A STUDY OF SOILS AS RELATED TO SITE INDEX OF DOUGLAS FIR AT HANEY, BRITISH COLUMBIA

BY

NURETTIN KESER

B.S.F., University of Istanbul, 1956

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER IN FORESTRY

in the Department

of

Forestry

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

September, 1960

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of FORESTRY

The University of British Columbia,
Vancouver 8, Canada.

Date Sept. 29. 1960

ABSTRACT

These soil studies were carried out on eight permanent plots at the University Research Forest, Haney, B.C. These plots ranged in Douglas fir site quality values 80 to 180 feet at 100 years.

The soil of each plot was examined by means of soil pits and soil samples were taken for laboratory analysis. For each plot, topography, vegetation, general moisture condition, degree of stoniness, nature of soil and for each profile depth of horizons, soil color, texture, structure, consistence, the amount and position of organic matter, drainage, physiologic depth, depth to mottling and special features of the profile such as hardpan, orstein, shot material, root mats were determined.

In the laboratory, per cent soil skeleton, texture specific gravity of soils, bulk density, total-pore space, macro-pore space, micro-pore space, hydraulic conductivity and available water between 0.1 and 15.0 atmosphere (corrected for soil skeleton and/or soil stoniness), soil acidity, total cation exchange capacity, exchangeable calcium and potassium, and organic matter content were determined.

Statistical analyses were conducted to determine the significancy of the values obtained in laboratory analysis.

Regression equations were determined for evaluating site index from morphological soil characteristics such as horizon thickness, depth to mottling.

The soils of the area were mainly derived from glacial till. Till is a coarse texture (coarse sandy loam to loamy sand) containing gravels, stones, and boulders. It was generally hard and impervious to water movement.

The profiles generally have shown A_{oo}, A_o, A_2, B_{11}, B_{12}, B_3 and C horizons. The development of eluvial and illuvial horizons (especially clay accumulation) appeared somewhat weak. Profiles have shown coarse texture similar to that of glacial till. The depth of profiles varied between 5 and 33 inches, the average range being from 20 to 30 inches.

Two main soil groups were observed among the eight plots. Plots 2, 3 and 4 were minimal podzol (Order: Podzols), plot 1 was concretionary brown (Order: Brunosolic), and plots 5, 6, 7 and 8 are classified as intergrade between concretionary brown and minimal podzol.

Generally the coarse skeleton comprises more than 50 per cent of the soil. All the soils were very low in clay content. Hydraulic conductivity was high. Micro-pore space showed higher per cent layers than macro-pore space.

The available water was low in general due to texture. The preponderance of stones in the soil had an adverse effect on the water-holding capacity of the soil. Consequently, stoniness had to be taken into consideration in determining the actual volume of available water.

All the soils were acid in reaction. The organic matter was high in upper horizons and decreased with depth. Total cation-exchange capacity exchangeable, calcium and potassium and calcium base saturation were low.

Correlation studies between soil properties and site quality indicated that the physical soil properties were more important than chemical characteristics as an indication of soil quality. Texture, bulk density, porosities (macro-, micro and total), hydraulic conductivity did not show any correlation with site quality but were significant at the 5 per cent level between the plots (except micro-pore space). Available water$_D$ was positively correlated with site quality when it was corrected for stoniness and coarse skeleton. Chemical properties were not significant between the plots and did not show any correlation to site quality.

Morphological features such as thickness of B_{11} horizon and depth to mottling were highly correlated to site quality and gave the smallest standard error of the estimate ($\pm$ 21.3 feet).

The study indicates that the volume of available water in the soil was most important for the growth of Douglas fir and that the site index of an area could be determined from a study of those morphological features of the soil which affects its water-holding capacity, as well as other morphological features such as depth to mottling.

TABLE OF CONTENTS

		PAGE
	INTRODUCTION	1
I.	REVIEW OF LITERATURE	2
	Soil Classification	2
	The Forested Soils of the Lower Mainland of British Columbia	12
	Soils and Forest Growth	20
II.	EXPERIMENTAL	26
	General Description of the Area	26
	Location	26
	Geology	27
	Climate	28
	Forest Type	29
	Location of the Plots	30
	Field Methods	30
	Mapping	30
	Microclimate	30
	Vegetation	31
	Soils Studies and Sampling	31
	Laboratory Methods	33
	Statistical Analyses	35
III.	RESULTS	36
	Physiography	36
	Vegetation	38

PAGE

Microclimate..... 41

Description of Soils..... 44

Generalized Profile Description..... 44

Horizon Depths..... 50

Stoniness..... 52

Chemical Properties..... 52

Physical Soil Properties..... 55

Statistical Analyses..... 58

IV. SOILS AND SITE QUALITY..... 60

Climate..... 60

Great Soil Groups..... 61

Physical Properties of Soils..... 61

Chemical Properties of Soils..... 64

Regression Analysis..... 65

V. SUMMARY AND CONCLUSION..... 67

BIBLIOGRAPHY..... 73

APPENDIX..... 87

TABLE — FOLLOWING PAGE

1. Podzolic and Brunosolic Orders from the Canadian Soil Classification (1958)..... 10

2. Stand Data for the Eight Study Plots, October 1956..... 19

3. Mean Monthly, Maximum and Minimum Precipitation and Temperature Data for Haney Recording Station 1946 - 1957..... 27

TABLE

4. Mean Weekly, Air, Maximum Minimum Temperature and Temperature Range, Relative Humidity and Dew Points for Plots 1,2,4 and 8..... 40

5. Horizon Thickness, Depth of Solum, physiologic Depth and Depth to Mottling for all Plots... 49

6. Stone Contents of Plots 1, 3 and 5..... 51

7. Soil Reaction (pH Values) for Soils of all Plots..... 52

8. Organic Matter, Total Exchange Capacity and Exchangeable Calcium and Potassium for the Soil of Plots 1,2,3 and 5..... 52

9. Mechanical Analysis and Coarse Skeleton for Soils of Plots 1,2,3 and 5..... 54

10. Field Texture of Soils..... 54

11. Bulk Density, Total, Macro, Micro Porosities and Hydraulic Conductivity of Soils of Plots 1, 3 and 5..... 54

12. Total Porosity Calculated by Two Methods for Plots 1, 3 and 5..... 54

13. Specific Gravity of Soils in Plots 1,3 and 5... 54

14. Ratio of the Macro-Porosity to Micro-Porosity for Plots 1,3 and 5..... 54

15. .1 and 15 Atmosphere Moisture, in inches per Horizon for the Soils of Plots 1,3 and 5.... 54

TABLE

16. Available Water (.1-15 atmosphere), In Per Cent and Inches Per Horizons for the Soils of Plots 1,3 and 5..... 54

17. Summary of F Values and Significance from Variance Analyses of Physical Data for Plots 1,3 and 5..... 57

18. Variance Analyses of Chemical Data for Plots 1,2,3 and 5..... 57

19. Matrix of Simple Correlation Coefficients for Variables, $X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8$ and Y.... 64

20. Simple Linear Equations of Y on X_2, X_3, X_4, X_7 and X_8..... 64

21. Anova for a Simple Regression of Y on X_2..... 64

22. Anova for a Simple Regression of Y on X_3..... 64

23. Anova for a Simple Regression of Y on X_4..... 64

24. Anova for a Simple Regression of Y on X_7..... 64

25. Anova for a Simple Regression of Y on X_8..... 64

26. Multiple Linear Equations of Y on Various Combinations of X_{1-8}..... 64

27. Anova for a Multiple Linear Regression of Y on X_1-X_8..... 64

28. Anova for a Multiple Linear Regression of Y on X_4 and X_8..... 64

29. Anova for a Multiple Linear Regression of Y on X_4 and X_3..... 64

TABLE

30. Anova for Multiple Linear Regression of Y on X_8 and X_3..... 64

31. Anova for Multiple Linear Regression of Y on X_4 and X_5..... 64

32. Anova for Multiple Linear Regression of Y on X_4,X_5 and X_8..... 64

33. Percentage of Total Variation in Site Index Associated with Each and All Factors..... 64

FIGURE

1. Illustration (after Kelley and Spilsbury showing the general futures of the soil zone and its associate in the lower Fraser Valley..... 11

2. University Research Forest Showing the surficial geology according to map 16-1957 of the Geological Survey of Canada, Dept. and Technical Survey..... 26

3. Average monthly precipitation and temperature at Haney, 1946 - 1958..... 27

4. Climograph (after Koeppe)showing the climatic pattern of Haney..... 27

5. Location of plots in U.B.C. Research Forest, Haney..... 29

6. Topographic map of plot 1..... 35

7. Projection map of plot 1..... 35

8. Topographic map of plot 2..... 35

FIGURE

9. Projection map of plot 2..... 35

10. Topographic map of plot 4..... 35

11. Topographic and projection map of plot 5..... 35

12. Topographic and projection map of plot 7..... 35

13. Average atmospheric temperature for plots 1, 2,4,8 and average dew-points for plots 1 and 4 for the period of May 21 to August 15, 1957..... 40

14. Average weekly relative humidity and temperature ranges for plots 1,2,4 and 8, for the period May 21 to August 15, 1957.... 40

15. Weekly average dew-points for plots 1,2,4,8 and 2 for the period May 21 to August 15, 1957..... 40

16. The profile pictures of plots 1,2,3,4 and 6... 43

17. Changes in soil porosity with soil depth for plots 1,3 and 5..... 56

18. Rainfall at several different elevations for July and August, 1957..... 59

19. Average depth of soil horizons for plots 1,2, 3,4 and 5 in relation to site index..... 59

20. Average thickness of B_{11},B_{12} and B_3 for plots 1,2,3,4,5,6,7 and 8 in relation to site index..... 59

FIGURE

21. Depth of solum, effective depth and depth to mottling in relation to site index..... 59

22. Maximum, minimum, and average effective depth for all plots in relation to site index..... 59

ACKNOWLEDGEMENT

The author is indebted and wishes to express his thanks to Dr. C.A. Rowles, Chairman of Soil Science Department and Dr. B.G. Griffith of the Faculty of Forestry.

The guidance of Dr. J.H.G. Smith of the Faculty of Forestry in the statistical analysis of the data in the thesis is gratefully acknowledged by the author.

The financial assistance from the Faculty of Forestry and the laboratory facilities provided by the Department of Soil Science are also acknowledged.

The author wishes to thank Mr. L. Heger, graduate student in the Faculty of Forestry for assistance in using Allwac III, and Mrs. Mona Lambden, laboratory technician, for her help in preparing the figures.

INTRODUCTION

This study arose from a research project begun several years ago by members of the Faculty of Forestry, University of British Columbia, at the University Research Forest, Haney, British Columbia (46). Its purpose was to study, by means of field observations and laboratory analysis, the nature and properties of the soils on a number of experimental plots for which Douglas fir site indices and other information had been established (61). It was hoped that the resulting information could be used as a basis for classifying the soils, for establishing correlations between field observations and for explaining differences in growth behavior on the different site plots. The field work was carried out from May 15th to September 2nd, 1957 at the University Research Forest, Haney; and the laboratory analyses were done in the laboratories of the Department of Soil Science, University of British Columbia.

I. REVIEW OF LITERATURE

1. Soil Classification

The purpose of soil classifications are similar to those of classifications of natural objects in general, namely, to facilitate the organization of facts concerning the objects and to discover order (99). Soil classification, therefore, constitutes one important element in the present study.

All systems of classification of natural bodies are more or less provisional because they are based on incomplete knowledge of the objects themselves and consequently, classification must be modified from time to time as new facts are established. This has characterized soil classification in the past and is still evident at the present time.

The earliest classification of soils was based entirely on geology. However, modern concepts of soil classification are very different and had their origin in the work of Russian pedologists about 1870. The Russian scientists conceived soils to be independent natural bodies, each with a unique morphology and resulting from a unique combination of climate, living matter, parent rock material, relief and time (148). The morphology of each soil as

expressed in its profile, reflected the combined effect of the particular set of genetic factors responsible for its development.

The modern concept of a soil is that:

> It is an individual in a continuum. It is a dynamic, three-dimensional piece of landscape that supports plants. It has a unique combination of both internal and external characteristics that have definable ranges of expression. Each individual type of soil has a model set of characteristics within the limits set by logic. Its upper surface is the surface of the land. The lower surface is defined by the lower limits of soil-forming processes and its boundaries are boundaries with other kinds of soil where changes occur in one or more differentiating characteristics related in turn to one or more of the genetic factors (148).

Marbut was largely responsible for introducing the Russian conception of soils into North America when he translated Glinka's book The Great Soil Groups of the World and Their Development (77). Marbut adapted and broadened the Russian conceptions in the United States. He emphasized the importance of soil morphology besides the soil genetic characteristics. He came to the conclusion that the examination of the morphological features of a soil profile were essential for the classification and mapping of soils. In 1921 Marbut listed eight important features of the profile that should be studied by the morphologist and used as a basis for classification of soils. These were:

1. Number of horizons in the soil profile.
2. Colour of various horizons with special emphasis

on the surface A-B.

3. The texture of the horizons.
4. The structure of the horizons.
5. The relative arrangement of the horizons.
6. The chemical composition of horizons.
7. The thickness of horizons.
8. The geology of soil material (123).

In 1935 Marbut published a scheme of soil classification as an introduction to his monograph of the soils of the United States. This represented a considerable revision of the earlier American system and contains much evidence of the influence of the Russian pedologists (72).

Marbut's classification recognized six categories: I - soil type; II - soil series; III - family; IV - soil groups; V - sub order; VI - orders. The concepts and definitions of these categories were subsequently modified by Marbut's successors (123)(160).

The soil type has remained a basic or common unit of soil mapping and classification in the United States and has been defined as "a group of soils having genetic horizon similar as to differentiating characteristics, including texture and arrangement in the soil profile, and developed from a particular parent material."(131)

The soil series represents a somewhat higher level of generalization and its definition has remained relatively unchanged:

> ...a group of soils having genetic horizons similar as to differentiating characteristics and arrangement in the soil profile, except for the texture of the surface soil, and developed from a particular type of parent material. A series may include two or more soil types differing from one another in texture of the surface soil.(131)

The third category, the family, was incompletely defined by Marbut and its concept, definition and use have been modified considerably. These three lower categories of soil classification I, II, III have been discussed in detail by Riecken and Smith (131). These authors viewed the family as a category of soils intermediate between the great soil group and the soil series. In fact, the soil family is still in the process of definition and development (131).

The higher categories of classification, great soil groups, sub order and order, have been modified considerably since the scheme was originally proposed by Marbut.

Order was the highest category in the soil classification scheme. The orders, as outlined by Baldwin et al. were zonal, intrazonal and azonal soils. Zonal soils were defined as "any one of the great groups of soils having well developed soil characteristics that reflect the influence of the active factors of soil genesis; climate and

living organisms, chiefly vegetation."(160)(147)

Intrazonal soils were defined as "any of the great groups of soils with more or less well developed soil characteristics that reflect the dominating influence of some local factor of relief, parent material, or age over the normal effect of the climate and vegetation."(147)

Azonal soils were defined as "any group of soils without well developed profile characteristics, owing to their youth or conditions of parent material or relief, that prevent the development of normal soil profile characteristics."(147)

Sub order was the second highest category in the soil classification system. The Great soil group, a group of soils having common internal soil characteristics, includes one or more families of soils (160). Among the zonal soils, each great soil group includes soils which have in common certain profile characteristics developed through the influence of environmental forces of broad geographic significance, especially vegetation and climate; among the intrazonal soils, each great soil group includes soils which have in common certain profile characteristics developed through the influence of environmental forces of both broad and local significance; among the azonal soils each great soil group includes similar soils that are without developed profile characteristics, owing to the influence of some local condition of parent material or relief.(160)(147)

Since 1938 some modifications have been made. The modification of order, sub order and great soil groups is discussed by Thorp and Smith (160). These authors state that "although a natural classification of soils should be based on physical and chemical properties of the soils themselves, it is difficult to adhere strictly to morphology." Also they suggested that "terms indicating zonality or lack of it may be abandoned eventually in favor of terms based on soil characteristics."

The soil phases and soil catena or toposequence are two other units that have often been used in soil classification. The Soil phase was defined as:

> That part of a soil unit or soil type having minor variations in characteristics from the characteristics normal for the type, although they may be of great practical importance. The variations are chiefly in such characteristics as relief, stoniness, accelerated erosion, soil depth, soil thickness or drainage.

Riecken and Smith stated that "the properties of a soil phase must be within a defined range of the soil type and series."(121).

The Soil catena was defined as "a group of soils within one zonal region, developed from similar parent material, but differing in characteristics in relief or drainage."(123). The catena concept was originally developed by Bushnell (10) and has been extensively used in soil surveys.

Ellis (123) advanced the same concept and suggested that the term Soil Association be used to refer to it.

A very complete and detailed description of soil classification and instruction for the field description and classification of soils is contained in the Soil Survey Manual (148), published by the Soil Survey Staff of the United States Department of Agriculture.

The classification of Canadian soils was begun about 1920, and since that time about 250 million acres of soil have been surveyed and classified (135). The methods of classification have paralleled, to a considerable degree, those outlined above for the United States and these methods have been described in the proceedings of the National Soil Survey Committee. (123)(124)(125)

Canadian pedologists have recognized the need for two approaches to soil classification and therefore in 1945 proposed two separate but related classifications. The first proposed was a "field classification" and was especially adapted to soil surveys (123)(153). It made use of seven categories as follows: Soil regions, zones, subzones, associations or catenas, series, type and phases.

The broadest category, the region, was based on common morphological features and the environmental factors under which the soils developed. The three soil regions

proposed were, the tundra soils region, the woodland soils region and the grassland soils region.

The soil zones were the main sub-division of the region and it is stated that:

> They are largely determined by soil characteristics that can be correlated with climate and vegetation over a comparatively broad area. The zone should be defined as a broad belt of soils in which the dominant normal soils correspond to the soils of a great soil group, such as podzols, black earths, etc. Due to local conditions many soils may be focussed in a soil zone which are not of the same type as the dominant soil.(123)

Three main zones of the grassland region were recognized as brown, dark brown, and black; and five in the woodland region as grey wooded, podzol, grey brown, podzolic, and pacific (yellow-brown podzolic).

Soil sub-zones were suggested "to cover major broad soil variations within a zone, which can be linked with gradual climatic and vegetative changes and which may or may not be accompanied with changes in parent materials."

The concepts and definitions of the remaining categories were similar to those outlined above. It should be noted that this classification was designed for surveying and the production of soil maps.

In 1955 the Canadian Soil Survey Committee undertook to develop and publish a natural taxonomic system of soil

classification. Modifications of this scheme were made in 1957 and 1958 and a revised taxonomic system of classification will be published in 1960.

Rowe, a forester with the Department of Northern Affairs and National Resources, Ottawa, represented the forestry point of view at the National Soil Survey Committee, Guelph, Ontario, 1960 (132). He commented on the proposed taxonomic system as follows:

> When the classification becomes available, I believe that we in the Forestry Branch should make every effort to use it, for these reasons:-
>
> (1) The classification and its terminology are endemic and therefore specific for Canadian conditions. Exotic classification can never be transplanted from one country to another without confusion.
>
> (2) There are obvious advantages in having all Canadian soils workers speaking the same language, and in having the common understanding that makes co-operative work possible.
>
> Soils are not ideal subjects for classification because (1) they are parts of ecosystems, and (2) they are not discrete entities, but rather are continuous and variable in space. Nevertheless they are arbitrarily classifiable. Classification is a necessary generalization; it serves the needs of communication, summarizes knowledge, indicates relationships, provides the key to identification and the basis for scientific study.
>
> The National Soil Survey Committee classification is based primarily on type of profile, with ecology, chorology (regional distribution) and composition (quantiative and qualitative analysis) brought in secondarily at some points, in the interests of clarification.

TABLE 1. PODZOLIC AND BRUNOSOLIC ORDERS FROM THE CANADIAN SOIL CLASSIFICATION (1958)

VI ORDER	V GREAT GROUP	IV SUB-GROUP
3. PODZOLIC SOILS (1958) Soils with leached eluvial (Ae) horizons and with illuvial (B) horizons having accumulations of sesquioxides and/or organic matter or clay (not solonetzic B).	3.1 Gray Brown Podzolic (1958)	
	3.2 Gray Wooded (1957)	
	3.3 Humic Podzol (1958)	
	3.4 Podzol (1958) Under undisturbed conditions the soils of this group have an organic surface layer (O) a light colored eluviated (Ae) horizon at least ½" thick and an illuvial B horizon in which organic matter and sesquioxides are the main accumulation products. The main B horizon contains less than 10% of organic matter but a thin Bh horizon (less than 3" thick containing 10% or more of organic matter) may be present. The solum is moderately to strongly acid and unsaturated.	3.41 Orterde (Modal) Podzol (1958) Podzol soils having an organic (O) surface horizon, a thin (less than 1") light colored eluvial (Ae) horizon (may be discontinuous) and an illuvial (B) which contains accumulations of organic matter and sesquioxides. Lacks distinct Bh subhorizon.
4. BRUNOSOLIC SOILS (1958) Soils with brownish colored sola without marked eluvial	4.1 Brown Forest (1958)	
	4.2 Brown Wooded (1957	

BRUNOSOLIC SOILS (Cont'd)

or illuvial horizons or both.
These are well drained and imperfectly drained soils developed under forest, mixed grass and forest or tundra. The major process involved is weathering and translocation is restricted largely to the easily soluble soil constituents.
It is considered that these soils are in a youthful stage of development.

4.3 Brown Podzolic (1958) Soils having either an O or a thin Ah horizon (less than 2" thick) or both, underlain by a brown (color) B of low or medium base saturation . Soils with a thin Podzol Ae (½" or less) are included with this group.

4.4 Acid Dark Brown Forest (1958)

4.31 Orthic Brown Podzolic (1958) Soils with a strongly to medium acid O horizon(generally of ½ to 2" thick) and may have d,f, and h sub-horizons. The Ah is less than 2" thick or lacking, medium to strongly acid and unsaturated. The Ae is generally absent, but if present does not exceed ½". The B is brown to yellowish brown, medium to strongly acid and unsaturated, without any noticeable accumulation of clay or sesquioxides, slight mottling may be found in the lower B. The C is acidic in reaction.

4.32 Gleyed Brown Podzolic (1958) These soils are similar to the orthic Brown Podzolic soils except for the presence of mottling throughout the solum but especially in the lower part.

