finer than two mm. using a Beckman pH meter, Model N, in a paste-like soil-water mixture.

Determination of Organic Matter

Reagents

1 N potassium dichromate. Dissolve 49.04 gm of reagent grade $K_2Cr_2O_7$ in water and dilute to 1 liter.

0.5 ferrous sulfate. Dissolve 140 gm. of reagent grade $FeSO_4 7H_2O$ in water, add 40 ml concentrated H_2SO_4, cool, and dilute to 1 liter. Standardize this reagent each day by titrating against 10 ml of N potassium dichromate, as directed in the method described below.

- Barium diphenylaminesulfonate. Prepare a 0.16 per cent aqueous solution.
- o-phenanthroline ferrous complex (optional). Prepare 0.025 M solution of one of the phenanthroline ferrous complex indicators.
- Sulfuric acid; not less than 96 per cent.
- Phosphoric acid; 85 per cent, U.S.P. grade.

Procedure

Transfer a weighed quantity of soil (ground to pass a 0.5 mm sieve) containing 10 to 25 mg. of organic carbon into a 500 ml Erlenmeyer flask, and add 10 ml of N potassium dichromate. Then add rapidly 20 ml of concentrated sulfuric acid, directing the stream into the solution. Immediately swirl vigorously by hand for 1 minute and let the flask stand on a sheet of asbestos for about 30 minutes. Then add 20 ml of water, 10 ml of phosphoric acid, and 0.5 ml of barium diphenylaminesulfonate indicator.

Proceed with the titration as follows: add the ferrous sulphate solution until the solution is purple or blue, then add the ferrous sulphate in small lots of about 0.5 ml until the color flashes to green with little or no warning. Add 0.5 ml of N potassium dichromate to restore an excess of dichromate and complete the titration by adding ferrous sulphate drop by drop to a light green end point. If more than 8 ml of the available 10 ml of potassium dichromate is reduced, the determination should be repeated with less soil.

Percentage of organic matter in soil sample =

$$\frac{(\text{Milliliters of 1 N } K_2Cr_2O_7 \text{ reduced}) \times 0.69}{\text{Weight of sample (gm)}}$$

Determination of Exchangeable Cations and Exchange Capacity

1. Extraction

Reagents:

(1) Ammonium acetate 1 N, pH 7.0 - Prepare sufficient volume by mixing 70 ml Nh_4OH, sp. gr. 0.90, and 58 ml of 99.5% HA_c per litre of solution desired. After cooling adjust to pH 7.0 and dilute with water to volume.

(2) HCl concentrated

(3) HNO_3 concentrated

(4) 1:1 HCl 1 part conc. HCl to part HOH

(5) 1:1 H_2O_2 1 part reagent grade H_2O_2, 30% and 1 part H_2O

(6) Li (Internal Standard) 1250 gamma/ml (see below)

2. Apparatus

400 ml beakers
Filtrators
Buchner funnels, 70 cm.
Whatman 42 filter paper 7.0 cm.
Graduate cylinders, 100 ml 250 ml.
100 ml beakers

Procedure

Place 20 gm of soil in a 100 ml beaker, add 50 ml NH_4Ac. Stopper flask, shake for several minutes and allow to stand overnight.

Transfer the soil to a small buchner funnel fitted to a filtrator and filter the solution into a 400 ml beaker.

Leach the sample with an additional 150 ml NH_4Ac using gentle suction (take about ½ hour) to complete leaching.

Place the filtrate on a steam bath or hot plate and evaporate to dryness. Keep beaker covered.

Add 5 ml concentrated HNO_3 and 1 ml concentrated HCl and evaporate to dryness.

Add 5 ml 1:1 H_2O_2 to destroy organic matter (add more if necessary) and heat gently to avoid spattering.

Add 5 ml 1:1 HCl and evaporate to dryness to dehydrate silica.

Take up the residue with 2 ml concentration HCl, policing any adhering residue.

Filter into a 250 ml volumetric flask and add 5 ml of a 1250 gamma Li/ml solution and make to volume. Designate this solution 'A'.

Note:

If care is used in taking aliquots from solution A, it may not be necessary to remove the siliceous residue by filtering.

2. Determination of Exchange capacity

Reagents:

95% Ethyl alcohol U.S.P.
Sodium chloride
Antifoam spray
NaOH 1 N Technical
Standard 0.2 N H_2SO_4
Standard 0.1 N HaOH (CO_2 free)
Methyl red indicator

Apparatus:

400 ml beaker
100 ml graduate, 25 ml graduate
600 ml Kjeldahl flasks
Kjeldahl distillation apparatus
2-50 ml burettes (1 base burette)
500 ml Erlenmeyer flasks

Procedure:

Leach the soil sample from step 1 with 80 ml ethyl alcohol in small portions to remove excess acetate.

Transfer soil with the filter paper to a Kjeldahl flask; add 400 ml H_2O, about 10 gm NaCl and a spray of the antifoam agent.

Add 25 ml of 1 N NaOH and connect immediately to the distillation apparatus.

Distill about 150 ml into a flask containing 50 ml 0.2 N H_2SO_4 and methyl red.

If the indicator in the acid starts to turn yellow immediately, add 10-20 more H_2SO_4.