BRUNOSOLIC SOILS (Cont'd)

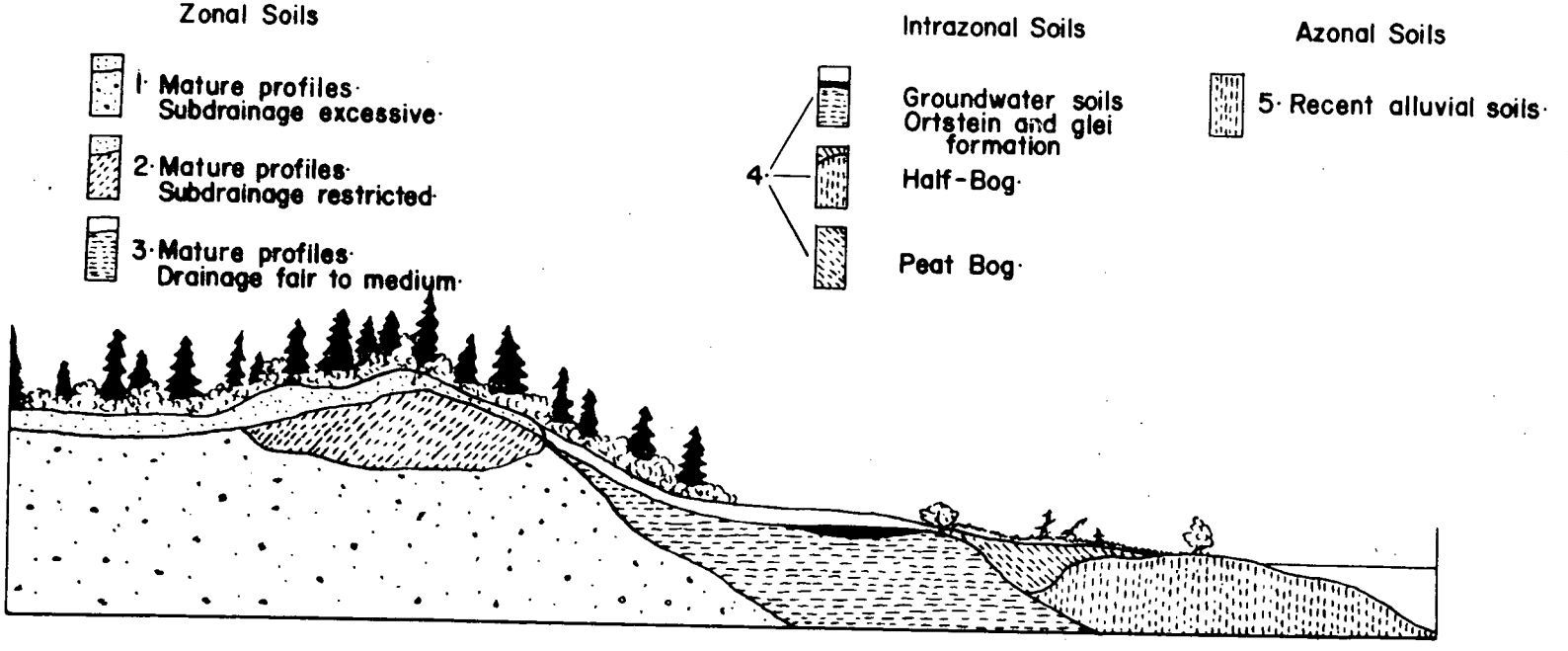
4.5 Concretionary Brown (1958) A group of soils having an O horizon, a brownish or reddish B horizon of low base saturation (below 50%) which contains concretions and prominent iron coatings. The parent material is usually of low base saturation and a thin Ae may be present.

4.51 Modal Concretionary Brown (1958) Soils having an O horizon, and a dark reddish brown, yellowish red or pale brown B horizon of low base saturation which contains concretions and prominent iron coatings. Mottling is absent in the B horizon.

> The classification scheme is based on our present knowledge of Canadian soils and on the concepts which gradually have been developed regarding their genesis and morphology (132).

The proposed system contains six categories. Category I corresponds to the present conception of the soil type; II to the soil series or catenary member; III to the soil family (low family -- consisting of a group of morphologically related series); IV sub group corresponds closely to the U.S. high family which consists of inter-grade or other major divisions of the great soil groups; V corresponds closely to the present conception of great soil groups; and VI, the highest category, consists of a number of morphologically and/or genetically related great soil groups. These categories and their sub-divisions are given in detail in the Report of the Third Conference of the National Soil Survey Committee (123). A part of this classification related to this study is given in Table 1.

The soil classifications discussed above may be referred to as "Natural Soil Classification Systems" to distinguish them from technical or practical classifications. A technical classification groups soils on the basis of their suitability for a particular purpose (30)(99). Technical classifications have been proposed for many purposes including Agriculture, Forestry, Engineering, susceptibility to erosion, productivity rating and land utilization or capability.



Fig· I Illustration (after Kelley & Spilsbury) showing the general features of the soil zone and its associates in the lower Fraser Valley (79)·

Since the categories of a natural soil classification system contain information about individual soils, they have been used as a basis for technical classifications (144)(131). It has been found that the choice of a category depends upon the purpose of the technical classification. The categories I, II, and III (type, series and family) are often sufficient for technical grouping. Lately, families are being widely used in Eastern Canada. Families are differentiated on the basis of texture of solum or parent material, thickness of solum, and the presence of impermeable horizons of substrata. These characteristics are very important in determining the water regime or water holding capacity of a profile (144)(131). Soil series or phases could be used for more detailed work.

2. The Forested Soils of the Lower Mainland of British Columbia

The soils of the University Research Forest have not been studied in detail but there have been a number of studies and publications dealing with the soils of the Lower Mainland.

One of the first reports on the soils of the lower mainland area of British Columbia was by Kelley and Spillsbury (79). These authors divided the soils into zonal, intrazonal and azonal orders and showed the general position and relationship. Figure 1 is from their report.

It is evident that the well drained upland soils of the University Forest correlate with the zonal soils described by Kelley and Spillsbury, and that the soils of the poorly drained depression and along the streams correlate with their intrazonal and azonal soils. These authors made a further sub-division of the soils into series on the basis of the mode or origin of the parent material and then grouped the zonal soils on the basis of drainage differences:

1. Zonal Soils, subdrainage excessive:
   - Everette Series
   - Lynden Series
2. Zonal Soils, subdrainage restricted;
   - Alderwood Series
   - Whatcom Series
3. Zonal Soils, drainage fair to medium:
   - Milner Series
   - Haney Series (79)

The Alderwood Series was described as being "characterized by a 2 to 6 foot layer of hard, sandy boulder clay containing stones and gravel, superimposed on a great thickness of stratified sands and gravels, and buried under 2 to 4 feet of alluvium."(79)

> The native vegetation consists of a luxuriant second growth of fir, cedar, hemlock, alder, maple and birch with scattered dogwood. There are many varieties of shrubs and a dense growth of bracken. In virgin areas

> the surface soil is covered with a layer of organic-matter accumulation about two inches or less in thickness, beneath which the soil is reddish-brown to pale reddish-brown, fading to brown and brownish-yellow with depth. A-B horizon of clay accumulation is absent, but numerous iron concretions are present. The soil profile is superior in moisture-holding capacity to upland soil types of light texture that are not overlaid by an impervious layer.(79)

The Alderwood Sandy soil type was described by Kelley and Spillsbury as follows:

"Horizon	Depth	Description
A_0	0-2"	Dark brown organic litter.
A_2	2-2¼"	Ash grey, slightly podzolized.
A_3	2¼-8"	Pale reddish-brown to rich brown; loose, open, single grained; sandy loam with iron concretions; deficient in humus; scattered gravel and surface stones.
A_4	8-20	Sandy loam, concretions of gravel and stone. Colour shades from brown to yellowish brown. Horizon ends in mat of roots which lies directly on hard boulder clay.
D		Grey boulder clay 20 - 24 inches thick, composed of hard cement-like sandy mixture containing stones."(79)

Topography is rolling or mountainous on the north side of the Fraser with included areas having more gentle slopes.

The mineral composition of Alderwood Silt loam from the Alderwood Series is given here from the same report:

"Nitrogen, Organic Matter and Mineral Composition of Alderwood Silt Loam

Horizon	Depth	Nitrogen	Organic Matter	SiO_2	Fe_2O_3	Al_2O_3
A_o-A_3	0-6	.182	6.62	61.72	5.76	14.56
A_4	6-12	.153	5.90	58.79	6.66	16.81
A_4	12-24	.106	4.33	63.32	5.95	16.41
D	24-	.030	1.26	68.48	5.04	14.75

Horizon	P_2O_5	CaO	MgO	K_2O	Na_2O	pH
A_o-A_3	.151	2.55	1.52	.54	1.68	5.20
A_4	.047	.88	1.35	.74	1.51	5.32
A_4	.056	1.68	1.97	.75	1.58	5.49
D	.032	2.41	1.98	.79	1.72	5.47"(79)

Rowles, Farstad and Laird described the general nature and distribution of soil groups in British Columbia (136). The University Research Forest occurs in the general soil area described by them as concretionary reddish brown. Within this area they reported that principal upland soil groups were concretionary Reddish Brown, Brown Podzolic and Podzols and that associated with these in the less well drained positions were muck, peat and gleizolic soils. These authors described the upland soils of the area as follows:

These soils have a relatively thin organic layer on the surface (A_0) derived mainly from coniferous vegetation and mosses. Immediately below this the upper mineral horizon is a reddish brown to yellowish brown, or strong brown horizon (B), highly concretionary (shotty) and of high porosity and permeability. Free oxides or iron are usually concentrated in this horizon and the base exchange capacity is generally low in relation to clay content. The lower part of the profile is often dense, cemented and of low porosity and permeability (B-C). As a consequence, internal soil drainage is frequently restricted and large volumes of water move laterally over these impervious horizons.

The degree of base saturation of the clay and organic colloids is low and hydrogen often accounts for 50 per cent or more of the exchangeable cations in the surface layers. As a result, the soils are strongly to slightly acid, the lower horizons tending to be somewhat better supplied with bases and less acidic than those at the surface. The soils are generally low in organic matter and nitrogen and respond well to nitrogen fertilization. Also, they generally are low in available phosphorus and have a marked capacity to fix or tie up phosphorus applied as fertilizer.

Characteristically, soil moisture is excessively high during the winter but falls to a very low level during mid-summer.

Concretionary reddish brown soils have developed on a variety of materials including glacial till, marine sediments, outwash sands and gravel. (136).

Brown podzolic on well drained sites, organic and gley soils on poorly drained localities, and podzols on high altitudes were observed as associated soils of this group by the authors.

The Forest Soils Committee of the Douglas-fir Region studied and discussed the soils which occur in the Coast, under the Douglas-fir and its associated species (9). In the report, the podzols and brown podzolic are classified under the zonal

order. The authors noted the A_1 horizon and A_2-B_2 horizons are the sequence for podzol soils. Brown podzolic soils showed a weakly developed A_1 horizon and a thin, fine, ashy A_2 horizon which was discontinuous. In its absence there usually is an incipient A_2 in the form of flecks, sprinklings of gray. Brown podzolics showed a thick B horizon. B_2 horizon had little or no textural development; but had weak structural formation which was usually medium blocky to weak prismatic (9).

Recently a soil survey was completed by Holland et al. of Pitt Meadow Municipality in the vicinity of the University Forest and was classified as belonging to the Brown podzolic (70). This series was mapped on Sheridan Hill, which shows somewhat similar topographic features to those occurring in the University Forest. The Alderwood Sandy Loam had a compact and hard parent material composed of glacial till which was impervious to the downward movement of water. In the areas in which the till was close to the surface, the rooting zone was restricted and a summer drought was observed. The well drained parts of the Alderwood Series also show some characteristics which were observed for Everett Sandy Loam. The authors noted:

> In well drained conditions there is a discontinuous A_2 horizon up to 2 inches thick, which indicates that this subtype is actually a thin podzol containing "shot" ...The well drained condition of the Everette series is

tentatively included under Forested Brown Soils pending further investigation.(70)

Everett Sandy Loam was also classified under Shotty Brown soils and was mapped on the forested upland in the same general area as Alderwood Sandy Loam.

A modal profile description of Alderwood Sandy Loam is given below:

"Horizon	Depth	Description
A_c	0-6"	Brown to dark brown (7.5YR 4/2 dry), dark brown (10 YR 2/2 moist) sandy loam. Weak fine granular structure, friable and slightly plastic, scattered stones. pH 5.6
B	6-30"	Dark yellowish brown (10 YR 4/4 dry), very dark yellowish brown (10 YR 3/4 moist) sandy loam. Weak granular structure, very few shot, friable, soft, scattered stones. pH 5.6
C	30"+	Light gray (10 YR 7.2 dry), grayish brown (2.5 YR 5/2 moist) sandy clay loam; massive, hard, compact glacial till containing stones and grit, impervious. pH 6.2" (70)

Textural analysis of the above profile is quoted here to give a more complete picture of the Alderwood Sandy Loam:

"The Soil Texture of Alderwood Sandy Loam

Horizon	Depth	% sand	% silt	% clay	Texture class
A_c	0-6"	55.6	34.6	9.8	Sandy loam
B	6-30"	57.5	24.6	7.9	Sandy loam
C	30"+	53.2	25.6	21.2	Sandy clay loam"(64)

The chemical analysis data of Everette sandy loam, a soil derived from a very similar material to Alderwood sandy loam, are given here:

"The exchangeable cations, milli-equivalent per 100 grams soils

Horizon	Depth	pH	Exch. cap.	% base saturation
B_1	0-6"	5.2	18.77	5.3
B_2	6-16"	5.3	16.35	4.6
C_1	14-26"	5.6	4.19	10.7
C_2	26-30"	6,2	3.03	50.7

	H	Ca	Mg	K	Na
B_1	17.77	.31	.52	.13	.04
B_2	15.60	.10	.52	.09	.04
C_1	3.74	.10	.30	.02	.03
C_2	1.19	.52	1.21	.04	.07" (70)

The most recent work on the soils of the University Research Forest was done by Griffith (61). He examined the soil properties on eight plots which were used in this study, and determined the soil moisture and soil temperature with Coleman type soil-moisture units placed at depths of 6, 12 and

TABLE 2. STAND DATA FOR THE EIGHT STUDY PLOTS, OCTOBER 1956(61)

Plot Number	1	6	5	7	8	2	4	3
Site Index	180	170	160	150	140	115	85	80
No. of Stems per Acre								
Douglas Fir	210	250	190	180	200	380	530	540
Western Hemlock	50	140	200	140	213	10	130	170
Western Red Cedar	60	60	30	110	187	440	450	330
TOTAL	320	450	420	430	600	830	1110	1040
Basal Area in Square Feet								
Douglas Fir	446.4	380.9	364.8	291.4	317.4	172.0	147.9	127.3
Western Hemlock	38.6	36.0	88.4	67.5	111.7	2.3	8.8	42.7
Western Red Cedar	7.7	8.0	4.4	32.5	24.5	50.9	23.4	30.5
TOTAL	492.7	424.9	457.6	319.4	453.6	225.2	180.1	200.5
Diameter of Tree of Ave.B.A.								
Douglas Fir	19.8	16.7	18.8	17.3	17.0	9.1	7.2	6.6
Western Hemlock	11.9	6.9	9.0	9.4	9.8	6.5	3.5	6.8
Western Red Cedar	4.8	4.9	5.2	7.4	4.9	4.6	3.1	4.1
Ave. He. of Dom. and Codom. Douglas Fir Trees:	162.8	153.3	145.0	137.1	127.1	94.4	69.7	67.9

18 inches below the soil surface of each plot. He found "the average temperatures of the soil for the period June 1 - September 30 were remarkably uniform for all plots, averaging 54°F. for the 6 inch depth, 53° for the 12 inch depth, and 50° for the 18 inch depth."(61)

Based on the work done by the various authors mentioned above, we may conclude that the soils of the area have podzolic characteristics. They are acid in character, low in exchangeable bases and are generally derived from glacial till with coarse textures having high contents of gravels, stones and cobbles.

3. Soils and Forest Growth

The plots used in the present study were selected by Griffith to represent a wide range of Douglas-fir sites. The stand data for the plots was taken from his report (61) (Table 2).

Site has been defined by Coile as "the combined factors that influence the growth and reproduction of a forest stand" (31); the site index was defined as "the height in feet that a particular stand may be expected to reach at the reference age, which is commonly 100 years."(50)

A great number of studies have been made of soil properties and conditions as they relate to plant growth but

relatively few studies have been made with specific reference to the growth of Douglas-fir.

Griffith studied the soil characteristics in relation to site index in the University Research Forest, Haney, B.C. He reported "the location of the plots in relation to topography and position on the slope appears to affect the amount of water present in their soils and thus plays a role in determining their site quality."(61) He also found that the site quality was influenced by factors which affect the water-holding capacity of soils, such as depth of soil, depth of B horizon, and bulk density. He correlated the average available soil moisture in the B horizons to site indices.

In Washington, Hill et al. studied the properties of soils in relation to Douglas-fir site quality (65). They examined the soil according to soil series and types which were mapped by the Soil Bureau in that area. The soil units and land capability classes which were described by the Soil Conservation Service were used for the study. They found that the soil units which were defined on the basis of profile, texture and depth were satisfactory for the evaluation of the site quality. However, besides the soil units, variations in the moisture regime of these soils as a result of variations in precipitation appeared to be an important factor.

Forristal et al. conducted their study in Lee Forest, Washington (49). The factors studied were effective rooting depth, bulk density, texture, and moisture equivalent. They reported that the depth to the hardpan layer was important for rating site quality and that soil effective depth was related to high bulk density. They found that low moisture was not a limiting factor on the tree growth, but poor drainage had the most influence on the forest quality.

Tarrant, studying Douglas-fir, did not find any correlation between site quality and the total nitrogen content, the available potassium, calcium, magnesium, phosphorus content or the base exchange capacity of soils (157). His conclusion was that the nutrient content of forest soils of Douglas-fir regions appears to be too high to constitute a limiting factor in tree growth.

Outside the Douglas-fir region, a number of studies have been carried out to determine if a correlation exists between site index of certain tree species and soils.

Gaiser reported that site qualities of loblolly pine in Virginia and Carolina were higher on land of poorer surface drainage than land which had a better one (52). The depth to impermeable layers and imbibitional water value of the least permeable horizon were effective on the growth. He presented regression equations for evaluating the site indices based

upon the depth of the least permeable horizon and the imbibitional water value of that horizon.

Auten studied yellow poplar sites (12). The factors studied were texture of surface soil, depth or organic matter penetration, thickness of A_1 horizon, depth to subsoil, colour of subsoil mottling. He prepared two tables to code the characteristics of each profile for evaluating site quality. He reported a direct and positive correlation in undisturbed soils between organic-enriched mineral horizons, thickness of A_1 horizons, depths to impermeable subsoil and site quality.

Einspahr and McComb conducted a study to determine the relationship between soil, topography and site quality of oaks in Iowa (45). They used the soil properties which were criteria for description of soil series, such as texture and thickness of A and B horizons, permeability of subsoil, and moisture condition due to topographical position of the soil profile. They gave a number of regression equations based on the factors mentioned above. They reported the site index of oak increased with increase in total soil depth and decreased as the per cent slop decreased. North and east aspects showed higher site indices than south and west aspects. Also, lower site indices appeared on the coarser soils.

Trimble and Weitzman studied the effect of environmental factors on oak sites in the Northern Appalachians (162).

They estimated the site quality by means of regression equations based on information of aspect of the site, position of the site on the slope, grade of the slope at the site, and total soil depth to bedrock. They reported that north and east aspects had higher site indices than south and west aspects. Site index increased from the ridge line to lower slopes; and site index decreased with increasing soil depth.

Copeland studied site quality of Western pine in the Northern Rocky Mountain Region (35). He found a positive correlation between site index and effective soil depth, depth to zone of reduced permeability and available water holding capacity.

White and Wood, studying a red pine plantation, found that growth was influenced by a deep-lying silty fine sand (172). A thicker layer provided additional water. Also they reported differences in soil depth occurred between the different site qualities.

Young studied the site of white pine in Maine (179). He found that site index decreased with increasing depth of A horizon. Also he reported that the site quality of spruce-fir stands in Penobscot decreased with increasing depth of A horizon and the imbibitional water value of that horizon. For both cases, Young evaluated the regression equation for estimation of site indices.

The results show that higher correlations were obtained between site index and physical soil properties. It should be remembered that the difficulties and bias of expressing the soil with single or with certain factors are to be considered. It is known that soil has many forms and that its characteristics in any one place result from the combined influence of climate and living matter acting upon the parent rock as conditioned by relief over periods of time including the effect of the cultural environment and man's use of the soil (148).

II. EXPERIMENTAL

1. General Description of the Area

(a) Location

The University Research Forest is situated north of Haney. It is 35 miles east by northwest from the centre of Vancouver. The area is trapezoid in shape, extending from north to south. Its average length is about 6 miles. The eastern boundary is 7 miles long from north to south. The western boundary is about 4 miles long. The average width of the area is 2½ miles. The area covers approximately 10,000 acres of forest land. It is the property of the University of British Columbia and is managed by its Faculty of Forestry.

The University Forest is situated in the south-western portion of British Columbia and lies between the Coast Mountains and the Fraser Valley. The land rises towards the mountains. The altitude ranges from about sea-level to 2600 feet. The area is bounded on the east and north by Garibaldi Park, on the northwest by Pitt Lake, on the west by Pitt Meadows and on the south by the Municipality of Haney.

The area contains three main valleys, running in a north-southerly direction. These are Blaney Creek, North

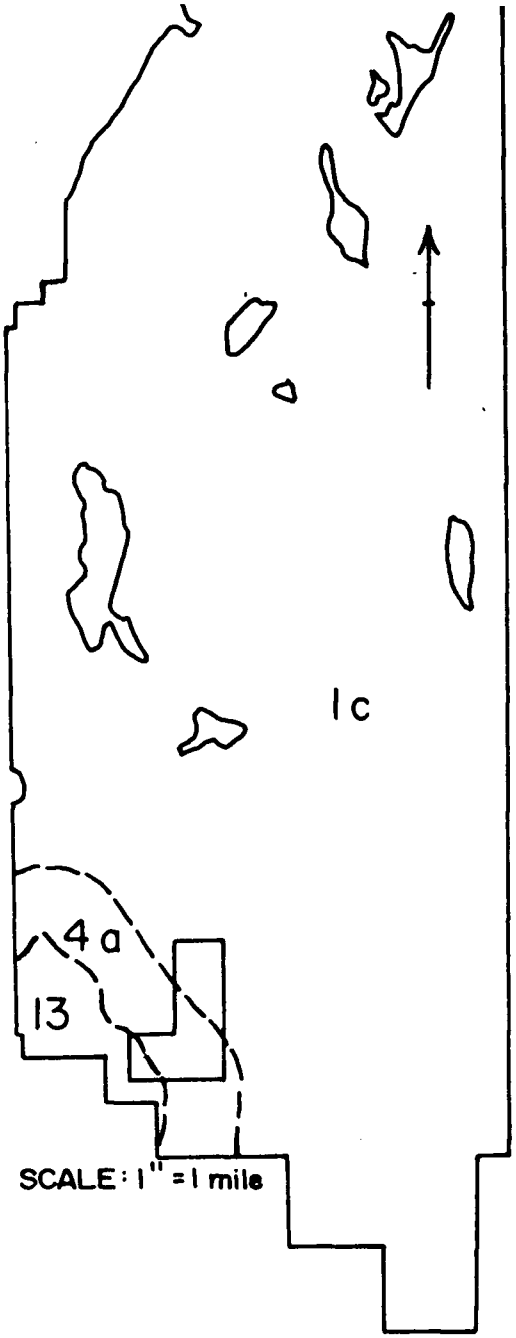


Fig. 2 University Research Forest showing the Surficial Geology according to Map 16-1957 of the Geological Survey of Canada, Dept. of Mines & Technical Surveys.

Legend:

Ic, rough mountainous country in which granitic and associated rock types occur at or near surface. Commonly overlain by till and outwash sand, gravel, and silt.

4 Surrey Till (glacial deposits): 4a, sandy to silty till and minor sub-stratified drift up to 75 feet thick but generally less than 25 feet.

13 Whatcom Glacio-Marine Deposits: stoney clayey silt and silty clay, clay, silt, and sand 25 to 300 feet thick.

Allouette River and Loon Lake Valleys. Several lakes occur in the area. The largest, Loon Lake, occupies the Loon Lake Valley. Blaney Creek and the North Allouette River drain most of the lakes in the area.

(b) Geology

The area is a part of the coastal mountain trench of British Columbia and studies of the local geology reported by Armstrong (10) indicate that most probably four glaciations occurred. One of them, the Sumas, was a minor advance, and the other three, Seymour, Semiamu and Vashon, were major advances. The most important glaciation as far as the soils of the area are concerned was the Sumas Valley glaciation. It was the latest glaciation on the area. It occurred about 11,000 years ago during the pleistocene epoch (10).

Glacial till is generally present over the tertiary rock formation. The till is thin at high altitudes and the steeper parts of the land. Depressions contain a relatively thicker till over the bedrock. A large till deposit, Surrey till[1], occurs at the southwest section of the area. Also a main deposition, Whatcom Glacio-marine deposit[2], is present at the edge of this section. (Figure 2).

---

[1]Surrey till: Sandy to silty and minor sub-stratified drift up to 75 feet thick but generally less than 25 feet deep. Throughout much of the area Surrey till deposits are mantled by Bose Gravel.

[2]Whatcom Glacio-marine Deposits: strong clayey silt and silty clay, clay, and silt and sand 25-300 feet thick.

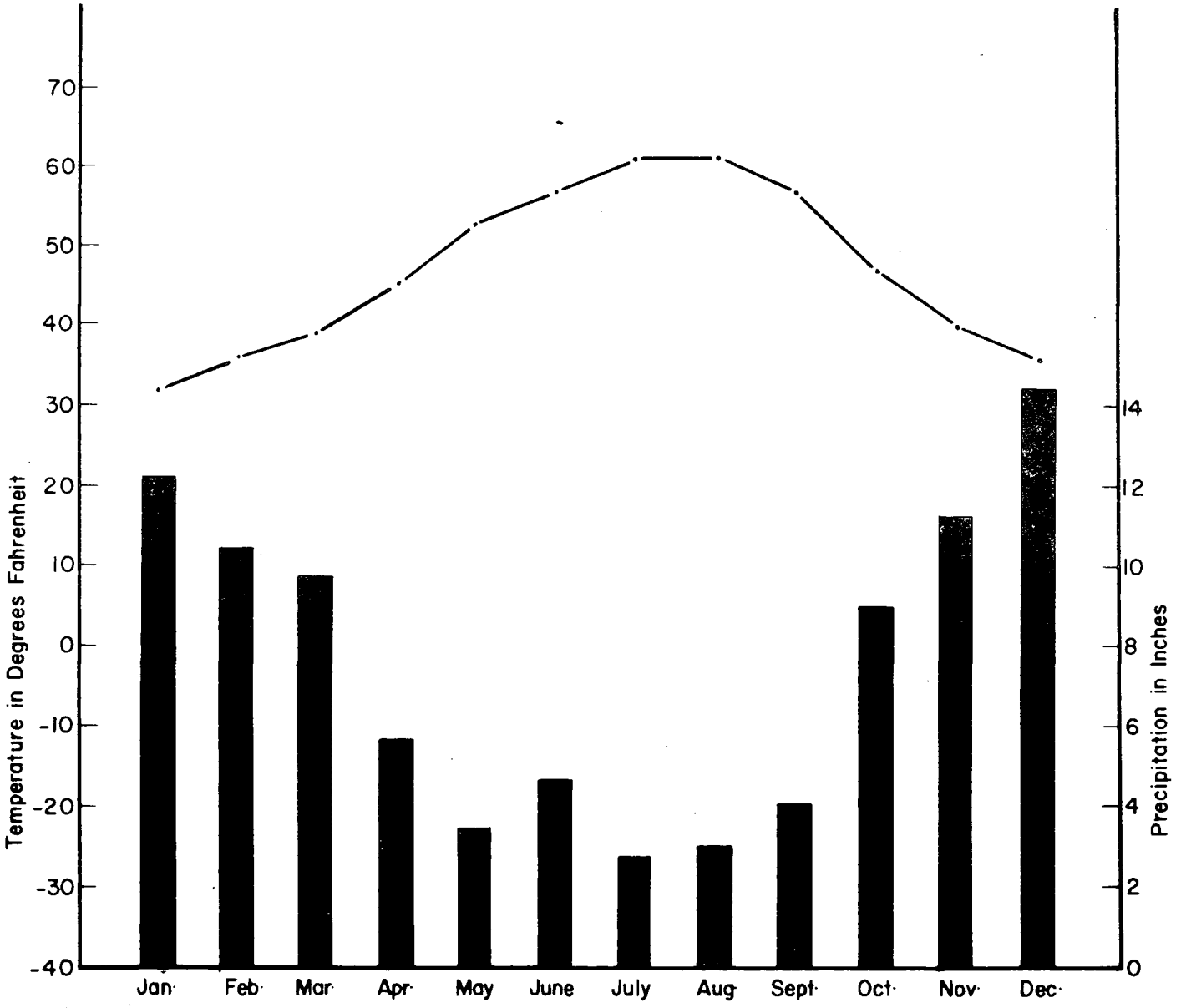


Fig. 3 Average monthly precipitation and temperature at Haney, 1946-1958

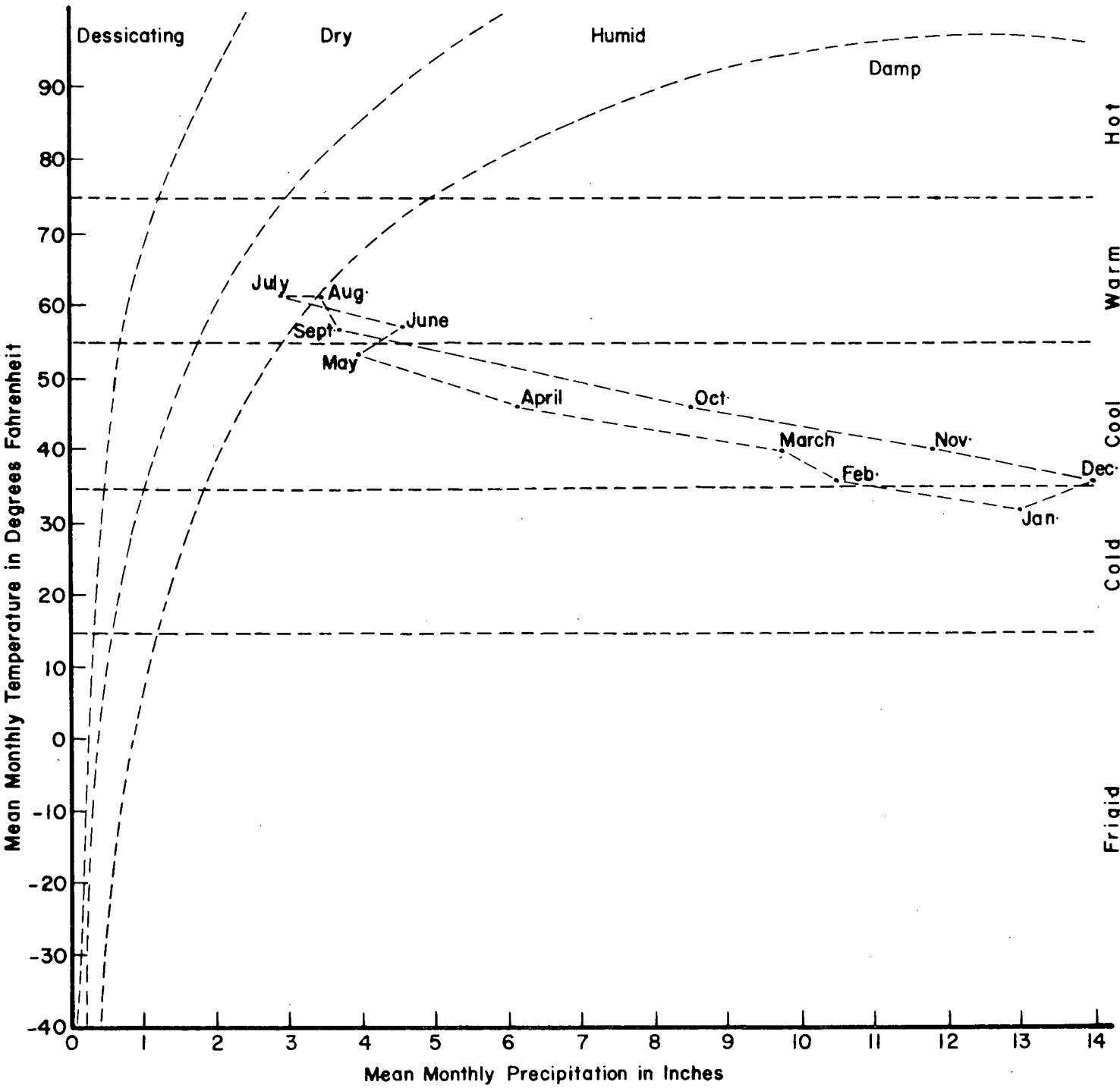


Fig. 4 Climograph (after Koeppe) showing the climatic pattern of Haney

TABLE 3. MEAN MONTHLY, MAXIMUM AND MINIMUM PRECIPITATION AND TEMPERATURE DATA FOR HANEY RECORDING STATION 1946 - 1957

Months	Temperature °F			Precipitation, inches			Snowfall, inches			Seasonal distribution of Precipitation %	
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean		
Jan.	41.0	18.0	32.0	21.42	1.00	10.22	60.00	-	19.6	Winter	40.76
Feb.	39.0	32.0	36.0	18.13	5.42	10.58	49.00	-	15.1		
Mar.	41.0	34.0	39.0	16.37	4.14	9.80	59.00	-	13.0		
Apr.	50.0	44.0	46.0	9.95	1.24	5.62	4.00	-	.4	Spring	20.72
May	57.0	51.0	53.0	5.66	.56	3.50	-	-	-		
June	59.0	55.0	57.0	9.55	1.21	4.72	-	-	-		
July	64.0	60.0	61.0	5.80	0.02	2.81	-	-	-	Summer	11.64
Aug.	63.0	59.0	61.0	7.28	.53	3.10	-	-	-		
Sep.	62.0	54.0	57.0	9.95	1.31	4.17	-	-	-		
Oct.	53.0	44.0	48.0	17.34	2.53	9.04	-	-	-	Autumn	26.88
Nov.	47.0	35.0	41.0	19.73	2.78	11.34	8.0	-	1.9		
Dec.	40.0	34.0	36.0	22.26	7.17	14.43	31.0	-	8.0		

Lakes of the area probably result from the last glaciation, the Sumas valley glacier, since they show features of valley glacier lakes. They are neither structural nor solution basins. The small ones, such as Placid Lake, are probably results of Kettle formation.

(c) Climate

The climate of the southwest portion of British Columbia in which the University Research Forest is located has been classified by Kendew and Kerr as belonging to the Littoral zone (80). This zone is characterized by the mildness and humidity of its winters, its heavy precipitation - gradually increased by the height of the mountains - and the decrease of precipitation after March until July or August (80).

The climatic station nearest to the plots for which data is available for a considerable period, is Haney. This station is located (within the entrance to) the Research Forest. Climatic data for the station are given in Table 3, and mean monthly distribution of precipitation and temperature is shown graphically in Figure 3. The table and graph indicate that most of the precipitation occurs in the winter months. Summers are dry and warm having 11.64 per cent of the total precipitation (10.63 inches) and an average temperature of 58°F. When the data of the station are classified according to the Koeppe system (85) the area appears as a humid

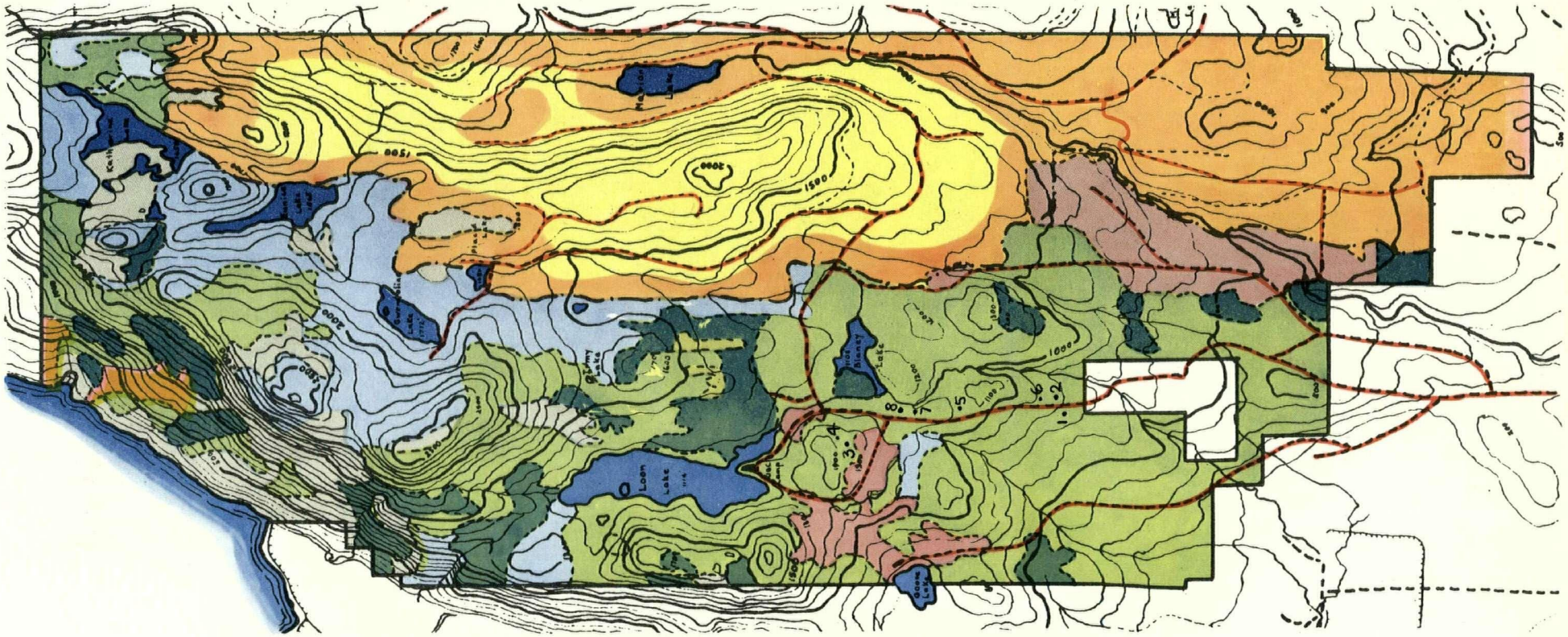


Fig. 5 Location of plots in U. B. C. Research Forest, Haney.

mesothermal climate (Cfb).[3]

The mean monthly temperature and precipitation for the station are plotted as a climograph, according to the method given by Koeppe (85), in Figure 4. The climate of the area shows different characteristics in different periods of the year. The longest period is the cool-damp type with 32 weeks, and secondly, the warm-damp with 12 weeks. The shortest periods are the warm-humid and cold-damp types both with 6 weeks each. The cool-damp type is predominant and repeated twice with 16 and 12 week periods in the year. In fact, these periods are during the time of year when the vegetation physiologically is (less active or) relatively inactive. The total of the warm-humid and warm-damp types are 12weeks and are also the most important periods for the growth of the vegetation as well as for the soil forming process.

(d) Forest Type

The University Research Forest is situated in the Southern Coast section of the coastal zone as defined by Rowe (132). The western portion of the Forest which includes the study area was destroyed by a large fire in 1868 (61). This

---

[3] C: Mesothermal (middle or intermediate heat) one or more months with a mean temperature below 64°F, but no month with a mean temperature below 27°F, at least one month above 50°f. f:Moist: Driest month has a mean precipitation of at least 2.4 inches. b:Warm summer: Mean temperature of the warmest month below 72°F; at least four months with a mean temperature of 50°F or more.

area has since regenerated to a mixed Douglas fir (Pseudotsuga menziesii (Mirb.) Franco), western hemlock (Tsuga leterophylla (Raff.) Sarg.), western red cedar (Thuja plicata Donn.) forest type. The average age of the Douglas fir is approximately 80 years; the western hemlock and western red cedar are somewhat younger. (61)

(e) Location of the Plots

The study area lies between Loon Lake and the southern boundary of the Forest on either side of the main road. The area and location of the plots are shown in Figure 5.

2. Field Methods

(a) Mapping

Six of the eight plots were surveyed with chain and level and contour lines plotted at 6 inch intervals. This resulted in a detailed map of the major and minor physiographic features of the plots.

(b) Microclimate

Four standard type weather stations were placed 4 feet above the ground on plots 1, 2, 4, and 8. Maximum and minimum atmospheric temperatures were recorded each morning from May 15th to August 14th, 1957. Five rain gauges were established along the main road at elevations of 650, 750, 850, 950 and 1,050 to determine the effect of precipitation

with changes in elevation. The gauges were read following each rain storm during July and August, 1957.

(c) Vegetation

The plant identifications were done for each plot according to handbook for this purpose (101).

(d) Soils Studies and Sampling[4]

Soil profile studies were made on the eight plots between May 15th and September 2nd, 1957. The procedure followed in obtaining the soil profile is given below:

Three pits were dug on each of the eight plots (on plot 4, however, four pits were dug). The dimensions of the pits were 8 feet by 4 feet, extending in depth to the parent material. A total of 25 pits were established.

The following information was recorded for each plot:

1. Topography
2. Vegetation
3. General moisture conditions
4. Degree of stoniness
5. Nature of the soil (parent material)

---

[4] The descriptions of the profiles were made in accordance with the Soil Survey Manual (148). Dr. Rowles, Chairman of the Soil Science Department of the University of British Columbia, and Messrs. A.V. Ryswyk and W. Holland, assistant soil surveyors from the B.C. Provincial Soil Survey Department, participated in this phase of the work.

A description of each profile was recorded including:

1. Color
2. Texture
3. Structure
4. Consistence
5. Special features of the profile, such as hardpan, orstein, shot material, root mats
6. The amount and position of organic matter
7. Drainage

Core and bulk soil samples were collected for the laboratory determinations. The core samples were obtained using 3 inch by 3 inch soil cores and a Baver type soil sampler. Plots 1, 3, and 5 were selected on a basis of field observation for core sampling. Five individual cores were taken from four horizons in each profile sampled, making a total of 60 cores from each plot. The horizons sampled were A, B_2, B_3, and C. The soil cores were removed from the sampling tool and placed in waxed-paper cartons for transfer to the Soil Science Laboratory of the University of British Columbia.

Bulk soil samples varying in weight from one to five pounds were collected from each horizon, making a total of 179 individual samples from the eight plots.

Stone content was determined on plots 1, 3 and 5. Stones larger than 1 inch diameter were sieved from the soil and the content of stones calculated on a per cent by volume

basis.

3. Laboratory Methods

Physical soil properties were determined using the samples from plots 1, 3, and 5, and chemical properties using those from plots 1, 2, 3, and 5. Soil reaction was determined on samples from all eight plots.

The core samples were used to determine bulk density, total pore space, macro and micro pore spaces. For the estimation of pore spaces a tension table and a tension of 40 cms. of water was used. Calculations were made by use of the following formulae:

$$\text{Bulk density} = \frac{\text{Oven dry soil weight (gm)}}{\text{Volume of the core(cc)}}$$

$$\text{Total pore space \%} = \left(\frac{\text{Weight of saturated core - oven dry soil}}{\text{volume of the core (cc)}}\right) \times 100$$

$$\text{Macro pore space \%} = \left(\frac{\text{Weight of water withdrawn between 0 and 40 cm tension (gm)}}{\text{Volume of the core (cc)}}\right) \times 100$$

$$\text{Micro pore space \%} = \left(\frac{\text{Weight of water remaining at tension of 40 cms (gm)}}{\text{Volume of the core (cc)}}\right) \times 100$$

Hydraulic conductivity was measured using soil cores and a constant water head equivalent to 1/2 inch. The hydraulic conductivity was calculated using the Darcy Flow Law (14).

Mechanical composition of soils was determined by the pipette method as modified by Tyner (164). The standard Chatelier Flask method was used for the determination of specific gravity of soils.

Field moisture capacity was estimated using the pressure pot and 0.1 atmospheric pressure (128). The moisture content of the soil was determined after equilibrium was reached in 6 days. Calculations were made on an oven-dry soil basis.

A pressure membrane was used for estimating the permanent wilting point using 15 atmospheres per square inch pressure and allowing 10 days for equilibrium. Moisture content of the soils was determined and expressed on an oven-dry basis (127).