Titrate the excess acid with the 0.1 N NaOH.

Calculate exchange capacity and express as me per 100 g soil.

Determination of Exchangeable Cations

1. Calcium

Reagents:

(1) Stock lithium internal standard - 12,500 gamma Li/ml. Dissolve 7,6377 g. LiCl in 1 l. Dilute 1:10 to give 1250 gamma Li/ml.

(2) Stock calcium standard - 1250 gamma Ca/ml. Place 3.1215 g. reagent grade $CaCO_3$ in a 1 l. flask. Add sufficient HCl to dissolve the $CaCO_3$ and add sufficient excess to make the solution 0.1 N in HCl (12.5 ml conc. HCl for 1 l. std.) After the carbonate has dissolved make to 1 l.

(3) Flame Photometer standards for Ca. Prepare a series of standards containing 0, 50, 100, 150 and 200 gamma Ca/ml and containing 25 gamma Li/ml.

(4) Li Internal Standard, 25 gamma Li/ml. This solution is to be used for diluting samples high in Ca and should be prepared exactly from the same Li stock solution used for the Flame Photometer standard.

Apparatus:

Volumetric flasks, 500 ml and 250 ml.
25 ml. Erlenmeyer flasks
Perkin Elmer flame photometer

Procedure:

Determine the calcium concentration of the samples as directed in the flame photometer manual. If the concentration is too high, dilute the sample with the 25 gamma Li/ml solution.

2. Potassium

Reagents:

(1) Lithium internal standard solutions - as above.

(2) Stock Potassium standard, 1250 gamma K/ml. Dissolve 2,3836 gm KCl per litre of solution.

(3) Flame photometer standards for K. Prepare a series of standards containing 0, 10, 20, 30, 40 and 50 gamma K/ml. and 25 gamma Li/ml. As before, prepare twice the volume of the 0 and the highest standard.

Apparatus:

As above.

Procedure:

As above.

3. Magnesium and Calcium

Reagents:

(1) Standard $MgCl_2$ 0.2 N. Place 4.2165 g. $MgCO_3$ in a 500 ml volumetric flask. Add 10 ml of HCl to dissolve the carbonate and add 15 ml 1/N. NaOH to make the solution nearly neutral.

(2) Standard $MgCl_2$ 0.02 N. Dilute the 0.2 N $MgCl_2$ solution 1:10.

(3) Standard EDTA. Dissolve di-disodium dehydrogen tetra-acetic acid (Versenate) in 2 litres (approx.) of H_2O. Add about 35 drops 0.1 N $MgCl_2$ to make for a sharp endpoint.

(4) Eriochrome black T indicator. Prepare a solution of 1 g. of hydroxydamine hydrochloride in 25 ml ethyl alcohol. Prepare the indicator as needed by adding 0.2 g. of eriochrome black T (1 - hydroxy -- 2 - naphthylazo -- 5 - nitro -- 2 - naphthol -- 4 - sulphonic acid sodium salt) and 5 ml. of this solution.

(5) NH_4Cl - NH_4OH buffer solution. Dissolve 67.5 g. of NH_4Cl in 200 ml. of water and mix with 570 ml of conc. NH_4OH. Dilute to 1 l. The pH should be 10.

Apparatus:

125 ml. Erlenmeyer flasks
50 ml. burette

Procedure:

Pippette a 5 ml aliquot of solution A into a 125 ml Erlenmeyer flask. Add sufficient water to make the volume approximately 40 ml. Place an additional 7 ml of buffer in the solution; add squint of cyanide; add 2-4 drops of the eriochrome black T indicator and titrate the solution until a clear blue endpoint is reached.

Absorbed Phosphorus

Reagents:

Ammonium floride - 1 N (approx.) Dilute 37 g. NH_4F/ liter. Keep in plastic bottle.

0.5 N HCl - (approx.) 20.2 ml. conc. HCl / 500 ml.

Extracting solution - 0.03/N NH_4F + 0.025 N HCl
30 ml. IN NH_4F + 50 ml. 0.5 N HCl / liter.

P.B. - Ammoniummolybdate - HCl reagent, boric acid saturated: Dissolve 100 g. reagent grade ammonium molybdate in 850 ml H_2O. Filter and cool. Make solution of 1700 ml conc. HCl in 160 ml H_2O. Cool. Add first solution to second slowly with constant stirring. Add approx. 110 g. reagent grade boric acid and dissolve.

P.C. - Amino naphtol sulphonic acid.
2.5 g. of 1 part amino 2 parts naphtol and 4 parts sulphonic acid,
5.0 g. sodium sulfite (Na_2SO_3).

146.25 g. sodium-bisulfite (meta $Na_2S_2O_5$)
Mix ingredients and grind to fine powder in mortar. For use dissolve 16 g. of powder in 100 ml warm H_2O. Add 2 g. reagent grade H_3BO_3, filter and allow to stand overnight. Store in dark glass and renew every two weeks.

P standard - 100 ppm.
0.4393 g. pure KH_2PO_4 / liter H_2O containing 100 ml 1N HCl.
Prepare 10, 20, 30, 40, 50 ppm standard solution by diluting the 100 ppm standard solution with extracting solution.