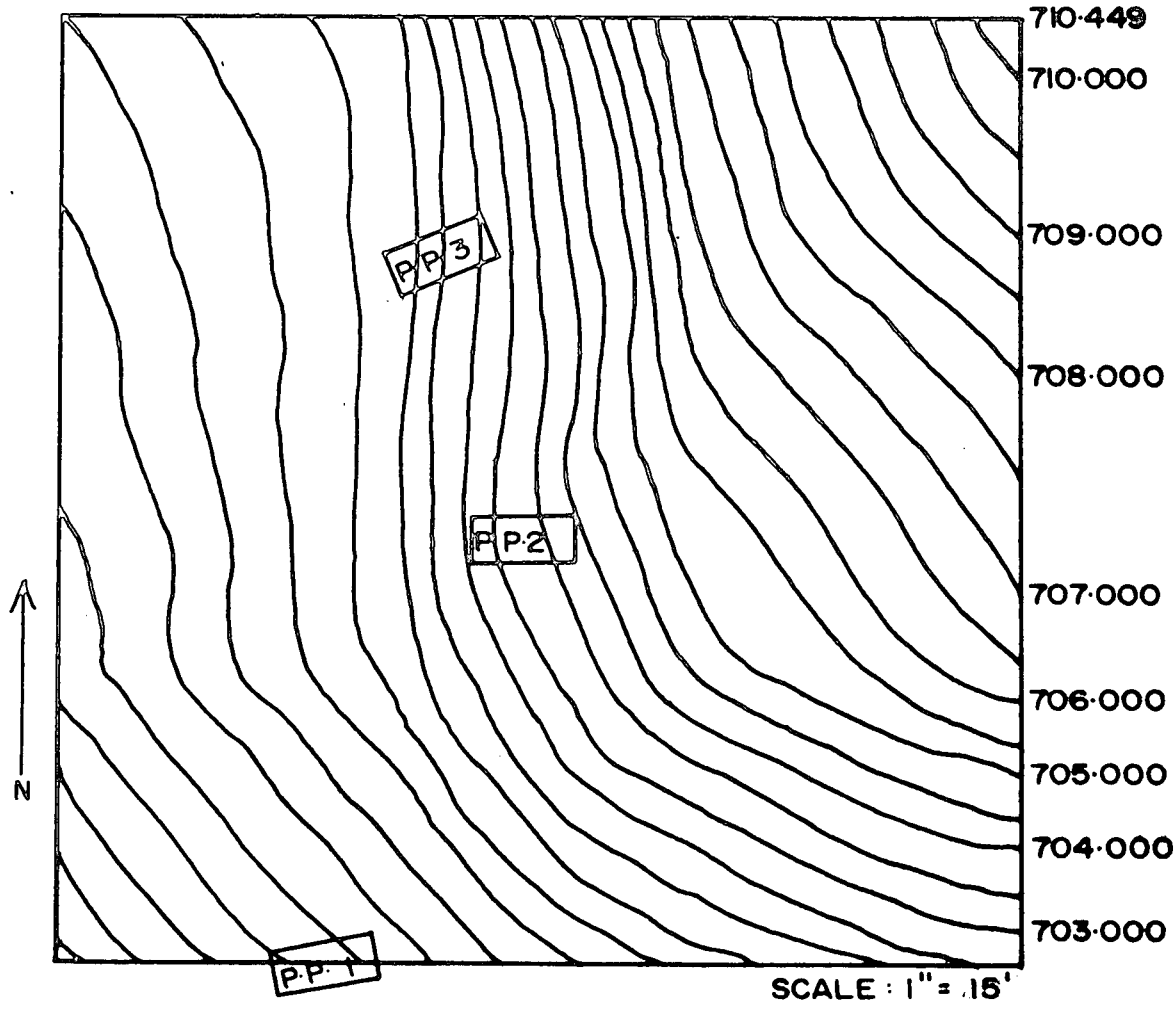
The pH of the soil was measured by a glass electrode using a 1:1 soil-water ratio (74). After stirring the soil with an equal volume of water, the samples were allowed to rest for 30 minutes before the measurements were taken. The samples were restirred before each reading. A Berckman type instrument was used.

The organic matter determination was made by the Walkley-Black method (74).

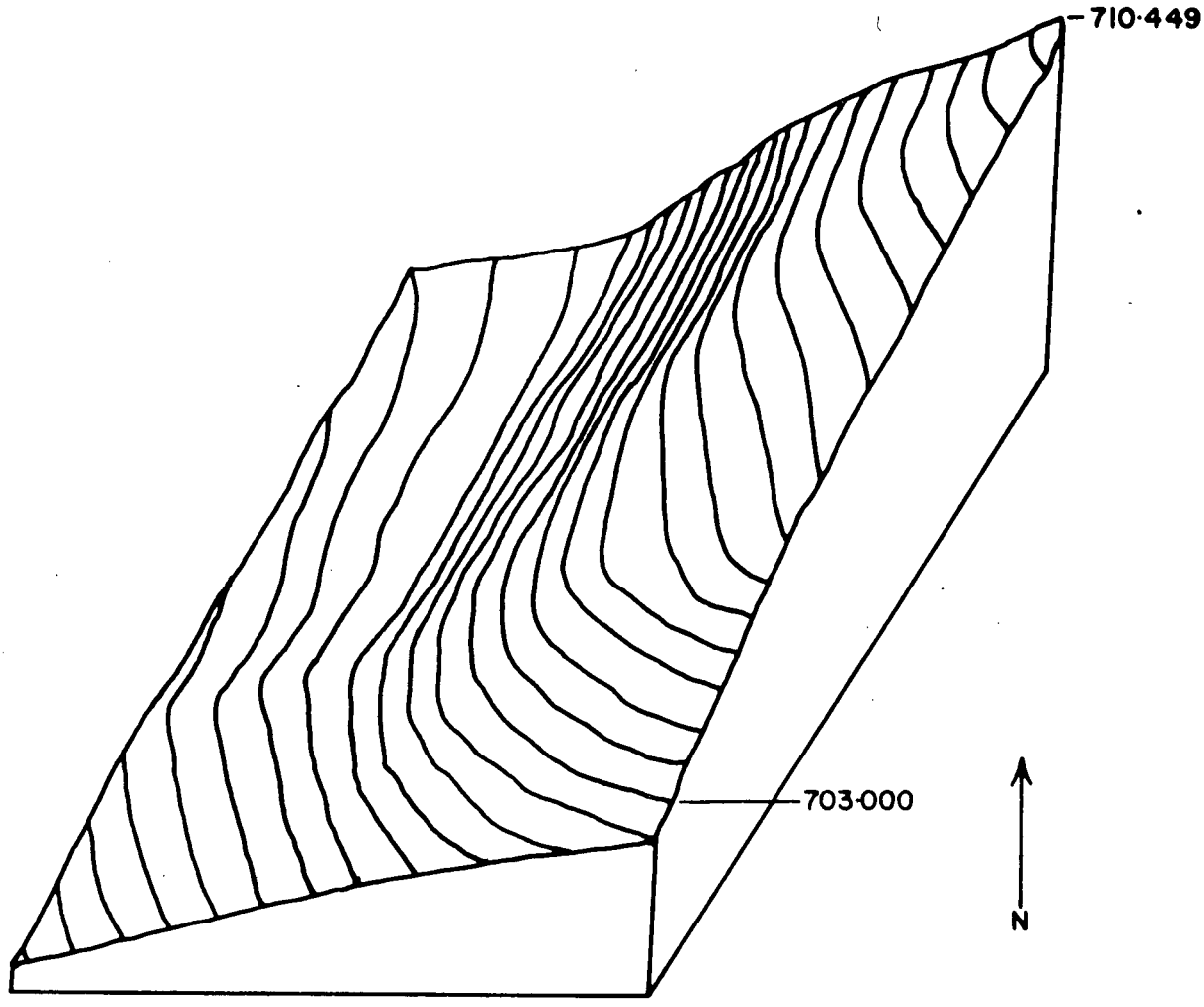
The amonium acetate method given by Peach et al was used for the determination of exchangeable cations (120). Exchangeable potassium and calcium were determined with a Perkin-Elmer flame photometer, using Lithium as the internal standard (120).

4. Statistical Analyses

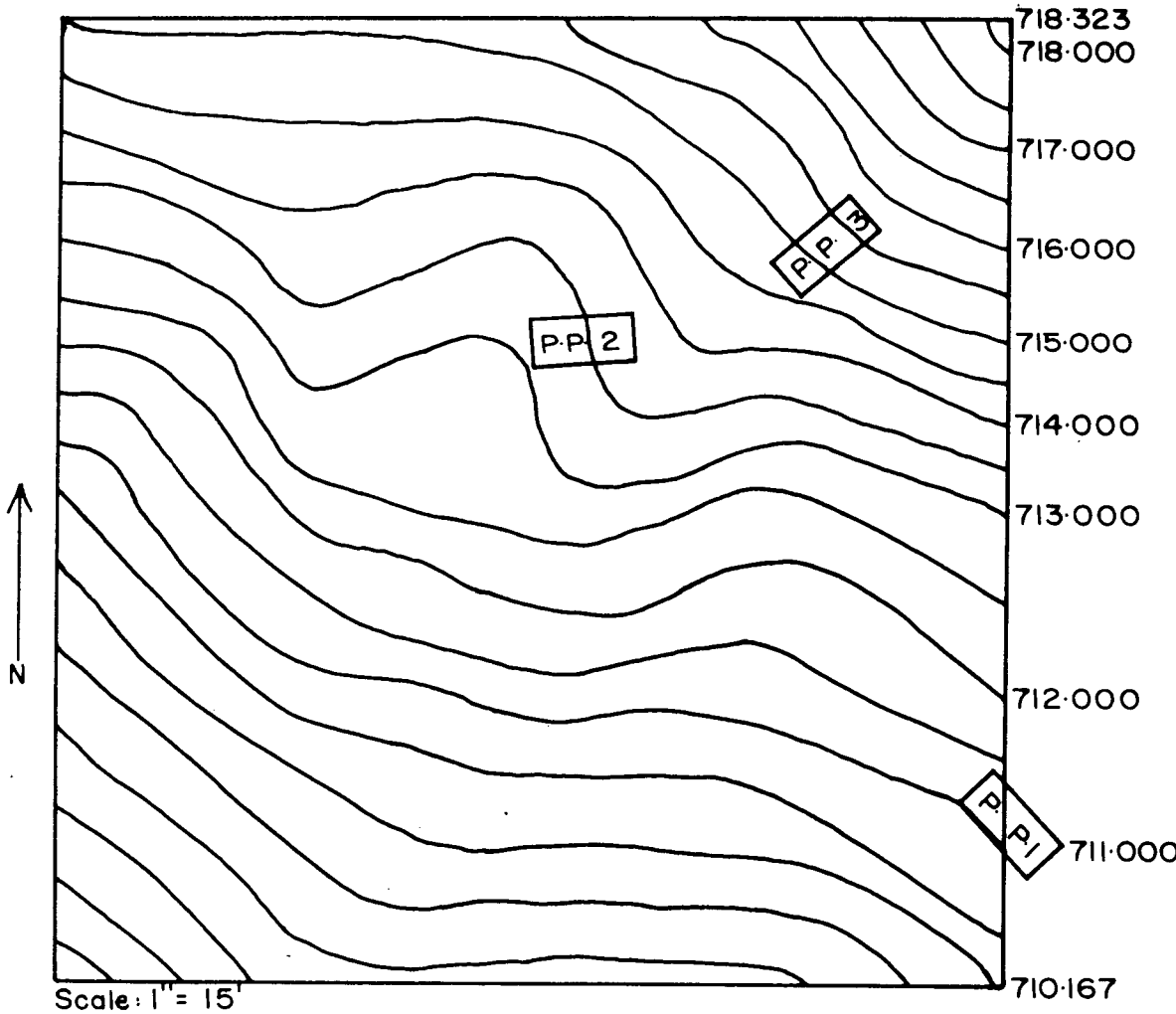
Variance analysis for bulk density, total pore space, macro pore space, and permeability were done for pits, horizons, and plots. Regression equations were evaluated from such factors as depth of horizons, depth of solum, total effective depth versus site indices. Calculations were done by use of an Allwac III, electric computer.



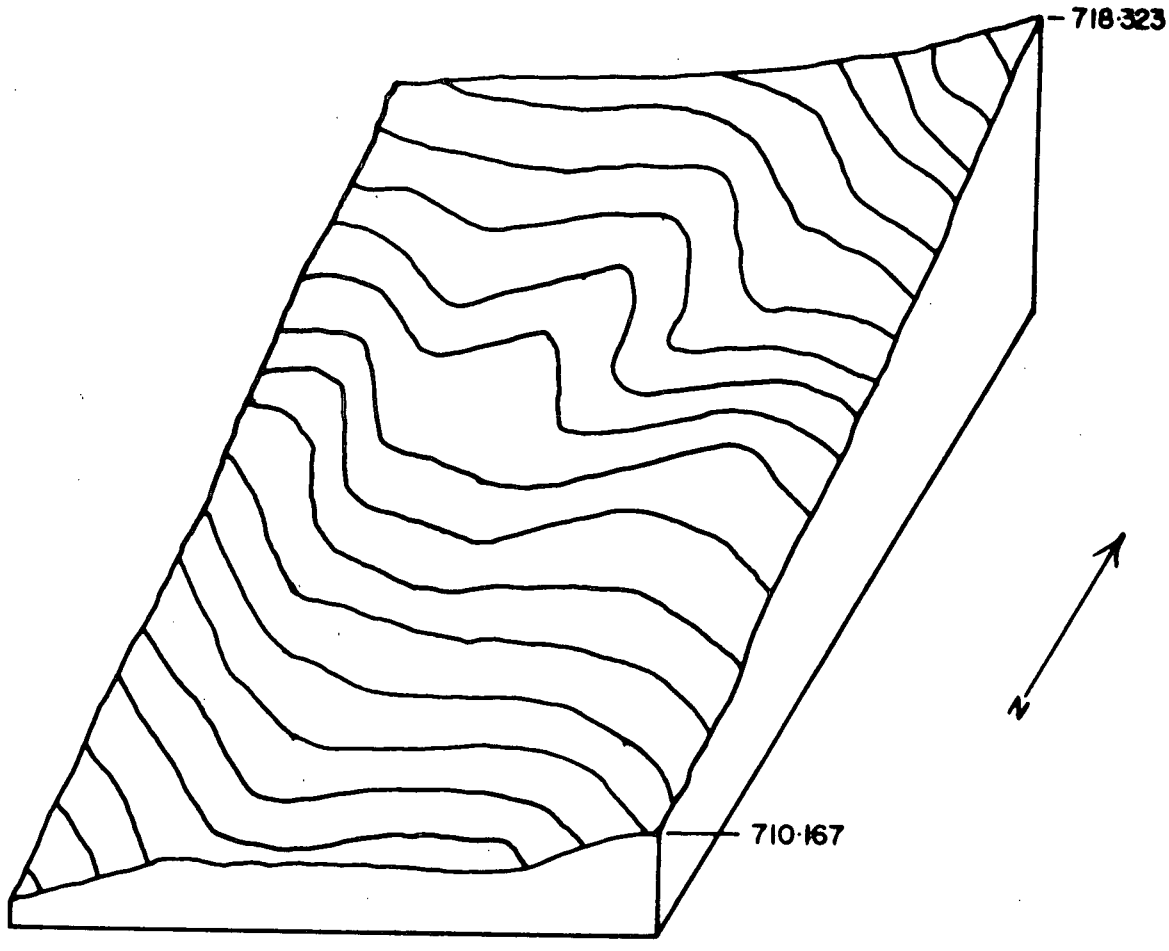
Fig· 6 Topographic map of plot 1·



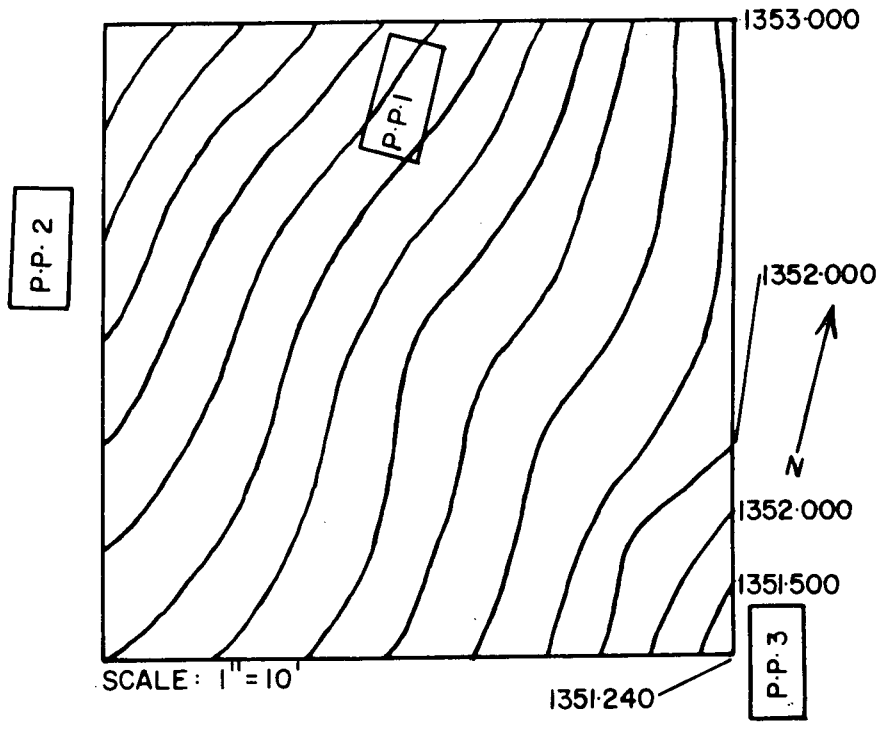
Fig· 7 Topographic projection of plot 1·