Procedure:

Extract - Shake 5 g. soil with 50 ml extracting solution for one minute, and filter. Take 5 ml unknown solution + 5 ml. H_2O + $\frac{1}{2}$ ml. P.B. + $\frac{1}{2}$ ml P.C. and reed with photoelectronic colorimeter in 30 minutes. Use 660 filter.

Nitrogen Determination

Weight out five g. of soil and transfer using folded filter paper to an 800 ml. Kjeldahl flask. Add approximately 30-40 ml conc. H_2SO_4, 10 gms. (1 tsp.) of a mixture of 10 parts anhydrous Na_2SO_4 and 1 part $CuSO_4$. Mix ingredients by swirling the flask. Add 2 - 3 selenized granules.

Digest until the solution is clear and continue digestion for twenty minutes. Cool and then add gradually 300 ml. of tap H_2O. Shake well. Cool again. Now add about 1 teaspoonful of glass beads and/or .5 gm. of granulated Zn and an excess (90 ml.) of conc. NaOH solution. (40%), pouring down the side of the flask to prevent mixing of solutions and loss of NH_3. Connect to the distilling apparatus immediately and then swirl the flask gently to mix the contents. Distill into a 300 ml. Erlenmeyer flask containing 25-50 ml. of saturated boric acid solution, measured with a graduate (50 ml. of boric acid takes care of 95 mg. of N as NH_3). Also add 4 drops of a mixed indicator of Bromocresol green and methyl red. The tube from the distilling apparatus must extend below the surface of the acid to prevent loss of NH_3.

Collect approximately 150 ml. of the distillate and titrate the boric acid on the complex with standard N/14 H_2SO_4. A blank should be run in every case as there is a slight correction. Subtract the blank from the total amount of acid required for the sample.

$$\frac{\text{ml of acid x normality x .014 x 100}}{\text{wt. of sample}} = \%N$$

where .014 represents the gms. N per ml. in a normal solution.

Where the normality is N/14 the equation becomes

$$\frac{\text{ml of acid x N/14 x .014}}{5\text{ g.}} \text{ x 100 = ml of acid x .02 = \%N}$$

If a 1 g. sample is used, say of alfalfa, the calculation simplifies to ml. of acid 0.1 = %N.

Mixed Indicator:

Mix 10 ml. of 0.1 per cent bromcresol green in 95 per cent alcohol with 2 mi. of 0.1 per cent methyl red in 95 per cent alcohol. The color produced by this indicator in boric acid is bluish green. Titrate with standard acid until the blue color just disappears. One drop in excess will turn the solution pink. If titrated to a faint pink, subtract 0.02 ml. from the reading.

DATA FOR STATISTICAL ANALYSIS AND ANALYSIS OF VARIANCE

1. Total Organic Matter in Kg/100 m^2

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	822.0	44.2	837.0	1703.2
	Pit 2.	870.0	8.1	802.0	1680.0
	Pit 3.	1010.0	434.0	0.0	1444.0
	Total	2702.0	486.3	1839.0	4827.2
T	Pit 1.	1464.5	94.2	4707.0	6265.7
	Pit 2.	375.0	53.3	1880.4	2308.7
	Pit 3.	355.0	32.5	689.1	1076.6
	Total	2194.5	180.0	7276.5	9651.0
AT	Pit 1.	2032.0	0.0	982.0	3014.0
	Pit 2.	2468.0	9.0	1295.0	3773.0
	Pit 3.	3104.0	77.3	3195.0	6376.0
	Total	7604.0	86.0	5472.0	13163.0
P	Pit 1.	1200.8	0.0	4524.0	5724.8
	Pit 2.	663.0	241.0	1587.0	2491.0
	Pit 3.	2951.0	47.0	1202.0	4200.0
	Total	4814.8	288.0	7313.0	12415.8
B	Pit 1.	2820.0	426.0	4070.0	7316.0
	Pit 2.	4040.0	412.0	634.0	5086.0
	Pit 3.	8240.0	156.0	3296.0	11692.0
	Total	15100.0	994.0	8000.0	24094.0
O	Pit 1.	0.0	803.0	742.0	1545.0
	Pit 2.	0.0	0.0	1885.0	1885.0
	Pit 3.	0.0	532.0	2770.0	3302.0
	Total	0.0	1335.0	5397.0	6732.0
Ly	Pit 1.	0.0	1130.0	4199.0	5329.0
	Pit 2.	3444.0	0.0	0.0	3444.0
	Pit 3.	4909.0	0.0	0.0	4909.0
	Total	8353.0	1130.0	4199.0	13682.0

Analysis of Variance

Source of variation	Df.	SS.	MS	F
Association	6	26,144.931	4,357.488	2.88 *
Pit	2	4,146.090	2,073.045	
Horizon	2	40,132.887	20,066.443	15.2 **
Association x pit	12	13,346.708	1,112.225	
Assoc. x horizon	12	36,249.077	3,020.755	
Pit x Horizon	4	18,474.963	4,618.741	3.0 *
Residual	24	36,268.554	1,511.189	
Total	62	174,763.210		

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* Significant at 5 per cent level
** Significant at 1 per cent level

2. Cation Exchange Capacity in Equivalents/100 m^2

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	916	80	3472	4468
	Pit 2.	1077	29	2237	3343
	Pit 3.	862	935	0	1797
	Total	2855	1044	5709	9608
T	Pit 1.	1769	401	19323	21493
	Pit 2.	462	162	7702	8326
	Pit 3.	431	110	3389	3930
	Total	2662	673	30414	33749
AT	Pit 1.	2511	0	3490	6001
	Pit 2.	2454	293	2064	4811
	Pit 3.	3575	957	9985	14571
	Total	8540	1250	15539	25329
P	Pit 1.	1558	0	24857	26415
	Pit 2.	1002	667	8575	10244
	Pit 3.	3329	113	3985	7427
	Total	5889	780	37419	44086
B	Pit 1.	3363	939	25105	29407
	Pit 2.	4891	100	3123	8114
	Pit 3.	8246	496	17656	26398
	Total	16500	1535	45884	63919
O	Pit 1.	0	3566	4620	8186
	Pit 2.	0	7859	139	7998
	Pit 3.	0	2102	13478	15580
	Total	0	13527	18237	31764
Ly	Pit 1.	4602	0	0	4602
	Pit 2.	5131	0	0	5131
	Pit 3.	0	1966	9043	11009
	Total	9733	1966	9043	20742

Analysis of Variance

Source of Variation	Df	SS	MS	F
Association	6	204	34.0	1.82
Pit	2	67	33.5	
Horizon	2	542	271.0	14.50 **
Assoc. x Pit	12	188	15.6	
Assoc. x Horizon	12	354	29.5	
Pit x Horizon	4	169	42.0	2.25
Residual	24	446		
Total	62	1970		

3. Total Amount of Exchangeable Calcium in Kg/100 m^2

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	2.29	0.06	0.26	2.61
	Pit 2.	2.17	0.02	t	2.19
	Pit 3.	1.01	0.90	0.00	1.91
	Total	5.47	0.98	0.26	6.71
T	Pit 1.	4.18	t	0.09	4.27
	Pit 2.	1.50	0.18	0.04	1.72
	Pit 3.	0.98	0.19	t	1.12
	Total	6.66	0.32	0.13	7.11
AT	Pit 1.	7.26	-	t	7.26
	Pit 2.	7.60	-	t	7.60
	Pit 3.	12.70	0.70	t	13.40
	Total	27.56	0.70	t	28.26
P	Pit 1.	1.41	0.00	9.71	11.12
	Pit 2.	2.74	3.34	t	6.08
	Pit 3.	5.86	0.91	0.01	6.78
	Total	10.01	4.25	9.72	23.98
B	Pit 1.	0.71	t	t	0.71
	Pit 2.	8.13	t	t	8.13
	Pit 3.	8.30	t	t	8.30
	Total	17.14	t	t	17.14
O	Pit 1.	0.00	2.32	7.07	9.39
	Pit 2.	0.00	0.53	22.40	22.93
	Pit 3.	0.00	4.50	21.50	26.00
	Total	0.00	7.35	50.97	58.32
Ly	Pit 1.	25.60	0.00	0.00	25.60
	Pit 2.	19.75	0.00	0.00	19.75
	Pit 3.	0.00	1.80	22.60	24.40
	Total	45.35	1.80	22.60	69.75

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	405.60	67.6	1.91
Pit	2	11.00	5.5	
Horizon	2	235.60	117.3	3.31 *
Assoc. x Pit	12	75.16	6.26	
Assoc. x Horizon	12	838.60	69.84	1.97
Pit x Horizon	4	66.45	16.61	
Residual	24	848.96	35.37	
Total	62	2481.37		

4. Total Amount of Exchangeable Magnesium in Kg/100 m^2

Assoc.		Horizon O	Horizon A	Horizon B	Pit
	Pit 1.	0.41	0.07	0.75	1.23
De	Pit 2.	0.58	0.01	0.54	1.13
	Pit 3.	0.52	0.49	0.00	1.01
	Total	1.51	0.57	1.29	3.37
	Pit 1.	0.79	0.64	3.38	4.81
T	Pit 2.	0.08	0.06	1.24	1.38
	Pit 3.	0.30	0.13	4.82	5.25
	Total	1.17	0.83	9.44	11.44
	Pit 1.	1.50	0.00	0.20	1.70
AT	Pit 2.	1.33	0.00	0.82	2.15
	Pit 3.	3.98	0.32	4.51	8.81
	Total	6.81	0.32	5.53	12.66
	Pit 1.	1.06	-	7.08	8.14
P	Pit 2.	0.31	1.13	3.17	4.61
	Pit 3.	2.16	0.05	3.29	5.50
	Total	3.53	1.18	13.54	18.25
	Pit 1.	1.27	0.61	5.75	7.63
B	Pit 2.	1.76	0.57	0.18	2.51
	Pit 3.	4.04	0.19	3.21	7.44
		7.07	1.37	9.14	17.58
	Pit 1.	0.00	2.18	3.21	5.39
O	Pit 2.	0.00	0.26	7.95	8.21
	Pit 3.	0.00	1.83	14.96	16.79
	Total	0.00	4.27	26.12	30.39
	Pit 1.	3.32	0.00	0.00	3.32
Ly	Pit 2.	4.99	0.00	0.00	4.99
	Pit 3.	0.00	1.15	4.71	5.86
	Total	8.31	1.15	4.71	14.17