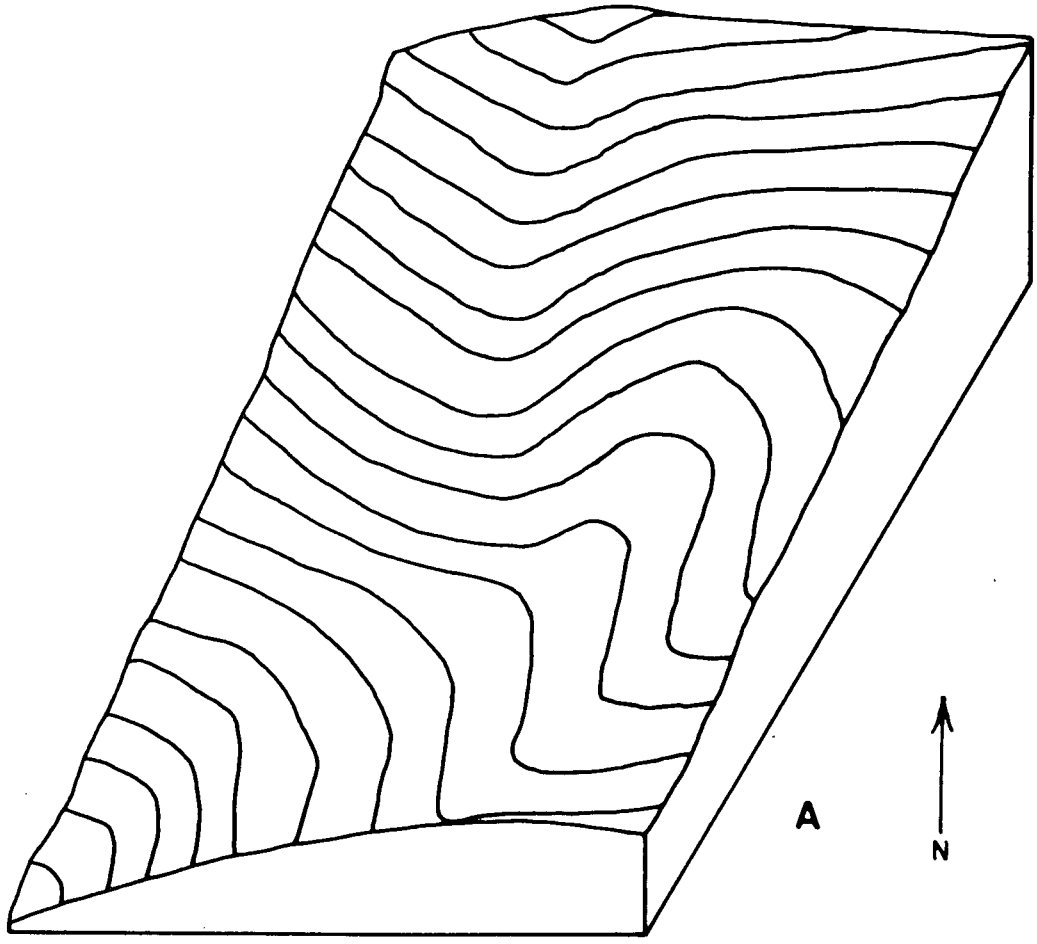
Fig· 8 Topographic map of plot 2·



Fig· 9 Topographic projection of plot 2·



Fig· 10 Topographic map of plot 4·



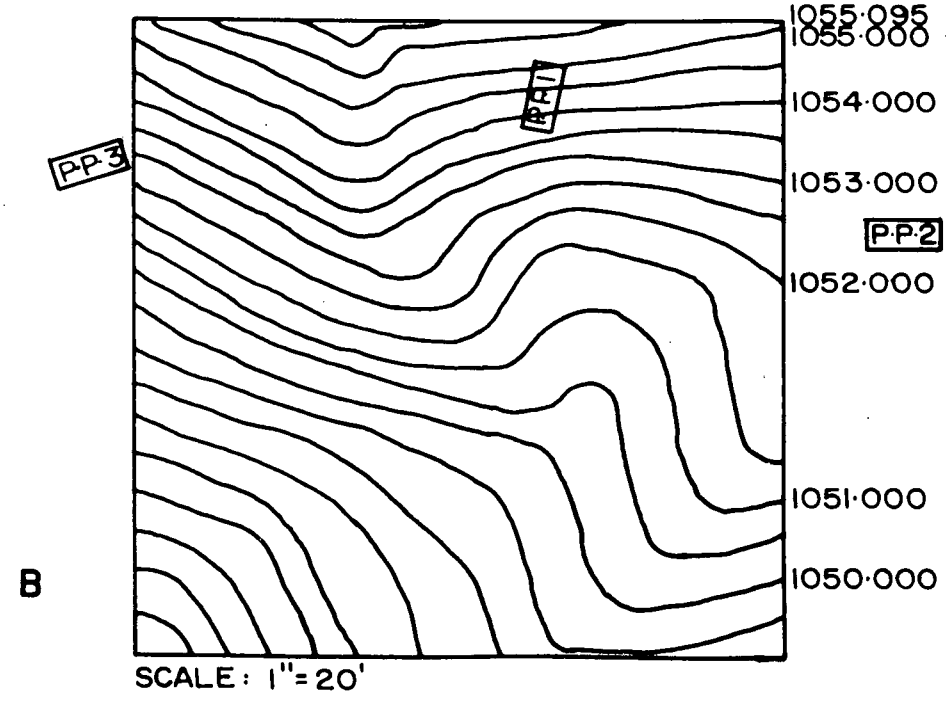
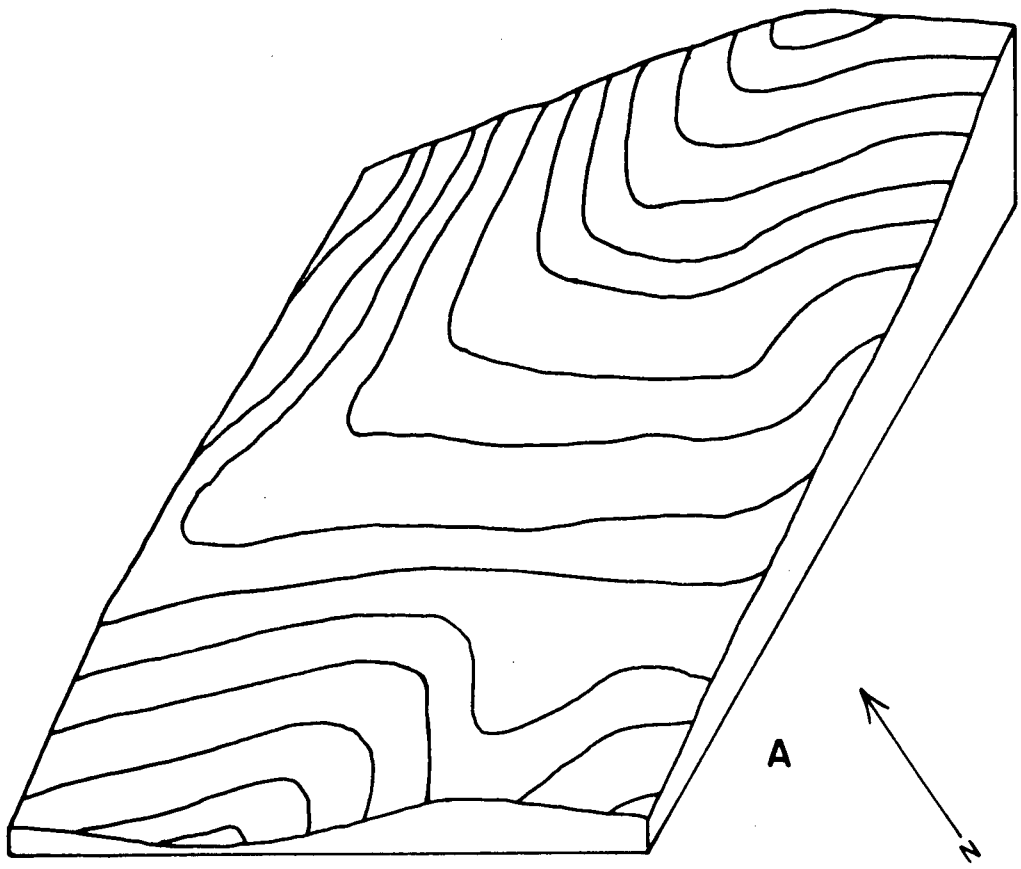
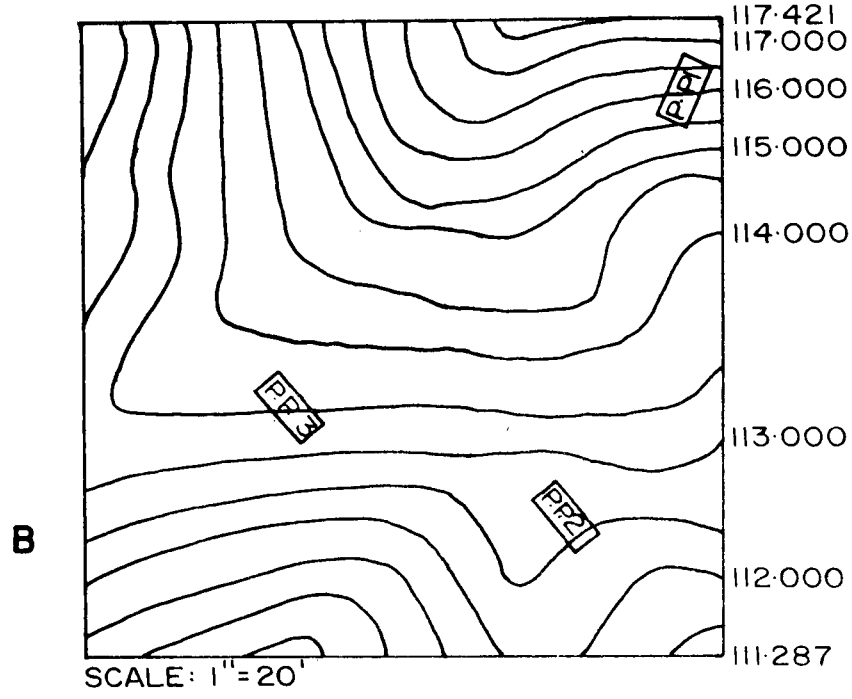


Fig. 11 Topographic projection (A) and map (B) of plot 5.





Fig· 12 Topographic projection (A) and map (B) of plot 7·

III. RESULTS

1. Physiography[1]

Plot 1 is situated in the south west part of the general area in the Blaney Creek Valley. It is about one-half mile east of Blaney Creek. This plot has the lowest altitude of all the plots, being about 650 feet above sea level.[2] Its aspect is to the southwest with a 12 per cent slope. The western half of the plot is quite flat. It slopes 3 to 4 per cent to the west and 5 to 6 per cent to the north. The northern part of the eastern half rises quickly and reaches 650 feet at the northern corner. The slopes of the area decrease towards the valley bottom. (Figures 6 and 7).

Plot 2 is approximately 900 feet east of plot 1. This plot has a higher elevation than plot 1. It is 100 feet from Blaney Creek and 100 feet above the creek. It drops abruptly, with about an 80 per cent slope to the creek. The elevation is 715 feet. General aspect is southwest with 8 to 9 per cent slope. (Figures 8 and 9).

---

[1]Full descriptions of the plots are given in appendix.

[2]All altitudes measured from sea level. The measurements were taken at the northwest corner of each plot by a barometer.

Plots 3 and 4 are at the other end of the area chosen for this study. They are one mile north of plots 1 and 2. These two plots are situated at the top of a hill, one-half mile from the south end of Loon Lake. The elevation is 1343 feet. The aspect is southwest with a 30 to 40 per cent slope.

Plot 4 is 50 feet up the slope from plot 3; it has a southeast aspect. Its slope is about 10 to 15 per cent and its elevation is 1353 feet. (Figure 10).

Plot 5 is situated near the centre of the study area. It is 600 feet west of Blaney Creek and has an elevation of 1055 feet. Its aspect is southwest with 10 to 15 per cent slope. (Figure 11).

Plot 6 is situated several hundred feet northwest of plot 2. Its topography is a depression of 2 to 3 feet deep to the east. It slopes down gently to west and south. This plot has a small gully on its east side. Its elevation is 700 feet and it has a slope of 14 per cent to the southwest.

Plots 7 and 8 are situated west of Blaney Creek and south of Blaney Lake. They are a few feet above the creek. A steep 100 foot bluff extends between the plots and the creek. Plot 7 has an elevation of 1120 feet and its aspect is southeast with a 10 per cent slope. The elevation of plot

8 is 1095 feet and has a slope of 5 to 10 per cent to the southwest. (Figure 12).

2. Vegetation

The general descriptions of the vegetation of the plots are given below:

In plot 1 the tree layer contains Pseudotsuga menziesii, Thuga heterophylla and Thuja plicata. The shrubs, Gaultheria shallon Pursh, Vaccinium parvifolia SM, Acer circinatum Pursh are present. Shrubs and ground floor vegetation are very dense and high. Two to three feet high ferns are quite abundant. In the lower part of the plot lesser vegetation becomes more dense. In ground vegetation Polystichum mnitum Presl., Blechnum spicant, Roth., Trillium ovatum Pursh., Tiarella trifoliata L. are present. Mosses and lichens are mostly on decaying wood. Hylocomium splendens Bsg., Eurhychium oreganum Jaeg and Sauerb., Dicranum fuscescens Turn., Rhytidiadelphus loreus Warnst.

In plot 2 the main species in the tree layer are Pseudotsuga menziesii, Tsuga heterophylla and Thuja plicata. Alnus rubra Bong., Rubus parviflorus Nutt., Vaccinium parvifolium, Menziesia ferruginea Sm., Acer circinatum, Gaulteria shallon are the species present in the shrub layer. Shrub layer is moderately dense. Ground vegetation is poor. Not many plants are present in this layer. The plants are:

Pleridium aquilinum Kuhn, Polystichum munitum, Blechnum spicant, Trillium ovatum. Mosses and lichens on the decaying wood, rocks and barks can be found. They are Hylocomium splendens, Rhytidiadelphus loreus, Dicranium sp., Plagiothecium undulatum-, Mnium punctatum Hedw.

In plot 3 the three layer contains Pseudotsuga menziesii, Tsuga heterophylla and Thuja plicata. Very few shrubs are present and include Vaccinium parvifolium, Gaultheria shallon. Ground floor vegetation also is very sparse; this layer contains Monotropa uniflora L., Pyrola sp., Pteridium aquilinum. Mosses and lichens mainly are Dicranum fuscescens, Hypnum sp., Eurinchnium oreganum. This layer is quite dense.

In plot 4 Pseudotsuga menziesii, Thuja plicata, and Tsuga heterophylla are the species comprising the tree layer. The shrub layer is not dense. Gaultheria shallon and Vaccinium parvifolium are present. Very few species of ground floor vegetation exist, Pteridium aquilinum being the main species. Mosses and lichens are generally present, Dicranium fuscescens, Mnium punctatum, Eurhynchium oreganum, Plagisthesia undulatum being the principal species.

In plot 5 the tree layer consists of Pseudotsuga menziesii, Thuja plicata and Tsuga heterophylla. Not very many shrubs are present. Shrubs are Gaultheria shallon,

Vaccinium ovalifolium, Acer circinatum. Ground vegetation is moderately dense. Polystichum minutum and Trillium ovatum are present. Mosses and lichens are mostly found on the small wind falls. Mnium punctatum and Hylocomium splendens are common.

In plot 6 Pseudotsuga menziesii, Thuja plicata and Tsuga heterophylla are the main species in the tree layer. Some suppressed Alnus rubra is present. As shrubs, mainly Vaccinium parvifolium, Gaultheria shallon, Acer circinatum, Rubus heterophylla and Rubus spectabilis Pursh., are present. The shrubs are at the eastern and southern corners of the plot. Ground vegetation contains Polystichum munitum, Sambucus pubens, Blechnum spicant, Dryopteris phegopteris Christens, Tiarella trifoliata. Mosses and lichens are mainly found on decaying wood, some barks and on humus layer. Hylocomium splendes, Blechnum spicant, Mnium puntatum, Dicranium scoparium Hedw. and Rhytididelphus oreus are present.

In plots 7 and 8 Pseudotsuga menziesii, Thuja plicata and Tsuga heterophylla are the main species in the tree layer. Shrub and ground vegetation layers are moderately dense. Gaultheria shallon, Acer circinatum and Vaccinium sp. are common in the shrub layer. Ground vegetation contains Polystichum munitum, Dryopteris phegopteris, Trillium ovatum. Mosses and lichens are mainly present on the ground floor. Eurhychium oreganum, Mnium punctatum are common.

TABLE 4. MEAN WEEKLY, AIR, MAXIMUM MINIMUM TEMPERATURE AND TEMPERATURE RANGE, RELATIVE HUMIDITY AND DEW POINTS FOR PLOTS 1,2,4 AND 8

Month	Week	PLOT 1						PLOT 2					
		Temperature						Temperature					
		air	min.	max.	ran.	R.H.	D.P.	air	min.	max.	ran.	R.H.	D.P.
May	4th	59.9	53.8	66.0	12.2	85.0	54.7	57.6	51.4	63.8	12.4	86.4	53.3
	1st	64.3	59.0	69.6	10.6	86.3	55.6	62.3	55.7	69.0	13.3	87.0	56.6
June	2nd	59.9	55.2	64.7	9.5	89.0	52.7	57.0	51.5	62.5	11.0	88.5	54.0
	3rd	37.7	50.2	65.2	15.0	90.5	52.7	57.0	51.0	63.0	12.0	90.8	56.2
	4th	55.8	50.6	61.0	10.4	97.0	51.3	52.4	49.6	55.3	5.7	92.0	51.3
	1st	55.6	48.7	62.5	13.8	96.0	52.7	54.9	49.2	60.7	11.5	93.7	50.2
July	2nd	56.5	53.4	60.2	6.8	98.8	54.6	67.8	53.6	62.0	8.4	96.4	55.0
	3rd	58.1	52.0	64.3	12.3	94.7	51.0	59.3	51.0	67.7	16.7	95.0	51.6
	4th	58.1	53.0	61.3	8.3	98.0	55.6	58.9	52.6	65.3	12.7	98.0	55.3
	1st	59.5	53.0	66.0	13.0	96.0	56.3	59.8	55.0	64.7	9.7	98.0	57.0
August	2nd	58.9	52.3	64.6	12.3	98.0	54.6	59.5	53.2	65.7	12.5	95.7	55.0
	3rd	57.3	51.3	63.3	12.0	93.0	53.0	51.5	51.0	64.0	13.0	92.7	52.3

Month	Week	PLOT 4						PLOT 8					
May	4th	59.1	56.1	62.2	6.1	88.0	55.0	56.9	50.1	63.7	13.6	83.2	55.0
	1st	62.1	57.8	66.0	8.7	86.3	56.4	61.0	56.5	67.6	11.1	86.8	54.8
June	2nd	57.6	51.0	64.2	13.2	92.7	55.0	51.8	51.2	64.5	13.3	91.0	52.0
	3rd	54.5	48.5	60.5	12.0	90.5	49.5	54.4	46.0	62.8	16.8	50.0	52.6
	4th	51.9	49.6	54.3	4.7	98.0	51.3	54.5	51.0	58.0	7.0	96.3	49.6
	1st	54.6	49.0	60.0	11.2	93.5	48.7	54.3	47.2	61.7	14.2	95.2	49.5
July	2nd	55.2	57.8	58.7	6.9	98.5	56.5	55.6	49.8	61.4	11.6	95.5	54.4
	3rd	59.5	51.0	68.0	17.0	94.6	52.3	57.6	69.0	68.3	19.3	92.7	51.0
	4th	57.0	55.0	59.0	4.0	97.0	54.5	55.1	51.6	60.7	9.1	95.6	54.7
	1st	58.9	55.7	62.0	6.3	93.0	55.3	56.5	53.7	63.3	9.6	94.0	55.6
August	2nd	60.8	53.0	68.0	15.0	97.0	54.5	58.3	52.0	64.6	12.6	96.0	55.0
	3rd	61.7	55.5	68.0	12.5	97.0	53.5	56.5	53.0	60.0	7.0	93.5	54.0

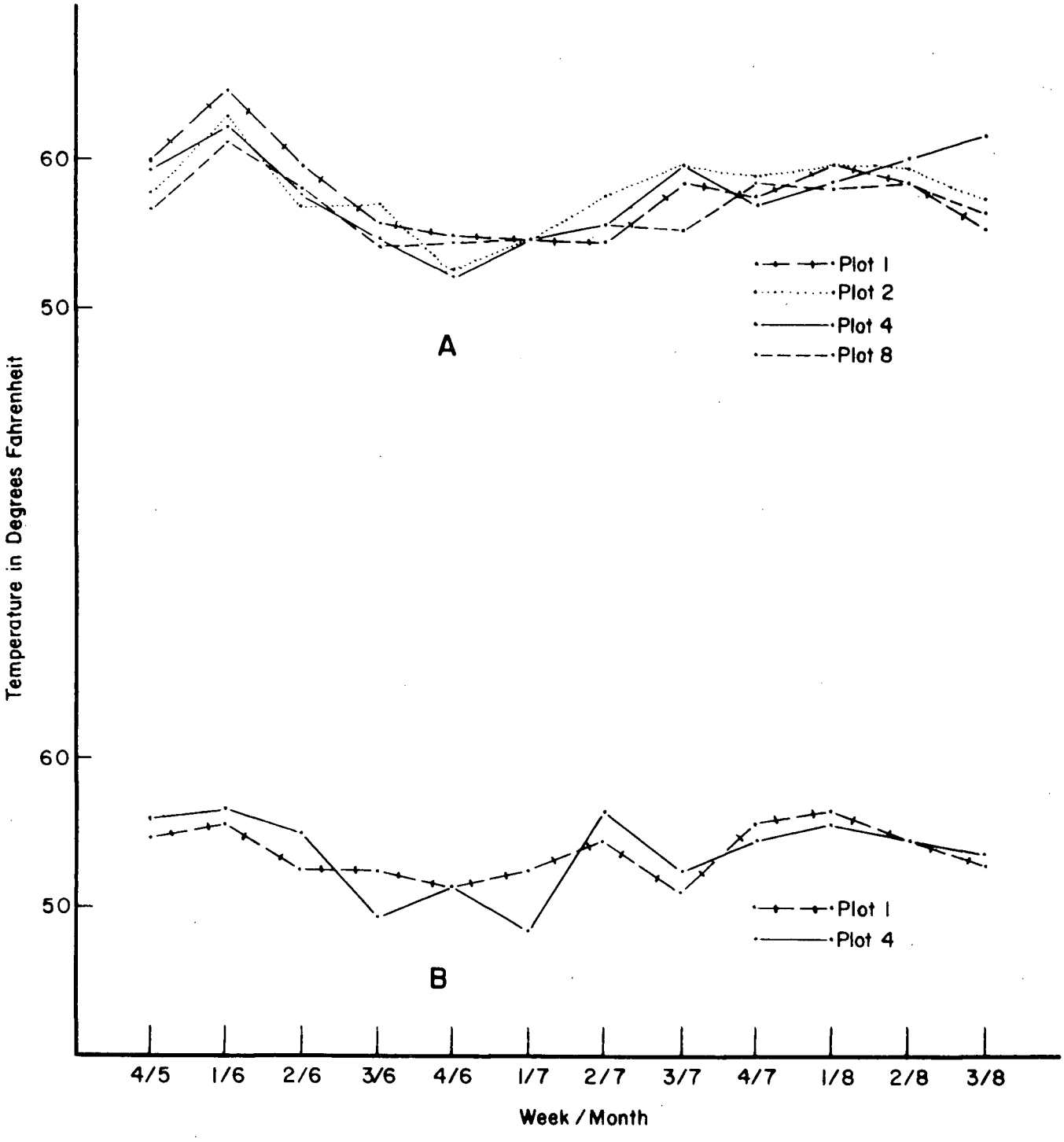


Fig. 13 A - Average weekly atmospheric temperatures for the period May 21 to August 15, 1957 for plots 1, 2, 4, and 8.
B - Average dew points for the same period for plots 1 and 4.

3. Microclimate

The microclimate or stand climate (58) of the plots for the summer months of 1958 are summarized in Table 4 and some of the data is shown graphically in Figures 13, 14, and 15. In interpreting this data it should be remembered that it is only one year and several years observations would be required to predict the optimum correlations between the microclimatic factors. However one year observation may be used to establish trends.

The mean weekly temperature statistics are given in Table 4 and are plotted in Figure 13A. The temperature changes on the four plots tend to parallel one another but fluctuations in plots 2 and 4 are larger and more abrupt than they are in 1 and 8. Temperature of plots 2 and 4 follow a most irregular path. Plot 8 has a comparatively more stable temperature than plot 4 and similarly, temperature of plot 1 is more stable than that of plot 2.

The comparison of the weekly temperature range in maximum and minimum for the plots are given in Table 4 and in Figure 14B. Plot 5 shows the smallest temperature ranges, except for the third week of July, but larger and abrupt changes. Plot 1 follows an intermediate path among the plots.

Plot 1 shows very small changes between the weekly temperature ranges compared to plot 4. Plot 4 is situated on the top of a hill. It is very much influenced by the macroclimatic changes. Its forest and ground vegetation cover are not as dense as those of plot 1. It is very much affected by the direct insolation of the sun. When the sun is innefective the temperature will drop down very quickly, because of topographic features of the plot, i.e. altitude, density of vegetation, aspect, etc.

The relative humidity[3] of the individual plots are given in Table 4. The data are plotted in Figure 14A. Plot 4 tends to show highest values, probably due to its elevation.

Data of dew-points[4] of the plots are shown in Figures 15A and 15B. Plots 2 and 4 show the big variations among the plots. The plots become parallel towards the end of the season.

Consequently, we conclude that plot 4 has a more unstable and colder microclimate than the others. Plots 2 and 8 show similarities in some cases because of similarity in their topographic situation. Plot 1 has the more stable microclimate and its climate is less affected by macroclimatic factors. Plots 2 and 8 are affected by macroclimatic factors

---

[3]Calculated at 30.0 inches air pressure.

[4]Calculated at 30.0 inches air pressure.

with less magnitude compared to plot 4. But they do not have as good a characteristic microclimate as plot 1 does.

The following four conclusions can be drawn from a study of the data and graphs of microclimate:

(1) All the microclimates of the plots show the main features of macroclimate in a certain extent at the certain time intervals.

(2) The plots may reflect the effects of any macroclimatic factor in different magnitudes as the result of their characteristic features, i.e. topographic, geographic and egologic.

(3) Often in some periods the microclimate of the plots does not show any similarity whatsoever to the macroclimate. These periods occur when the macroclimate is uneffective and microclimate becomes dominant.

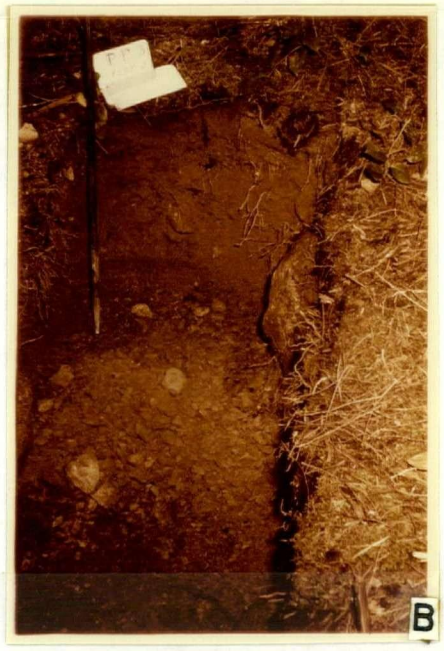
(4) Identical climatic values occur for some periods on the plots. These are the periods when the bioeffect of the plots is not dominating the macroclimate.

The question arises to what extent does the effect of macroclimate alter the microclimate of the plots and how strongly do they create their own microclimate, and what is the significant alteration which has effect on plant-association of each plot towards a change. Unfortunately, from the available data and observations, it is impossible

Fig. 16. The profile pictures of plots 1, 2, 3, 4 and 6

A. Plot 1 - P.P.3
B. Plot 2 - P.P.3
C. Plot 3 - P.P.2
D. Plot 4 - P.P.4
E. Plot 6 - P.P.2
F. Plot 6 - P.P.1

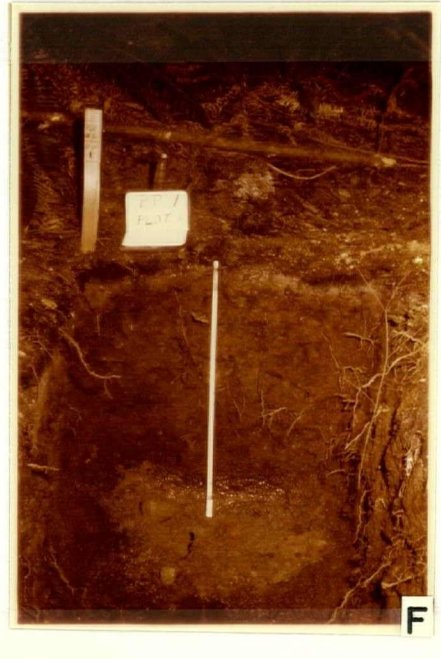
PP 3
PLOT 1
A


B

PP1
C

D

PP 2
PLOT 1
E


PP 1
PLOT
F

to answer these questions.