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	45.2	7.53	2.17
Pit	2	16.4	8.20	2.19
Horizon	2	90.0	45.00	12.03 **
Assoc. x Pit	12	29.73	2.47	
Assoc. x Horizon	12	112.9	9.4	2.51 *
Pit x Horizon	4	19.7	4.92	
Residual	24	89.87	3.74	
Total	62	403.80		

5. Total Amount of Exchangeable Potassium in Kg/100 m^2

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	0.81	0.05	0.52	1.38
	Pit 2.	0.81	0.01	0.56	1.38
	Pit 3.	1.42	0.68	-	2.10
	Total	3.04	0.74	1.08	4.86
T	Pit 1.	0.99	0.24	2.27	3.50
	Pit 2.	0.38	0.06	1.50	1.94
	Pit 3.	0.23	0.05	1.19	1.47
	Total	1.60	0.35	4.96	6.91
AT	Pit 1.	1.19	0.00	0.77	1.96
	Pit 2.	1.34	0.25	0.73	2.32
	Pit 3.	0.61	0.23	0.70	1.54
	Total	3.14	0.48	2.20	5.82
P	Pit 1.	0.39	0.00	9.22	9.61
	Pit 2.	0.41	0.18	1.70	2.29
	Pit 3.	0.83	0.30	0.97	2.10
	Total	1.63	0.98	11.89	14.00
B	Pit 1.	0.78	0.31	3.84	4.93
	Pit 2.	1.33	0.14	0.61	2.08
	Pit 3.	1.30	0.30	1.99	3.59
	Total	3.41	0.75	6.44	10.60
O	Pit 1.	0.00	0.97	3.29	4.26
	Pit 2.	0.00	0.17	4.72	4.89
	Pit 3.	0.00	0.78	7.72	8.50
	Total	0.00	1.92	15.73	17.65
Ly	Pit 1.	0.39	0.00	0.00	0.39
	Pit 2.	1.95	0.00	0.00	1.95
	Pit 3.	0.00	0.89	3.76	4.65
	Total	2.34	0.89	3.76	6.99

Analysis of Variance

Source of Variation	Df	SS	MS	F
Association	6	15.1	2.51	1.34
Pit	2	2.2	1.1	
Horizon	2	42.57	21.28	11.37 **
Assoc. x Pit	12	18.94	1.57	
Assoc. x Horizon	12	45.6	3.8	2.13
Pit x Horizon	4	6.01	1.5	
Residual	24	44.93	1.87	
Total	62	175.35		

6. Total Amount of Available Phosphorus in 10 grams/100 m^2

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	4.98	2.92	28.81	36.71
	Pit 2.	5.12	0.19	89.91	95.22
	Pit 3.	5.20	6.42	0.00	11.62
	Total	15.30	9.53	118,72	143.55
T	Pit 1.	8.78	5.92	39.81	54.51
	Pit 2.	3.60	2.53	35.01	41.14
	Pit 3.	3.55	2.27	151.71	157.53
	Total	15.93	10.72	226.53	253.18
AT	Pit 1.	6.27	0.00	3.32	9.59
	Pit 2.	9.94	2.06	34.88	46.88
	Pit 3.	12.51	0.00	27.95	39.96
	Total	28.72	2.06	65.65	96.43
P	Pit 1.	3.42	0.00	324.11	327.53
	Pit 2.	1.64	1.35	13.41	16.40
	Pit 3.	12.28	0.39	22.56	35.23
	Total	17.34	1.79	360.08	379.16
B	Pit 1.	6.58	6.66	146.59	159.83
	Pit 2.	8.12	4.71	72.77	85.60
	Pit 3.	8.64	0.00	55.44	64.08
	Total	23.34	11.37	274.80	309.51
O	Pit 1.	0.00	24.30	113.95	138.25
	Pit 2.	0.00	2.22	97.68	99.90
	Pit 3.	0.00	16.38	267.50	283.88
	Total	0.00	42.90	479.13	522.03
Ly	Pit 1.	4.87	0.00	0.00	4.87
	Pit 2.	5.08	0.00	0.00	5.08
	Pit 3.	0.00	41.95	38.39	80.34
	Total	9.95	41.95	38.39	90.29

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	17153	2858	
Pit	2	3167	1583	
Horizon	2	66553	33276	12.7**
Assoc. x Pit	12	30540	2545	
Assoc. x Horizon	12	35910	2992	
Pit x Horizon	4	4420	1105	
Residual	24	62700	2610	
Total	62	220443		

7. Total Organic Matter in %

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	77	4	15	96
	Pit 2.	69	2	5	76
	Pit 3.	84	9	-	93
	Total	230	15	20	265
T	Pit 1.	73	2	16	91
	Pit 2.	75	4	9	88
	Pit 3.	70	2	2	74
	Total	218	8	27	253
AT	Pit 1.	80	0	9	89
	Pit 2.	88	1	9	98
	Pit 3.	87	1	13	101
	Total	255	2	31	288
P	Pit 1.	79	0	14	93
	Pit 2.	66	22	5	93
	Pit 3.	83	7	7	97
	Total	228	29	26	283
B	Pit 1.	82	3	5	90
	Pit 2.	79	3	9	91
	Pit 3.	96	2	7	105
	Total	257	8	21	286
O	Pit 1.	0	5	2	7
	Pit 2.	0	2	1	3
	Pit 3.	0	4	1	5
	Total	0	11	4	15
Ly	Pit 1.	82	0	0	82
	Pit 2.	66	0	0	66
	Pit 3.	0	7	12	19
	Total	148	7	12	167