4. Description of Soils

(a) Generalized Profile Description

The soil profiles found in three pits on each of the eight plots were described in detail and these individual descriptions are included in the Appendix. In general, within each plot the soil profiles are quite similar except for the thickness of the horizons and the depth of solum.

The individual descriptions also showed that the soils on some of the eight plots are quite similar, while on others they are different. On the basis of these descriptions the soils may be divided into three groups.

Group 1: plot 1
Group 2: plots 2, 3 and 4
Group 3: plots 5, 6, 7 and 8

From the individual profile descriptions, generalized profile descriptions representative of these three groups have been prepared. Profile pictures of plots 1, 2, 3, 4, 5 and 6 are given in Figure 16.

Generalized Profile Description of Group 1

Horizon	Depth	Description
A_{00}	2½-2	Coniferous needles and twigs. pH. 4.78
A_o	2-0	Black to dark brown. Soft and fluffy.

Horizon	Depth	Description
		Numerous fine roots. pH. 4.18
A_2	trace	Grayish brown (2.5 YR 5/2-4/2, moist) sandy loam, friable, non-sticky, non-plastic. Some granite rock fragments. pH. 4.32
B_{11}	0-6	Very dark yellowish brown to dark reddish brown (10 YR 3/4 to 5 YR 3/3-3/5, moist) coarse sandy loam. Strong coarse angular blocky structure. Firm to hard, non-sticky, non-plastic. Contains abundant concretions and orstein fragments to 2 inches diameter. Subangular granitic stones. pH. 5.33
B_{12}	6-18	Brown to dark brown (7.5 YR 4/2-4/4, moist) coarse sandy loam. Weak medium to coarse subangular blocky structure. Slightly firm, non-sticky, non-plastic. Some stones. pH. 5.43
B_3	18-27	Brown to dark brown (7.5 YR 4/2-4/4, moist) coarse sandy loam. Weak, coarse, subangular blocky, slightly firm to firm, non-sticky, non-plastic. Slightly mottled. Some stones, gravels and cobbles. pH. 5.47

Horizon	Depth	Description
C	27+	Light gray (2.5 YR 7/2 moist) mottled reddish brown (5 YR 4/4) coarse sandy loam. Massive, hard, compact glacial till containing stones and gravels. pH. 5.91

This is the only soil which shows restricted drainage throughout the profile. The Texture, coarse sandy loam, does not change among the horizons except for the A_2 which is sandy loam. The strongest structure development occurs in this soil. The B_{11} horizon shows strong coarse subangular blocky with orstein development and shots. A well developed A_2 horizon is found only under decaying logs where there is an accumulation of organic debris, otherwise development of the A_2 horizon was only incipient. (Figure 16).

The profile is classified as belonging to the Brunosolic Order (4,1958) as there is little evidence of eluviated and illuviated horizons. The B horizon of the profile showed a dark brown color and contained a considerable content of iron concretions, indicating that the profile belongs in the concretionary brown (4.31, 1958) and modal concretionary brown great-soil group and sub-group respectively.

Generalized Profile Description of Group II

Horizon	Thickness	Description
A_{oo}	1½-1¼	Coniferous needles and twigs. pH. 4.37
A_o	1¼-0	Black to very dark brown. Moderately well decomposed. Soft and fluffy. Many roots. pH. 3.75
A_2	0-1	Grayish brown (2.5 YR 5/2 moist) sandy loam. Medium blocky, breaking to medium granular structure. Friable, non-sticky, non-plastic. pH. 3.81
B_{11}	1-3	Dark reddish brown (5 YR 3/4) coarse sandy loam. Weak medium subangular blocky breaking to medium granular structure a few shotty concretions. Non-sticky, non-plastic, friable, numerous roots, some angular cobbles. pH. 4.93
B_{12}	309	Strong brown (7.5 YR 5/6 moist) coarse sandy loam. Weak subangular blocky breaking to weak fine blocky structure. Friable, non-sticky, non-plastic. Angular cobbles, and stones. pH. 5.37
B_3	9-17	Strong brown (7.5 YR 5/6 moist) coarse sandy loam to loamy sand. Weak medium to fine blocky structure. Slightly firm, non-sticky, non-plastic. Highly mottled.

Horizon	Thickness	Description
		Root mat. pH. 5.49
C_1	17+	Grayish brown (2.5 YR 5/2 moist) coarse sandy loam to loamy sand. Massive, hard, compact glacial till. Sometimes absent, in which case the B_3 rests on bedrock.

The soils on plots 2, 3 and 4 are classified in this group. In these profiles the structure is weak. The solum is often over bedrock, and some exposed bedrock was observed in plot 3. These three profiles show the characteristics of the Podzolic Order (3,1958) having distinct eluvial and illuvial horizons. (Table 1)(Figure 16). The sesquioxides accumulation occurs in the B_{11} horizon. Also the B_{11} horizon shows an organic matter accumulation (Table 8). It should be noted that the high organic matter content of the B_3 horizon of plots 2, 3 and 4 is due to the bedrock which underlies the solum. Clay accumulation in the profiles on plots 2 and 3 is evident (Table 9); it is concluded that the B_{11} horizon corresponds to the illuviated horizon in these profiles.

These profiles may be classed in the podzol great group (34,1958) and minimal podzol sub-group (3.42, 1958) since they have the characteristics given as "having an organic (O) surface horizon, a thin (less than 1 inch) light colored eluvial (A_e) horizon (may be discontinuous) an illuvial (B) which contains an accumulation of organic matter and

sesquioxides. Lacks distinct B_h sub-horizon." (Table 1) (Figure 16).

General Profile Description of Group III

Horizon	Depth	Description
A_{oo}	2¼-2	Coniferous needles and twigs. pH. 3.97
A_o	2-0	Black to very dark brown decayed litter. Soft and fluffy. Many roots. pH. 3.73
A_2	0-1/8	Gray brown (10 YR 5/2 moist), sandy loam. Friable, massive. Non-sticky, non-plastic. Discontinuous. pH. 3.95
B_{11}	1/8-1¼	Strong brown (7.5 YR 4/6 moist) coarse sandy loam. Very weak subangular blocky structure. Friable, non-sticky, non-plastic. Slightly mottled, a few concretions fine subangular gravels. pH. 4.98
B_{12}	½-20	Yellowish brown (10 YR 5/6 moist) sandy loam. Very weak subangular blocky breaking to granular structure a few concretions. Friable, non-sticky, non-plastic. Slightly mottled. pH. 5.66
B_3	20-23	Light yellow brown to light olive brown (2.5 YR 5/6-5/4 moist) sandy loam to loam. Very weak subangular blocky breaking to granular structure. Friable,

TABLE 5. HORIZON THICKNESS, DEPTH OF SOLUM, PHYSIOLOGIC DEPTH AND DEPTH TO MOTTLING FOR ALL PLOTS (AVERAGE FOR THREE PITS, IN INCH)

	Groups	I		II			III		
	Plots	1	2	3	4	5	6	7	8
Horizons	A_{oo}	.25	.50	.25	.25	.25	.42	.25	.25
	A_o	1.70	1.33	1.66	1.41	1.75	1.41	2.00	2.83
	$A_{oo}+A_o$	1.75	1.83	1.91	1.66	1.90	1.83	2.21	3.08
	A_2	Trace	0-.50*	0-1.5*	0-1.0*	0-.75*	0-50	.40	.60
	B_{11}	6.00	2.13+	1.50+	2.03	2.92	5.30	1.77	1.66
	B_{12}	12.00	15.00	14.60	6.58	13.36	13.10	18.00	19.10
	B_3	9.00	15.00	11.66	8.66	13.36	11.00	13.30	2.66
	Solum ($B_n+B_n+B_3$)	27.00	32.13	27.76	12.27	29.74	29.40	33.07	23.42
Physiologic depth	Max.	28.00	34.00	27.33	26.30	30.00	30.00	33.66	28.00
	Min.	20.00	2.00	7.00	3.00	6.00	15.00	4.00	2.00
	Ave.	24.00	18.00	17.00	15.00	18.00	20.00	19.00	15.00
	Depth to Mottling	23.30	9.50	11.16	12.00	18.00	18.00	19.00	14.00

* - Discontinuous

\+ - Partly discontinuous

compact in low parts. Non-sticky, non-plastic. Slightly mottled. pH. 5.66

C_1 23+ Very thin glacial till over bedrock. Often absent. pH. 5.70
Stoniness: subangular to rounded cobbles throughout profile.

This profile description is given to represent the soils found on plots 5, 6, 7 and 8. Profile development is considered to be an intergrade between concretionary Brown and Minimal Podzol (Figure 16). Plot 6 shows more similarity to concretionary Brown than to Minimal Podzol. Plot 5 shows the best texture, a sandy loam throughout the profile (Table 9). The structure is generally weak in these profiles.

(b) Horizon Depths[5]

The thickness of A_{oo} and A_o layers and A_2, B_{11}, B_{12}, B_3 horizons, depth of solum, maximum, minimum and average physiologic depth (depth of rooting zone) and depth to mottling are tabulated in Table 5.

The depth of layers and horizons shows considerable variations both between and within the soil groups.

The A_{oo} horizon shows little variation among the

---

[5]Identification and nomenclature of soil horizons are given in Soil Survey Manual (pp. 173-188).

plots but the A_o horizon does. There is an observed correlation between increasing thickness of the A_o horizon and increasing leaching (podzolization) of the soil within groups II and III. In general, the profiles in group II show thinner A_o layers than the profiles of groups I and III, probably because the former have a lighter vegetative cover.

Only a trace of A_2 horizon (eluviation horizon) is found in plot 1. The thickness of that horizon is thinner on the soils of group II (podzols soil) than the soils of Group III, and in all cases the eluvial horizon is partly discontinuous.

The B_{11} horizon varies up to 6 inches in thickness, and may be discontinuous in group II soils. The thickness of the B_{11} horizon decreases from group I to III and further decreases from III to II. Within any group, as podzolization increases, the thickness of the B_{11} horizon decreases.

The B_{12} horizon is generally thicker than the B_{11}, but thinner than the B_3 horizon. The thickness of this horizon increases with podzolization within groups I and III.

The B_3 horizon is similar in thickness to the B_{12} except on plot 8, which shows the thinnest B_3 horizon (2.66 inches) of any profile.

TABLE 6. STONE CONTENTS OF PLOTS 1, 3 AND 5
(Per cent by volume of whole soil)

Plots	Diameter of Stones			Field stoniness rating
	1 - 3"	3"	Total	
Plot 1	14.25	21.25	35.50	light
Plot 2	-	-	-	very stony
Plot 3	15.92	34.52	50.44	very strong
Plot 4	-	-	-	very strong
Plot 5	14.02	25.66	39.68	moderate
Plot 6	-	-	-	moderate
Plot 7	-	-	-	mod.to severe
Plot 8	-	-	-	moderate

The depth of solum shows a general increase with increasing podzolization in groups I and II. In Group III a decrease in thickness is evident with an increase in podzolization.

Physiological depths show a decrease from group I to group III to group II. Also within group II there is a decrease in physiological depth as podzolization increases.

The depth of mottling also decreases with an increase of podzolization.

It appears that there is a correlation between the thickness of the horizons and depth to mottling with degree of podzolization. These correlations are less pronounced in the soils of group III.

(c) Stoniness

The stone content of soils on Plots 1, 3 and 5 is shown on table 6. All plots show a high stone content, particularly in plot 3 where one-half the soil volume is composed of particles in excess of 1 inch diameter. This high stone content markedly reduced the soil moisture holding capacity (Tables 15 and 16). Also it is noticeable that field ratings are comparable to those calculated.

(d) Chemical Properties

The soils are all acid in reaction, their reaction

TABLE 7. SOIL REACTION (PH VALUES) FOR SOILS OF ALL PLOTS

	Plots	1	2	3	4	5	6	7	8
Horizons	A_{oo}	4.78	4.09	4.26	4.37	4.18	4.65	3.97	4.20
	A_o	4.18	3.67	3.97	3.75	3.74	4.20	3.73	3.70
	A_2	4.32	3.96	3.80	3.81	4.31	4.31	3.95	3.71
	B_{11}	5.33	4.79	4.83	4.93	4.97	5.34	4.98	4.90
	B_{12}	5.43	5.07	5.27	5.37	5.36	5.36	5.38	5.55
	B_3	5.47	5.27	5.42	5.49	5.51	5.44	5.66	5.73
	C	5.91	5.74	-	5.33	5.68	5.72	5.70	5.57

TABLE 8. ORGANIC MATTER, TOTAL EXCHANGE CAPACITY AND EXCHANGEABLE CALCIUM AND POTASSIUM FOR THE SOILS OF PLOTS 1, 2, 3 AND 5

Plots	Hors.	Organic Matter %	Total Ex.Cap. me/100gm	Ex. Ca me/100gm	Ex. K me/100 gm	Ca Saturation %	pH
Plot 1	A_{oo}	75.54	91.10	4.52	1.49	4.96	4.78
	A_o	36.01	93.70	2.91	1.24	3.10	4.18
	B_{11}	8.06	10.65	.37	.22	3.47	5.33
	B_{12}	4.58	20.50	.56	.27	2.72	5.43
	B_3	4.30	16.20	.40	.19	2.83	5.47
	C	.72	6.55	.62	.19	9.46	5.91
Plot 2	A_{oo}	70.38	92.50	5.82	1.05	6.29	4.09
	A_o	62.37	97.3	3.93	.95	4.04	3.67
	B_{11}	6.68	19.5	.37	.15	1.89	4.79
	B_{12}	4.73	16.5	.40	.19	2.42	5.07
	B_3	2.90	10.2	.52	.24	5.09	5.27
	C	.78	3.45	.52	.19	15.07	5.74
Plot 3	A_{oo}	77.28	95.9	5.79	1.02	6.03	4.26
	A_o	69.00	113.0	5.20	.93	4.60	3.97
	B_{11}	4.22	20.45	.53	.15	2.73	4.83
	B_{12}	3.59	15.8	.37	.19	2.34	5.27
	B_3	5.27	27.9	.60	.19	2.14	5.42
	C	-	-	-	-	-	-
Plot 5	A_{oo}	78.66	112.80	4.03	2.20	3.57	4.18
	A_o	52.44	101.70	3.62	1.52	3.55	3.74
	B_{11}	7.15	18.45	.37	.22	2.00	4.97
	B_{12}	3.40	10.80	.43	.22	3.98	5.36
	B_3	2.06	20.35	.50	.19	2.13	5.51
	C	1.24	10.35	.40	.17	3.86	5.68

ranging from pH 3.67 to 5.91. Generally, there is an increase in acidity going from the A_{oo} to A_o horizons and below that the acidity tends to decrease with depth. The least acid horizon is the C horizon of plot 1 which has a pH of 5.91. Strong acidity is known to slow down mineralization of nitrogen by micro-organisms and encourage high fixation of phosphorus by iron and aluminum. The slightly less acidic conditions in plot 1 may tend to minimize these effects in the plot which may result in a high site value.

Organic matter is very high in the A_{oo} and A_o horizons and decreases in all plots with depth (Table 8). Of the mineral horizons the B_3 horizon of plot 3 is high in organic matter (5.27 per cent) due to a root mat which has formed on the underlying bedrock. The organic matter content of the A_o horizons shows an increase as we go from plot 1 to plot 3 (from 36.06 to 69.0 per cent). Probably this is a sign of a decreasing rate of organic matter decomposition. Plot 1, has a more uniform microclimate which probably provides better conditions for micro-organism activity.

Total cation exchange capacity was found low for all soils. The total cation capacity of plots 1, 2, 3 and 6 is given in Table 8. These values increase with depth. A_o horizons generally show higher values than A_{oo}, probably because the organic matter in the A_o layer is better decomposed. Organic matter of the A_o horizon will have

higher negative charges due to broken bonds as a result of decomposition of organic compounds and consequently a higher cation exchange capacity.

The total cation exchange capacity shows a relation to clay and organic matter content of the horizons. The B_{12} horizon of plot 1 and the B_3 horizon of plot 5 have high cation exchange capacities (20.5 m.e./100 gm, 20.3 m.e/100 gm respectively) and high clay values compared with other horizons and plots. B_3 horizon of plot 3 is high in total exchange and organic matter content. High values in the surface layer are due to the high organic content.

The values of exchangeable calcium are given in Table 8. A_{oo} and A_o layers are relatively high in exchangeable calcium. The A_o layer has lower values than the A_{oo} layer. It seems that the calcium which has been freed from leaves by decomposition has been leached out by rainfall and drainage water. Values tend to be higher for B_3 and C horizons. The values of A_o horizon increase as we go from plot 1 to plot 3(from 2.5 m.e/100 gm to 5.2 m.e./100 gm).

Per cent calcium saturation is high on the surface layers and in the C horizon of minimal podzols (average 5.0 per cent surface, 15.0 per cent) because of slower decomposition of organic matter at the surface (plots 2 and 3).

TABLE 9. MECHANICAL ANALYSIS AND COARSE SKELETON FOR SOILS OF PLOTS 1,2,3 AND 5
(per cent by weight)

Plots	Hor.	Soil Separates				
		Sand 2.-.02 mm	Silt .02-0.002 mm	Clay .002mm	Clay+ Silt	Coarse Skeleton 2mm
Plot 1	B_{12}	70.31	26.58	4.11	29.69	36.4
	B_3	69.97	27.97	2.36	30.33	49.2
	C	70.89	26.54	2.57	29.11	28.2
Plot 2	B_{12}	70.88	25.77	3.33	29.12	56.5
	B_3	69.17	27.88	2.95	29.32	58.0
	C					
Plot 5	B_{12}	66.94	29.38	3.68	33.06	61.7
	B_3	69.98	25.11	4.51	30.02	64.8
	C	80.80	17.16	2.04	19.10	60.5

TABLE 10. FIELD TEXTURE OF SOILS

Horizons	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
A_2	Sandy loam	Sandy loam	Sandy loam to loamy sand	Sandy loam	Coarse Sandy loam	Coarse Sandy Loam	Sandy loam	Coarse Sandy loam
B_{11}	Coarse sandy loam	Coarse sandy loam	Sandy loam	Coarse sandy loam	Sandy loam	Coarse sandy loam	Coarse sandy loam	Coarse sandy loam
B_{12}	Coarse sandy loam	Sandy loam	Coarse sandy loam	Coarse sandy loam	Sandy loam	Coarse sandy loam	Sandy loam	Coarse sandy loam
B_3	Coarse sandy loam	Sandy loam	Coarse sandy loam	Coarse sandy loam	Sandy loam	Coarse sandy loam	Sandy loam to loam	Coarse sandy loam
C	Coarse sandy loam	Sandy loam	Bedrock	Bedrock	Sandy loam	Coarse sandy loam	Bedrock	Coarse sandy loam

TABLE 11. BULK DENSITY, TOTAL, MACRO, MICRO POROSITIES AND HYDRAULIC CONDUCTIVITY OF SOILS OF PLOTS 1,3 AND 5

Plots	Hor.	Bulk Density gm/cm^3	S.D.	Total Porosity %	S.D.	Macro-Porosity %	S.D.	Micro-Porosity %	S.D.	Hyd. Conduct. cm/hr.	S.D.
Plot 1	O-3	.92	.20	64.4	6.96	20.8	4.91	37.6	12.36	83.4	63.45
	B_{12}	1.13	.09	55.9	6.67	20.2	10.71	35.1	6.87	67.1	71.16
	B_3	1.12	.37	57.3	5.84	15.2	14.21	45.6	6.58	33.6	52.87
	C	1.81	.12	30.5	5.99	9.9	3.33	25.7	6.53	19.6	27.08
Plot 3	O-3	.82	.17	59.7	5.74	29.71	4.71	30.6	5.43	275.0	80.69
	B_{12}	1.09	.45	57.3	5.76	25.9	5.01	31.0	3.22	315.0	97.59
	B_3	1.21	.17	52.3	6.71	17.5	4.76	32.7	9.62	170.3	52.77
	C	-	-	-	-	-	-	-	-	-	-
Plot 5	O-3	.84	.24	67.4	10.01	27.1	3.93	34.6	4.59	129.50	63.22
	B_{12}	1.19	.37	54.2	3.79	24.4	3.50	27.8	4.93	189.0	83.33
	B_3	1.40	.19	45.4	7.70	23.1	3.58	26.6	5.62	189.2	92.29
	C	1.65	.32	35.7	3.27	17.1	5.88	23.7	5.00	41.9	30.05

TABLE 12. TOTAL POROSITY CALCULATED BY TWO METHODS[1] FOR PLOTS 1, 3 AND 5 (Per cent by Volume)

Plots	1 Methods		3 Methods		5 Methods	
	I	II	I	II	I	II
Hors.						
B_{12}	55.9	56.9	57.3	57.9	54.2	54.6
B_3	57.3	57.2	52.3	55.7	45.4	47.9
C	30.5	33.9	-	-	35.7	39.8

(1)

Method I. Calculated from saturated weight of soil cores.