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	6762.0	1127.0	7.1**
Pit	2	71.0	35.5	
Horizon	2	47766.0	23883.0	150.0**
Assoc. x Pit	12	855.0	71.0	
Assoc. x Horizon	12	10365	863.0	8.6**
Pit x Horizon	4	209.0	52.0	
Residual	24	3825	159.0	
Total	62	69853		

8. Cation Exchange Capacity in me/100 g

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	86	12	58	156
	Pit 2.	84	9	15	108
	Pit 3.	84	19	0	103
	Total	254	40	73	367
T	Pit 1.	88	6	46	140
	Pit 2.	92	12	40	144
	Pit 3.	86	8	9	103
	Total	266	26	95	387
AT	Pit 1.	88	4	15	107
	Pit 2.	100	0	25	125
	Pit 3.	100	15	40	155
	Total	288	19	80	387
P	Pit 1.	102	-	27	129
	Pit 2.	97	61	27	185
	Pit 3.	94	17	25	136
	Total	293	78	79	450
B	Pit 1.	94	9	30	133
	Pit 2.	96	13	24	133
	Pit 3.	95	5	34	134
	Total	285	27	88	400
O	Pit 1.	0	24	9	33
	Pit 2.	0	9	3	12
	Pit 3.	0	17	8	25
	Total	0	50	20	70
Ly	Pit 1.	109	-	-	109
	Pit 2.	81	-	-	81
	Pit 3.	0	17	26	43
	Total	190	17	26	233

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	11571	1928	5.3 *
Pit	2	316	158	
Horizon	2	48009	24004	66.1 **
Assoc. x Pit	12	2415	201	
Assoc. x Horizon	12	13370	1114	3.06*
Pit x Horizon	4	1067	266	
Residual	24	8717	363	
Total	62	85465		

9. Exchangeable Calcium in me/100 g

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	8.49	0.27	t	8.76
	Pit 2.	10.81	0.32	0.31	11.44
	Pit 3.	5.02	0.90	0.00	5.92
	Total	24.32	1.49	0.31	26.12
T	Pit 1.	10.35	0.00	0.56	10.91
	Pit 2.	15.00	0.69	0.02	15.71
	Pit 3.	9.82	0.54	0.00	10.36
	Total	35.17	1.23	0.58	36.98
AT	Pit 1.	14.93	0.00	0.00	14.93
	Pit 2.	13.60	0.00	0.00	13.60
	Pit 3.	17.78	0.50	0.00	18.28
	Total	46.31	0.50	0.00	46.81
P	Pit 1.	4.64	0.00	0.38	5.02
	Pit 2.	13.47	15.49	0.32	29.23
	Pit 3.	8.23	0.70	0.01	8.94
	Total	26.34	16.14	0.71	43.19
B	Pit 1.	0.99	0.00	0.00	0.99
	Pit 2.	8.03	0.00	0.00	8.03
	Pit 3.	4.78	0.00	0.00	4.78
	Total	13.80	0.00	0.00	13.80
O	Pit 1.	0.00	0.77	0.44	1.21
	Pit 2.	0.00	1.26	0.60	1.86
	Pit 3.	0.00	1.78	0.63	2.41
	Total	0.00	3.81	1.67	5.48
Ly	Pit 1.	30.52	0.00	0.00	30.52
	Pit 2.	14.47	0.00	0.00	14.47
	Pit 3.	0.00	0.79	0.77	1.56
	Total	44.99	0.79	0.77	46.55

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	182.94	30.49	1.82
Pit	2	42.21	21.1	
Horizon	2	1003.23	501.6	30.00**
Assoc. x Pit	12	233.94	19.49	
Assoc. x Horizon	12	441.45	36.78	2.2
Pit x Horizon	4	50.95	12.73	
Residual	24	400.07	16.66	
Total	62	2354.79		

10. Exchangeable Magnesium in me/100 g

Assoc.		Horizon O	Horizon A	Horizon B	Pit
	Pit 1.	3.23	0.60	0.75	4.58
De	Pit 2.	3.74	0.30	0.29	4.33
	Pit 3.	4.17	0.82	0.00	4.99
	Total	11.14	1.72	1.04	13.90
	Pit 1.	5.03	0.85	1.05	6.93
T	Pit 2.	1.32	0.39	0.66	2.37
	Pit 3.	4.99	0.81	0.80	6.60
	Total	11.34	2.05	2.51	15.90
	Pit 1.	4.86	0.00	0.17	5.03
AT	Pit 2.	3.92	0.00	0.50	4.42
	Pit 3.	9.17	0.42	1.49	11.08
	Total	17.95	0.42	2.16	20.53
	Pit 1.	5.76	0.00	2.97	8.73
P	Pit 2.	2.57	8.63	0.60	11.80
	Pit 3.	4.98	0.64	1.85	7.47
	Total	13.31	9.27	5.42	28.00
	Pit 1.	2.93	0.46	0.67	4.06
B	Pit 2.	2.85	1.44	0.38	4.67
	Pit 3.	3.83	0.16	0.38	4.37
	Total	9.61	2.06	1.43	13.10
	Pit 1.	0.00	1.19	0.30	1.49
O	Pit 2.	0.00	0.49	0.73	1.22
	Pit 3.	0.00	1.20	0.72	1.92
	Total	0.00	2.88	1.75	4.63
	Pit 1.	6.49	0.00	0.00	6.49
Ly	Pit 2.	6.08	0.00	0.00	6.08
	Pit 3.	0.00	0.84	0.28	1.12
	Total	12.57	0.84	0.28	13.69

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	34.58	5.76	1.8
Pit	2	0.20	0.10	
Horizon	2	111.04	55.52	17.3 **
Assoc. x Pit	12	22.62	1.88	
Assoc. x Horizon	12	48.35	4.03	
Pit x Horizon	4	10.75	2.69	
Residual	24	76.84	3.20	
Total	62	304.38		

11. Exchangeable Potassium in me/100 g

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	1.96	0.14	0.17	2.27
	Pit 2.	1.63	0.08	0.09	1.80
	Pit 3.	3.57	0.36	0.00	3.93
	Total	7.16	0.58	0.26	8.00
T	Pit 1.	1.26	0.10	0.16	1.52
	Pit 2.	1.97	0.13	0.13	2.23
	Pit 3.	1.16	0.10	0.11	1.37
	Total	4.39	0.33	0.40	5.12
AT	Pit 1.	1.20	0.00	0.14	1.34
	Pit 2.	1.22	0.09	0.14	1.45
	Pit 3.	0.44	0.10	0.07	0.61
	Total	2.86	0.19	0.35	3.40
P	Pit 1.	0.66	0.00	0.22	0.88
	Pit 2.	1.05	0.43	0.11	1.59
	Pit 3.	0.59	0.12	0.16	0.87
	Total	2.30	0.55	0.49	3.34
B	Pit 1.	0.56	0.07	0.14	0.77
	Pit 2.	0.67	0.11	0.11	0.89
	Pit 3.	0.40	0.07	0.08	0.55
	Total	1.63	0.25	0.33	2.21
O	Pit 1.	0.00	0.16	0.09	0.25
	Pit 2.	0.00	0.10	0.14	0.24
	Pit 3.	0.00	0.16	0.12	0.28
	Total	0.00	0.42	0.35	0.77
Ly	Pit 1.	0.24	0.00	0.00	0.24
	Pit 2.	0.89	0.00	0.00	0.89
	Pit 3.	0.00	0.15	0.12	0.27
	Total	1.13	0.15	0.12	1.40

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	4.04	0.67	7.5 **
Pit	2	0.08	0.04	
Horizon	2	9.26	4.63	51.4 **
Assoc. x Pit	12	1.33	0.11	1.2
Assoc. x Horizon	12	7.29	0.60	6.7
Pit x Horizon	4	0.14	0.03	
Residual	24	2.16	0.09	
Total	62	24.30		

12. Saturation of Ca^{++} + Mg^{++} + K^{+} in %

Assoc.		Horizon O	Horizon A	Horizon B	Pit
De	Pit 1.	18	9	5	32
	Pit 2.	16	7	3	26
	Pit 3.	15	11	0	26
	Total	49	27	8	84
T	Pit 1.	19	15	11	45
	Pit 2.	20	10	2	32
	Pit 3.	18	17	30	65
	Total	57	42	43	142
P	Pit 1.	11	0	13	24
	Pit 2.	18	40	8	66
	Pit 3.	15	8	8	31
	Total	44	48	29	121
B	Pit 1.	5	6	3	14
	Pit 2.	12	49	2	63
	Pit 3.	9	4	5	18
	Total	26	59	10	95
O	Pit 1.	-	9	17	26
	Pit 2.	-	24	38	62
	Pit 3.	-	19	19	38
	Total		52	74	126
Ly	Pit 1.	40	0	0	40
	Pit 2.	32	0	0	32
	Pit 3.	0	10	18	28
	Total	72	10	18	100
AT	Pit 1.	21	2	4	27
	Pit 2.	21	0	1	22
	Pit 3.	27	7	4	38
	Total	69	9	9	87

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	322	53.6	
Pit	2	219	109.5	
Horizon	2	379	189.5	1.8
Assoc. x Pit	12	1098	91.5	
Assoc. x Horizon	12	2762	230.1	2.1
Pit x Horizon	4	550	137.0	
Residual	24	2665	111.0	
Total	62	7995		