Method II. Calculated using relationship

$$\left(1 - \frac{\text{Bulk density (gm/cm}^3)}{\text{Specific gravity}}\right)_{100}$$

TABLE 13. SPECIFIC GRAVITY OF SOILS IN PLOTS 1,3 AND 5 (gm/cm^3)

Plots	1	3	5
Hor.	2.		
B_{12}	2.62	2.59	2.62
B_3	2.63	2.61	2.69
C	2.74	-	2.70

TABLE 14. RATIO OF THE MACRO-POROSITY TO MICRO-POROSITY FOR PLOTS 1, 3 AND 5

Plots	1	3	5
Hor.			
O-3	.553	.866	.783
B_{12}	.575	.835	.877
B_3	.333	.535	.868
C	.382	-	.72

TABLE 15. .1 AND 15 ATMOSPHERE MOISTURE, IN INCHES PER HORIZON FOR THE SOILS OF PLOTS 1, 3 AND 5

Plots	Hor.	.1 atm. %	15 atm. %	Water in Inches per Horizon: Based on less than 2mm particles .1atm	Based on less than 2mm particles 15atm	Corrected for Coarse skeleton .1atm	Corrected for Coarse skeleton 15atm	Corrected for Stoniness .1atm	Corrected for Stoniness 15atm	Corrected for coarse skeleton and stoniness .1atm	Corrected for coarse skeleton and stoniness 15atm
Plot 1	$B_{11}+B_{12}$	24.92	12.91	5.07	2.62	3.22	1.67	3.27	1.69	2.07	1.07
	B_3	23.89	11.01	2.40	1.11	1.22	.56	1.54	.71	.78	.36
	C	14.94	7.90	1.62	.85	1.15	.61	1.04	.55	.74	.39
	$B_{11}+B_{12}+B_3$			7.47	3.73	4.44	2.23	4.81	2.40	2.85	1.43
Plot 3	$B_{11}+B_{12}$	22.45	15.52	3.57	2.00	1.56	.87	1.76	.99	.77	.43
	B_3	22.06	12.04	4.14	2.24	1.76	.94	2.05	1.11	.85	.46
	C	-	-	-	-	-	-	-	-	-	-
	$B_{11}+B_{12}+B_3$			7.71	4.24	3.32	1.81	3.81	2.10	1.62	.89
Plot 5	$B_{11}+B_{12}$	23.42	13.00	4.66	2.63	1.80	1.03	2.80	1.57	1.09	.63
	B_3	22.67	12.91	3.81	2.17	1.34	.77	2.28	1.30	.80	.46
	C	12.00	6.20	1.18	.61	.48	.24	.72	.36	.29	.14
	$B_{11}+B_{12}+C$			8.47	4.80	3.14	1.70	4.08	2.87	1.89	1.09

TABLE 16. AVAILABLE WATER (.1-15 ATMOSPHERE), IN PER CENT AND INCHES PER HORIZONS FOR THE SOILS OF PLOTS 1,3 AND 5

Plots	Hor.	.1 atm. %	15 atm. %	Available Water (.1-15 Atm.) Based on less than 2mm particles %	inches	Corrected for soil skeleton %	inches	Corrected for Stoniness %	inches	Corrected for coarse skeleton and stoniness %	inches
Plot 1	$B_{11}+B_{12}$	24.92	12.91	12.01	2.45	7.63	1.55	7.74	1.58	4.92	.99
	B_3	23.89	11.01	11.67	1.30	5.93	.66	7.53	.83	3.82	.43
	C	14.94	7.90	7.04	.67	5.05	.76	4.54	.54	3.25	.40
	$B_{11}+B_{12}+B_3$			23.68	3.75	13.56	2.21	15.27	2.41	8.74	1.42
Plot 3	$B_{11}+B_{12}$	22.45	12.52	9.93	1.56	6.03	.68	4.02	.77	1.99	.34
	B_3	22.06	12.04	10.20	1.90	5.91	.81	4.14	.94	2.05	.39
	C	-	-	-	-	-	-	-	-	-	-
	$B_{11}+B_{12}+B_3$				3.63	14.94	1.48	8.16	1.61	4.04	.73
Plot 5	$B_{11}+B_{12}$	23.42	13.00	10.42	2.03	4.09	.77	6.25	1.23	2.45	.46
	B_3	22.67	12.91	10.27	1.64	3.61	.57	6.16	.98	2.17	.34
	C	12.00	6.20	6.20	.61	2.47	.24	3.72	.37	1.46	.15
	$B_{11}+B_{12}+B_3$				3.67	7.70	1.34	12.41	2.21	4.62	.80

The values for exchangeable potassium are lower than those of calcium (Table 8), and the potassium values decrease by depth. Plots 2 and 3 show low values in A_{oo} and A_o layers and B_{11} and B_{12} horizons (average 1.0 m.e./100 gm for surface and 0.17 m.e./100 for B horizon).

(e) Physical Soil Properties

The soils of the area are quite uniform in texture, being classed generally as coarse sandy loams. The clay, silt and sand content of the soils does however vary somewhat from horizon to horizon within the profile.

The low clay content is evident in all soils (1.0-4.0 per cent). Plots 1 and 5 show highest clay values in B_{12} horizon (4.1 per cent and 3.3 per cent) but plot 5 shows this in the B_3 horizon (4.51 per cent). In plots 1 and 3 the clay content decreases by depth. In all plots, the B_{12} and B_3 horizons have the highest value within the profile. It was concluded that a slight clay accumulation occurs in the B horizon. This accumulation could happen by vertical or lateral movement of water. The lateral movement of water is quite effective in the area since the plots occur on slopes varying between 5 and 30 per cent. Also the higher clay content of the upper horizons could be due to a breakdown of particles to clay size by means of weathering. As for silt, plots 1 and 3 show uniformity among the horizons. In plots 2 and 5 the silt

content decreases with depth. The C horizon of plot 2 shows the lowest silt content (0.7 per cent).

The sand content of the plots shows little variation, being high in all soils (66.9-85.1 per cent). In plots 2 and 5 the sand content increases by depth, whereas plots 1 and 3 show uniformity with depth in the sand content of the horizons (average 26.0-27.0 per cent).

The texture classes of the plots appear very close to one another. The field-hand texture classes of horizons of all plots are given in Table 10. The texture varies between coarse sandy loam and sandy loam.

Coarse skeleton (larger than 2 mm. particles) often makes up a large percentage of the soil bulk. It is 60 per cent in plot 5. The lowest value occurs in the C horizon of plot 1 (28.2 per cent).

Bulk density increases by depth within a profile (Table 11). The greatest values (1.65-1.85) occur in the C horizon because of their compaction. The surface horizons show the lowest values (0.82-0.92) due to a thick organic layer. Because the high bulk density restricts root penetration in the profile (57), the bulk density values of plot 1 are more favorable for root penetration compared with the other plots.

Total pore-space methods are calculated by two

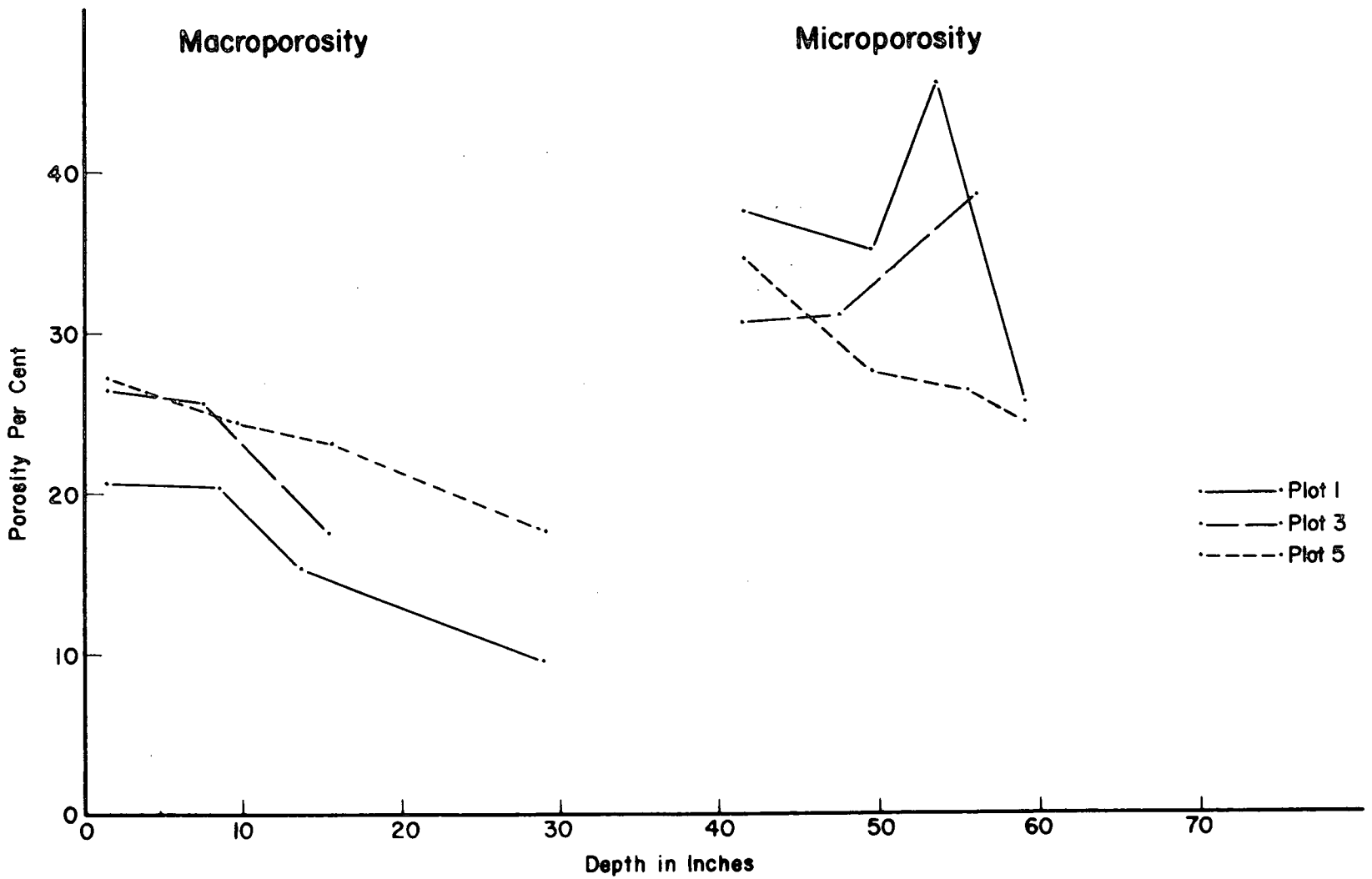


Fig. 17 Changes in soil porosity with soil depth for plots 1, 3, and 5.

methods (Table 12). For the first method, the values are based on the saturated weight of the cores, while for the second method the specific gravity (Table 13) and bulk density (Table 11) of the soils were used. Since the values between the two methods did not show appreciable differences, the values obtained from the first method are tabulated in Table 11. The values for total and macro-pore space decrease by depth (Table 12)(Figure 17). The values for micro-pore content of the soils (Tables 9 and 11).

The ratios of macro-pore space/micro-pore space for plots are given in Table 11. The values vary between 0.333 and 0.877. The smallest values occur in plot 1. There is a tendency for the ratios to decrease with depth.

Hydraulic conductivity values show a great variability within a profile and among the profiles (Table 11). There is a positive correlation between macro-pore space values and hydraulic conductivity. As the per cent macro-pore space decreases, the hydraulic conductivity decreases.

The 0.1 and 15 atmosphere values are given in Tables 15 and 16 on the basis of (1) less than 2mm. soil particles; (2) corrected for coarse skeleton of soil; (3) corrected for stoniness; (4) corrected for both stoniness and coarse skeleton. The values generally decrease by depth except for plot 3, which shows the highest value in the B_3 horizon.

TABLE 17. SUMMARY OF F VALUES AND SIGNIFICANCE FROM VARIANCE ANALYSES OF PHYSICAL DATA FOR PLOTS 1, 3 AND 5

Source	Pit			Hor.			Plot		
	D.F.	F[1]	P[2]	D.F.	F	P	D.F.	F	P
Bulk Density	8	.33	N.S.	4	.66	N.S	2	12.0	S
Total-Pore Space %	8	.52	N.S	4	.77	N.S	2	8.98	S
Macro-Pore Space %	8	1.53	N.S	4	4.50	S	2	5.21	S
Micro-Pore Space %	8	2.83	N.S	4	8.31	S	2	1.15	S
Hydraulic Cond. cm/hr.	8	.91	N.S	4	26.16	S	2	4.80	s

TABLE 18. VARIANCE ANALYSES OF CHEMICAL DATA FOR PLOTS 1, 2, 3 AND 5

(A horizon = A_{oo} and A_o; B horizon = B_{11}, B_{12} and B_3)

Source		Horizons			Plots		
		D.F	V.R	P	D.F	V.R	P
Organic Matter %	A horizons	1	7.209	N.S	3	.876	N.S
	B horizons	2	4.933	N.S	3	.636	N.S
Total Cation Ex.Capacity me/100 gm.	A horizons	1	.335	N.S	3	2.59	N.S
	B horizons	2	.22	N.S	3	.68	N.S
Ex. Ca me/100 gm	A horizons	1	9.374	N.S	3	5.433	N.S
	B horizons	2	1.0898	N.S	3	.375	N.S
Ex. K me/100 gm	A horizons	1	4.105	N.S	3	8.984	N.S
	B horizons	2	.909	N.S	3	1.273	N.S
Ca-Saturation %	A horizons	1	8.46	N.S	3	3.20	N.S
	B horizons	2	.208	N.S	3	.326	N.S
pH	A horizons	1	.206	N.S	3	.0818	N.S
	B horizons	2	20.52	S	3	7.29	S

The moisture retained by a soil between 0.1 and 15 atmospheres is considered the available water. One tenth atmosphere values were used instead of 1/3 atmosphere values because in all profiles the internal drainage was restricted by impervious parent material, thus it is assumed that tension in the field capacity will be closer to 1/10 atmosphere than to 1/3 atmosphere. The available water values which are corrected for both stoniness and coarse material seem to express the available water best because they should approximate true values of water available for plants.

(f) Statistical Analyses

The statistical results for the physical analyses are tabulated in Table 17 and show the degree of significance of each factor at the 5 per cent level. Bulk density, total-pore space, micro-pore space, hydraulic conductivity are non-significant between the pits within a plot; macro-pore space, micro-pore space, and hydraulic conductivity are significant among the horizons within a profile, but the rest of the factors are not; all factors except micro-pore space, and macro-pore space are significant among the plots.

The statistical results for the chemical analyses are tabulated in Table 18. The variance analyses of A and B horizons are made separately because there exists a large difference in values between A and B horizons (Table 8). The study of Table 18 shows that organic matter, total

exchange capacity, per cent Ca-saturation exchangeable Ca and K are non-significant between plots and within subhorizons of A and B horizons. pH values for B horizons appear significant between plots and within subhorizons of that horizon.

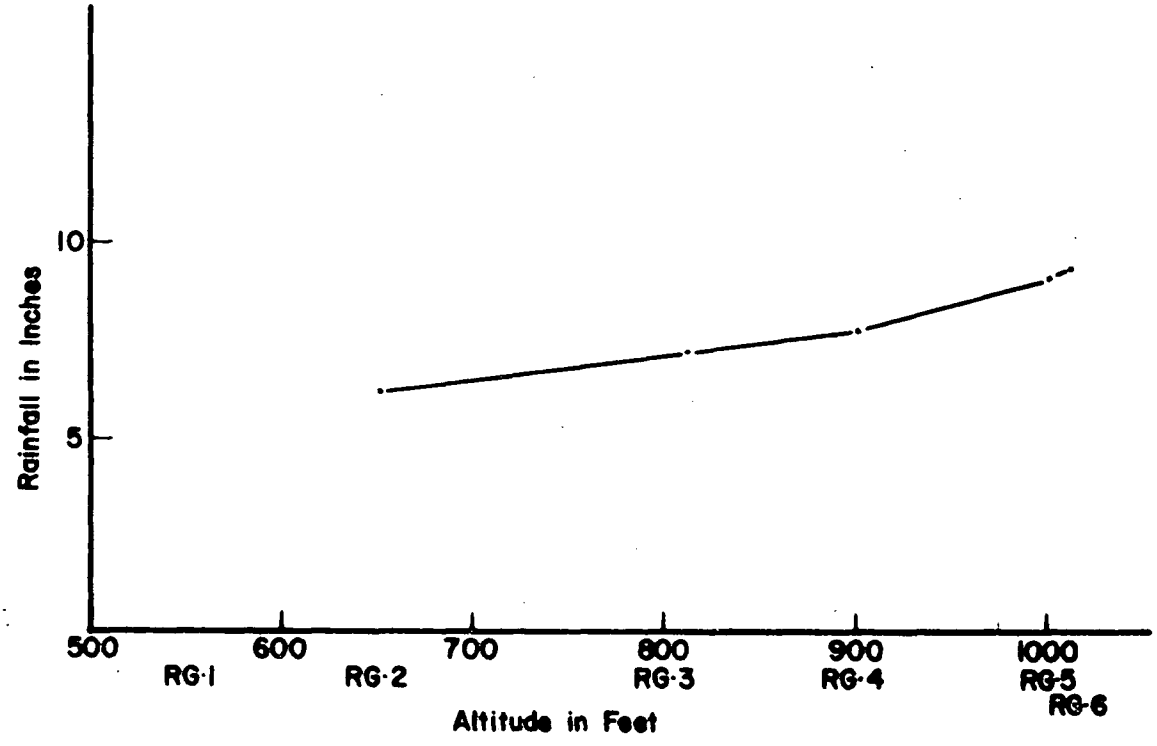


Fig. 18 Rainfall at several different elevations for July and August, 1957.

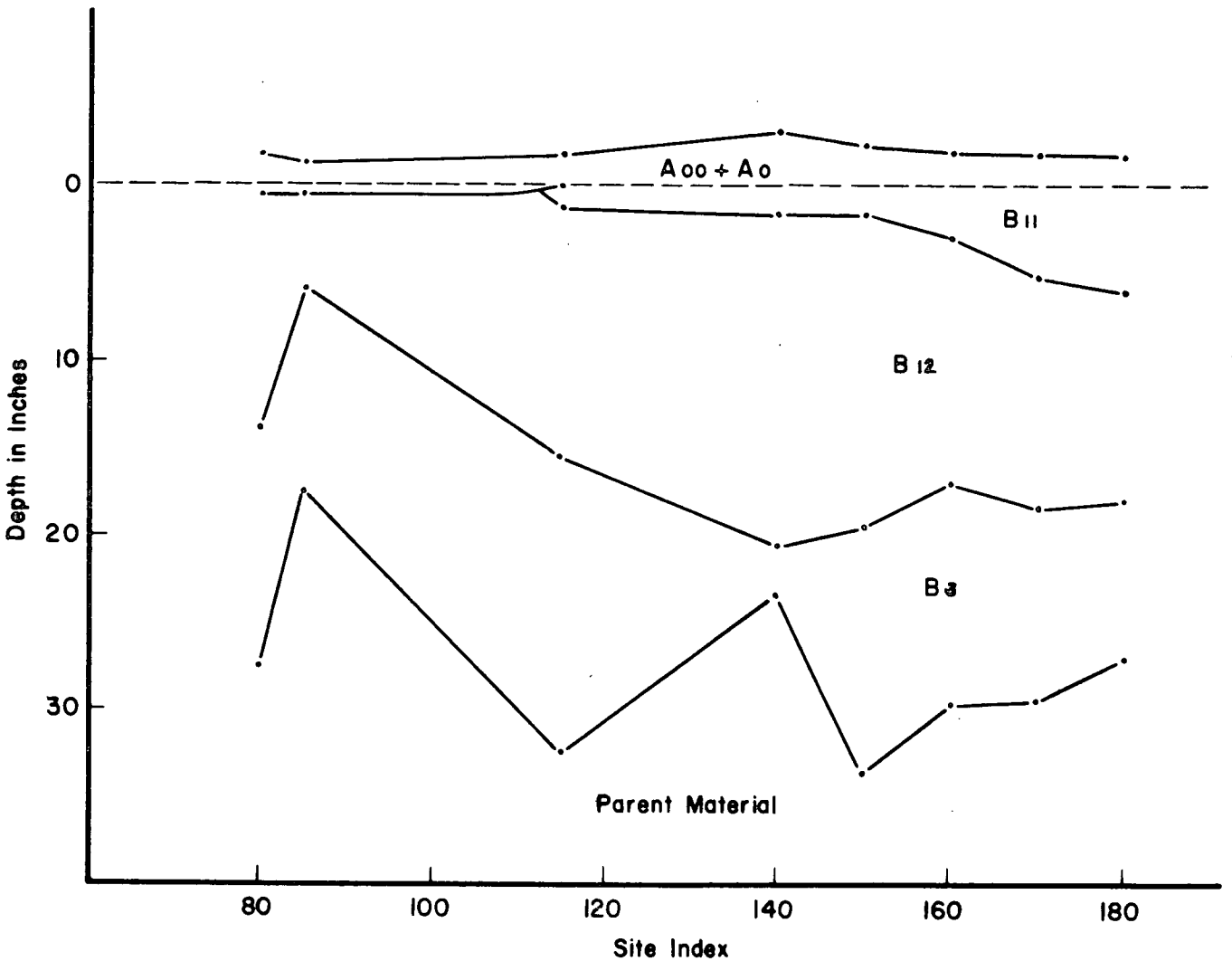


Fig. 19 Average depth of soil horizons for plots 1, 2, 3, 4, and 5 in relation to site index.

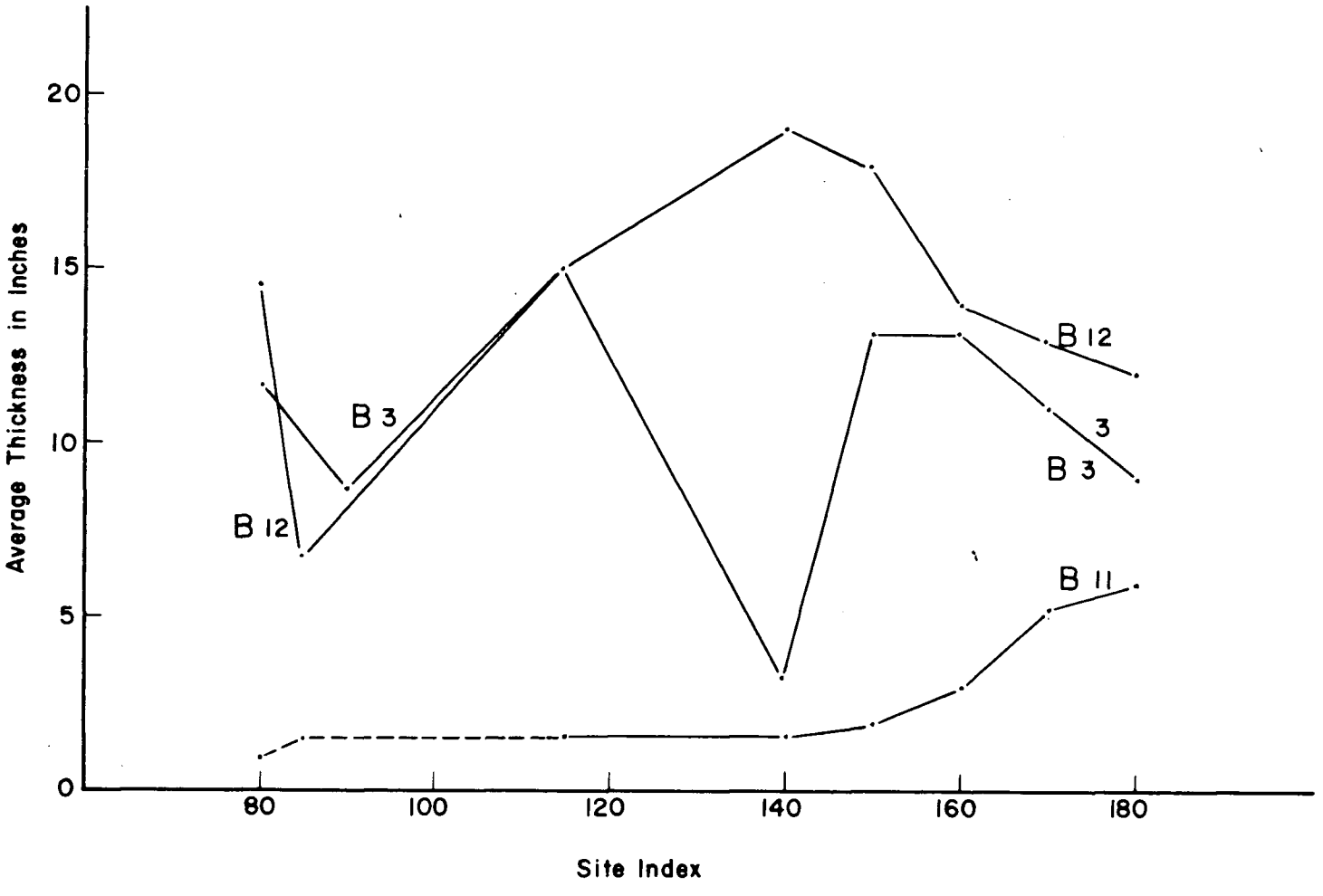


Fig. 20 Average thickness of B 11, B 12, and B 3 horizons for plots 1,2,3, 4,5,6,7, and 8 in relation to site index.