13. Available Phosphorus in ppm

Assoc.		Horizon O	Horizon A	Horizon B	Pit
	Pit 1.	47	30	35	112
De	Pit 2.	40	6	59	105
	Pit 3.	51	13	0	64
	Total	138	49	94	281
	Pit 1.	43	9	13	65
T	Pit 2.	72	19	13	104
	Pit 3.	71	17	33	121
	Total	186	45	59	290
	Pit 1.	25	0	4	29
AT	Pit 2.	35	30	25	90
	Pit 3.	35	0	11	46
	Total	95	30	40	165
	Pit 1.	22	-	22	44
P	Pit 2.	16	12	12	40
	Pit 3.	34	6	26	66
	Total	72	18	60	150
	Pit 1.	10	-	11	21
B	Pit 2.	16	14	41	71
	Pit 3.	18	6	25	49
	Total	44	20	77	141
	Pit 1.	0	16	13	29
O	Pit 2.	0	13	16	29
	Pit 3.	0	11	5	16
	Total	0	40	34	74
	Pit 1.	12	-	-	12
Ly	Pit 2.	9	-	21	30
	Pit 3.	0	37	22	59
	Total	21	37	43	101

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	4660	776	5.6 **
Pit	2	617	308	2.2
Horizon	2	2396	1198	8.7 **
Assoc. x Pit	12	2004	167	
Assoc. x Horizon	12	5209	434	3.1 **
Pit x Horizon	4	300	75	
Residual	24	3305	138	
Total	62	18491		

14. Organic Matter / Nitrogen Ratio in the Humus Horizon of the Associations

	De	T	AT	P	B	Ly	O
Pit 1.	65	60	62	49	51	54	28
Pit 2.	58	61	64	45	78	36	25
Pit 3.	73	64	55	43	70	40	23
Total	196	185	181	137	199	130	76

Analysis of Variance

Source of variation	Df	SS	MS	F
Association	6	4110.0	685.00	37.2 *
Pit	2	0.1	0.05	
Residual	12	220.9	18.40	
Total	20	4331.0		

Calculation

Df = degrees of freedom = n-1; if n = number of data
eg. The number of associations is 7; Df for assoc. = 7-1 = 6

In interactions, Df is the product of the degrees of freedom of the items making up the interaction.
eg. Assoc. x Pit interaction, Df = 6x2 = 12

$$\text{Correction factor: } C = \frac{(\sum X)^2}{n} \quad ; \quad X = \text{individual data}$$

$$\text{Association SS} = \frac{\sum \text{association}^2}{9} - C \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ A$$

9 is the number of data making up an association.

$$\text{Pit SS} = \frac{(\sum \text{Pit 1.})^2 + (\sum \text{Pit 2.})^2 + (\sum \text{Pit 3.})^2}{21} - C \ \ldots\ldots\ldots\ldots \ P$$

$$\text{Horizon SS} = \frac{(\sum \text{Horizon 0})^2 + (\sum \text{Horizon A})^2 + (\sum \text{Horizon B})^2}{21} - C \ \ldots\ldots\ldots \ H$$

$$\text{Association x Pit SS} = \frac{\sum \text{Pit}^2}{3} - (C+A+P) \ \ldots\ldots\ldots\ldots \ AP$$

$$\text{Assoc.x Hor.SS} = \frac{(\text{De assoc.} \sum \text{Hor.0})^2 + \ldots + (\text{Ly assoc.} \sum \text{Hor.0})^2}{3} + $$
$$+ \frac{(\text{De assoc.} \sum \text{Hor.A})^2 + \ldots + (\text{Ly assoc.} \sum \text{Hor.A})^2}{3} + $$
$$+ \frac{(\text{De assoc.} \sum \text{Hor.B})^2 + \ldots. + (\text{Ly assoc.} \sum \text{Hor.B})^2}{3} - (C+A+H) \ \ldots\ldots\ldots\ldots AH$$

$$\text{Pit x Horizon SS} = \frac{(\sum \text{Pit 1.Hor.0})^2 + (\sum \text{Pit 1.Hor.A})^2 + (\sum \text{Pit 1.Hor.B})^2}{7} + $$
$$+ \frac{(\sum \text{Pit 2.Hor.0})^2 + (\sum \text{Pit 2.Hor.A})^2 + (\sum \text{Pit 2.Hor.B})^2}{7} + $$
$$+ \frac{(\sum \text{Pit 3.Hor.0})^2 + (\sum \text{Pit 3.Hor.A})^2 + (\sum \text{Pit 3.Hor.B})^2}{7} - (C+P+H) \ \ldots\ldots\ldots \ PH$$

$$\text{Residual SS} = \sum X^2 - (C+A+H+P+AP+AH+PH)$$

$$\text{Total SS} = \sum X^2 - C$$

$$\text{Association MS} = \frac{\text{Association SS}}{6}$$

$$\text{Pit MS} = \frac{\text{Pit SS}}{2}$$

$$\text{Horizon MS} = \frac{\text{Horizon SS}}{2}$$

$$\text{Association x Pit MS} = \frac{\text{Association x Pit SS}}{12}$$

$$\text{Association x Horizon MS} = \frac{\text{Association x Horizon SS}}{12}$$

$$\text{Pit x Horizon MS} = \frac{\text{Pit x Horizon SS}}{4}$$

$$\text{Residual MS} = \frac{\text{Residual SS}}{24}$$

$$F = \frac{\text{MS}}{\text{Residual MS}}$$

Comparison of the association means by Tukey's Studentized Range Test:

$$S_{\bar{x}} = \sqrt{\frac{s^2}{f}} \quad ; \quad Q = 4.54$$

s^2 = Residual MS

f = number of items making up the means

$$D = S_{\bar{x}} Q$$

If the difference between two means are larger than the value of D, the difference is significant.