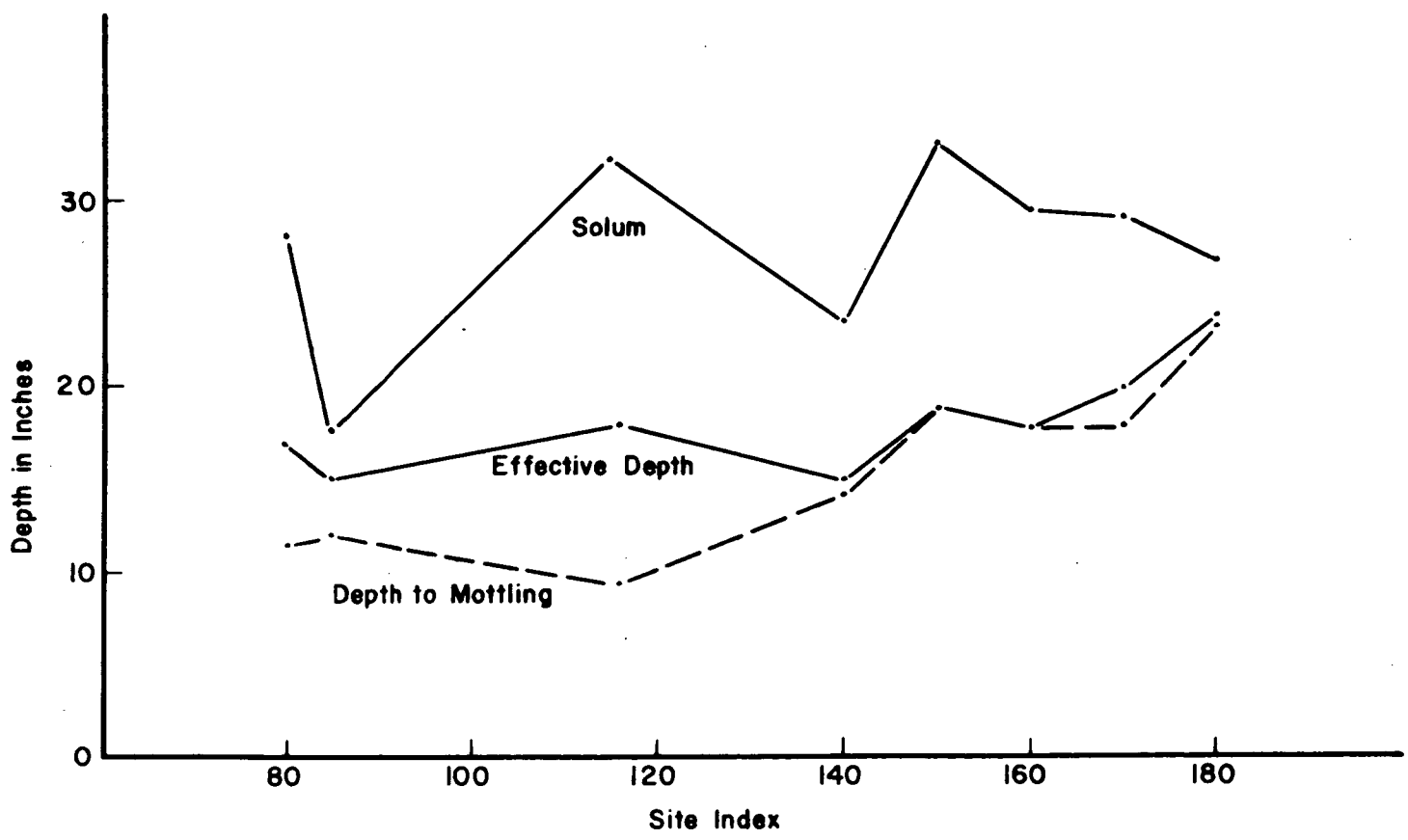


Fig. 21 Depth of solum, effective depth, and depth to mottling in relation to site index.

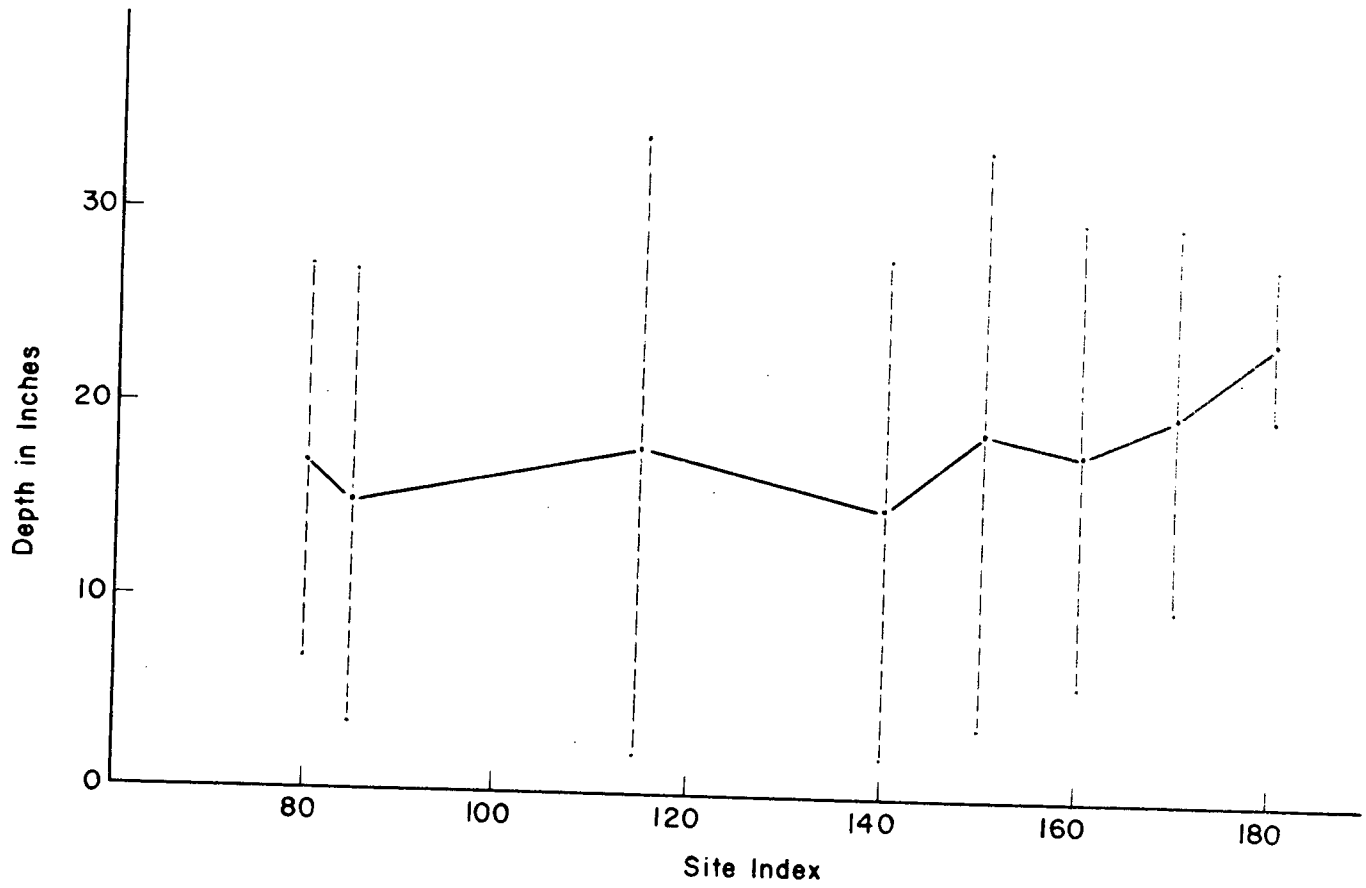


Fig. 22 Maximum, minimum, and average effective depth for all plots in relation to site index.

IV. SOILS AND SITE QUALITY

The eight study plots show site indices ranging from 80 to 180. The site indices of plots are as follows:

Plot	Soil Group	Site Index - feet
1	Concretionary brown	180
6	Intergrade between concretionary brown and minimal podzol	170
5	" " "	160
7	" " "	150
8	" " "	140
2	Minimal podzol	115
4	" "	85
3	" "	80 (61)

1. Climate

The summer precipitation increased with increasing elevation (Figure 18).

As far as the general micro-climate of plots is concerned, the plot which has a more uniform micro-climate (see II-2, pp. 41-42) shows a better site quality as regulating effect of macro-climate on soil and biota of the plot.

2. Great Soil Groups

The great soil groups or soil order of all plots show a correlation to site quality. Plot 1 is a concretionary brown soil (Brunosolic Order) and has the highest quality (site index 180). The poorest sites, plots 2, 3 and 4 have minimal podzol soils (Podzolic Order) having site indices of 115, 85 and 80 respectively. Plots 5, 6, 7 and 8 with medium site quality (site indices 160, 170, 150 and 140) have soils integrating between concretionary brown and minimal podzols.

3. Physical Properties of Soils

Among the plots 1, 3 and 5, clay content of B_{12} and C horizons, silt plus clay content of B_3 and C horizons show a relation to site indices (Table 10). Clay and clay plus silt decrease with decreasing site index. Plot 3 has a high clay and clay plus silt similar to plots 1 and 5. Probably plot 3 has to be discussed under a different group as classified before.

In plots 1, 3 and 5 the specific gravity shows a decrease towards the lower sites (Table 13). Plot 3 has the lowest value most likely because of much mineral material washed away by drainage water. Plot 1 has the highest value, probably due to the accumulation of minerals by lateral movement of water.

Bulk density does not show a relation to site index. As bulk density at the 0-3 inch layers decrease site quality also decreases. In plot 1 the (o) layer was thin and consequently the core samples contained more soil from the B_{11} horizon as compared to the other plots.

Total macro- and micro-porosity does not show a relation to site index (Table 11) but to depth (Figure 17). Only the macro-pore space of 0-3 horizon decreases with decrease in site indices probably due to (O) horizon as explained above.

Most correlations were found between physical properties of soil and site indices. Since profile characteristics are the result of more than one factor, it may be more advantageous to use them to evaluate the site indices. The observation and determination of this type of feature is easy in the field by a well trained person.

The thickness of A_{oo} layers does not show a relation to site index but among the plots 1, 5, 6, 7 and 8 the thickness of the A_o layer is negatively correlated with the site index (Table 5, Figure 18).

As the thickness of the A_2 horizon increases, podzolization is increased which in turn decreases the site index. Plot 1 having a trace A_2 horizon has the highest site index (Figure 18).

The depth of B_{11} horizon shows a positive correlation with site index (Table 5, Figure 19). As the thickness of the B_{11} decreases, site index also decreases (Figure 20). It becomes discontinuous in more podzolized soils (plots 2, 3 and 4). The higher the podzolization the thinner the B_{11} horizon.

The depth of B_{12} horizon shows a close relationship to site index (Table 5, Figure 19). As the depth increases the site index also decreases, except plot 3. The thickness of B_{12} horizon increases until site index 140 then decreases (Table 5). Thickness of that horizon does not show a correlation with site index (Figure 20).

The depth and thickness of B_3 horizon are more variable from profile to profile compared to the other horizons.

As the effective depth and depth of solum decreases site index is decreased (Table 5, Figures 21, 22). It seems that physiologic depth has a better correlation than the depth of solum. Also the range of physiologic depth is larger in low sites.

The depth of mottling appears to be correlated with site index. Probably minimal podzols should be discussed separately. Among plots 1, 5, 6, 7 and 8 as the depth to mottling decreases, so does the site index (Table 5, Figure 21).

Stoniness shows a negative correlation to site index (Table 6), with increases in site index, stoniness decreases.

The values of available water show correlation to site index when they are corrected both with stoniness and coarse skeleton or with stoniness alone. As available water decreases, site index also decreases (Tables 15, 16). Probably this is the most important characteristic in relation to site index as far as the Douglas-fir region goes.

4. Chemical Properties of Soils

The acidity of A_{oo} and A_o layers of the plots tends to increase towards the low sites (Table 7). The pH values of plots 1 and 6 are much higher than the other plots.

The organic content values for A_o layer increase with decreasing site index values; but the organic matter content of B_{11} and B_{12} horizons decreases (Table 8). Total cation exchange capacity of B_{11} horizon increases with decreasing site index values (Table 8).

Exchangeable calcium of A_{oo} and A_o layer increase with decreases in site index values.

There is little relationship between exchangeable potassium and site index. In general the values for plots 1 and 5 are higher than the values for plots 2 and 3 (Table 8).

TABLE 19. MATRIX OF SIMPLE CORRELATION COEFFICIENTS FOR VARIABLES X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8 and Y

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	Y
X_1	1.000	.112	.137	.186	.058	.457	.299	.213	.005
X_2	.112	1.000	.832	.217	.389	.271	.011	.072	.124
X_3	.137	.832	1.000	.102	.404	.409	.131	.119	.203
X_4	.186	.217	.102	1.000	.314	.148	.157	.494	.581
X_5	.058	.389	.404	.314	1.000	.001	.537	.162	.229
X_6	.457	.271	.409	.148	.001	1.000	.792	.023	.102
X_7	.299	.011	.131	.157	.537	.792	1.000	.189	.105
X_8	.213	.072	.119	.494	.162	.023	.189	1.000	.721
Y	.005	.124	.203	.581	.229	.102	.105	.721	1.000

TABLE 20. SIMPLE LINEAR EQUATIONS OF Y ON X_2, X_3, X_4, X_7 and X_8

Equation no.	X_i	a	b_{yx}	r	SE_E
1	X_2	123.33	6.63	0.124	35.9
2	X_3	108.32	12.77	0.203	35.4
3	X_4	100.73	11.35	0.581	29.5
4	X_7	120.23	0.539	0.105	36.0
5	X_8	57.40	4.98	0.721	25.1

TABLE 21. ANOVA FOR A SIMPLE REGRESSION OF Y ON X_2

Source	D.F.	S.S.	M.S.	V.R.	P
Regression	1	20.13	20.13	0.338	N.S
Residual about the line	22	1290.70	54.0		
Total about the mean	23	1310.87			

TABLE 22. ANOVA FOR A SIMPLE REGRESSION OF Y ON X_3

Source	D.F.	S.S.	M.S.	V.R.	P
Regression	1	53.76	53.76	0.913	N.S
Residual about the line	22	1257.11	52.6		
Total about the mean	23	1310.87			

TABLE 23. ANOVA FOR A SIMPLE REGRESSION OF Y ON X_4

Source	D.F.	S.S.	M.S.	V.R.	P
Regression	1	441.86	441.86	11.30	**
Residual about the line	22	869.01	139.05		
Total about the mean	23	1310.87			

TABLE 24. ANOVA FOR A SIMPLE REGRESSION OF Y ON X_7

Source	D.F.	S.S.	M.S.	V.R.	P
Regression	1	14.50	14.50	0.260	N.S
Residual about the line	22	1296.37	54.35		
Total about the mean	23	1310.87			

TABLE 25. ANOVA FOR A SIMPLE REGRESSION OF Y ON X_8

Source	D.F.	S.S.	M.S.	V.R.	P
Regression	1	681.06	681.06	23.41	**
Residual about the line	22	629.81	28.6		
Total about the mean	23	1310.87			

TABLE 26. MULTIPLE LINEAR EQUATIONS OF Y ON VARIOUS COMBINATIONS OF X_{1-8}

Equations	X_i	a	b	R	SE_E
6	X_{1-8}	-2.17	20.6,-4,162,8.1, 3.04,1.68,-1.75, 3.89	0.844	19.4
7	X_4, X_5, X_6	24.24	8.8,2.5,3.10	0.809	21.3
8	X_4, X_8	55.66	5.81, 3.97	0.765	23.3
9	X_8, X_3	15.15	18.4, 5.22	0.777	22.8
10	X_4, X_5	37.15	14.15, 3.92	0.724	24.9
11	X_4, X_3	64.32	16.67, 11.88	0.789	27.9

TABLE 27. ANOVA FOR A MULTIPLE LINEAR REGRESSION OF Y ON $X_1 - X_8$

Source	Degrees of freedom (D.F.)	Sum of square (SS)	Mean Square (MS)	Variance ratio	p
Multiple regression on X_1-X_8	8	943.58	117.97	66.33	**
Residual about regression	207	367.29	1.77		
Total about the mean	215	1310.87			

TABLE 28. ANOVA FOR A MULTIPLE LINEAR REGRESSION OF Y ON X_4 and X_8

Source	D.F.	S.S.	M.S.	V.R.	P
Multiple regression X_4 and X_8	2	768.87	384.4	32.0	**
Res. about the regression	45	542.34	12.0		
Total about the mean	47	1310.87			

TABLE 29. ANOVA FOR A MULTIPLE LINEAR REGRESSION OF Y ON X_4 and X_3

Source	D.F.	S.S.	M.S.	V.R.	P
Multiple regression on X_4 and X_3	2	532.52	266.26	15.39	**
Res. about the regression	45	778.35	17.296		
Total about the mean	47	1310.87			

TABLE 30. ANOVA FOR MULTIPLE LINEAR REGRESSION OF Y ON X_8 and X_3

Source	D.F.	S.S.	M.S.	V.R.	P
Multiple regression on X_8 and X_3	2	791.49	395.29	34.29	**
Residual about regression	45	519.38	11.54		
Total about the mean	47	1310.87			

TABLE 31. ANOVA FOR MULTIPLE LINEAR REGRESSION OF Y ON X_4 and X_5

Source	D.F.	S.S.	M.S.	V.R.	P
Multiple Regression on X_4 and X_5	2	687.07	343.53	24.78	**
Residual about regression	45	620.80	13.86		
Total about the mean	47	1310.87			

TABLE 32. ANOVA FOR MULTIPLE LINEAR REGRESSION OF Y ON X_4, X_5 and X_8

Source	D.F.	S.S.	M.S.	V.R.	P
Multiple Regression on X_4 and X_5	3	857.67	285.89	42.92	**
Residual about regression	68	453.20	6.66		
Total about the mean	71	1310.87			

TABLE 33. PERCENTAGE OF TOTAL VARIATION IN SITE INDEX ASSOCIATED WITH EACH AND ALL FACTORS

X_i	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	Total Variation
%	0.37	0.09	5.20	24.00	8.00	-2.9	-3.8	40.38	71.36

It appears that the chemical characteristics discussed in the study do not show sufficient correlation with site quality to be useful for the evaluation of site quality.

5. Regression Analysis

In this part of the study regression analyses were done for the evaluation of site indices from soil characteristics. Since soils are the result and the dynamic equilibrium of several factors, it is impossible to express soil behaviour completely with a single factor, but site index provides a useful measure of productivity. Eight independent variables X_1 - X_8 and one dependent variable (Y) were used for regression studies. Variables were:

X_1 - A_{oo} (Thickness in Inches)
X_2 - A_o " " "
X_3 - A_{oo} plus A_o " " "
X_4 - B_{11} " " "
X_5 - B_{12} " " "
X_6 - B_3 " " "
X_7 - Depth of solum (in inches)
X_8 - Depth to mottling (in inches)
Y - Site index (in feet at age 100)

The correlation matrix is given in Table 19. The study of the table shows that both X_4 and X_8 are highly

correlated with Y. Also some intercorrelation occurs between X_1 and X_6; X_2 and X_3; X_2 and X_5; X_3 and X_5; X_3 and X_6; X_4 and X_8; X_5 and X_7; X_6 and X_7.

Simple linear equations of Y on X_2, X_3, X_4, X_7, and X_8 are given in Table 20. This table also includes correlation coefficients (r), standard deviations (S.D) and standard errors of estimate (SE_E). The analyses of variance for a single regression of Y on X_2, Y on X_3, Y on X_4, Y on X_7, and Y on X_8 are given in Tables 21, 22, 23, 24, 25 respectively. A study of the tables shows that among the five simple linear equations only (3) and (5) could be best used for evaluation of the site. The standard error of estimate (SE_E) has been reduced to 25.1 feet in equation (5).

The calculated multiple linear regression equations are given in Table 26. The testsof the regression analysis of Y on X_{1-8}, Y on X_4 and X_8, Y on X_4 and X_3, Y on X_8 and X_3, Y on X_4 and X_5, and Y on X_4, X_5, and X_8 are shown in Tables 27, 28, 29, 30, 31 and 32 respectively. The standard error of estimate was reduced to 19.4 feet in equation (6) and to 21.3 feet in equation (7).

Percentage total variation and partial regression of each variable are given in Table 33. The highest per cent variation comes from X_8 (depth to mottling) with 40.38 per cent. The variable X_4(thickness of B_{11} horizon) contributes 24.00 per cent.

V. SUMMARY AND CONCLUSION

The soils on eight plots established on the University Research Forest Survey were studied by means of field observations and laboratory tests. The plots were established in 1951 for "a comprehensive study of site" (61) and the purpose of the present study was to characterize the sites on these plots which range in Douglas-fir site quality values from 80 to 180 feet at 100 years.

Three soil pits were established in each plot and from examination of these it was concluded that the soils could be broadly classified into three groups.

Plot No.	Soil Groups
1	Concretionary Brown
2,3 and 4	Minimal Podzol
5,6,7 and 8	Intergrade between Concretionary Brown and Minimal Podzol

Soils of the study area are derived from a glacial till under a Douglas-fir forest. These soils show a coarse texture between sandy loam and gravelly loamy sand. The clay content is low (1-4 per cent) in general and does not show an accumulation within a profile.

Some physical characteristics such as bulk density, total-pore space, macro-pore space, micro-pore space and hydraulic conductivity are determined for the soils.

Bulk density varied between 0.92 per cent and 1.81 per cent and increases with depth (Table 11, Figure 17). The micro-pore space was of a higher percentage than the macro-pore space (35 per cent, 25 per cent respectively). Total-pore space decreased by depth from 68 per cent to 30 per cent because of compaction. The hydraulic conductivity was high, probably due to the concretions and extreme stoniness of the soils (Table 11).

Bulk density, total pore space, macro-pore space and hydraulic conductivity values are found significant between the plots (Table 17). None of the characteristics were significant between pits, but some of them were significant between horizons for example macro and micro spaces and hydraulic conductivity.

Stoniness (Table 6) and the effect of stoniness on the available water have been found important. The available water has been determined on the basis of less than 2 mm. particles of soils and this amount corrected for soil skeleton and stoniness (Tables 16, 17). The available water varied between 0.73 and 1.42 inches for solums after the corrections where the values were 3.75 and 3.63 previously.

Soil reaction was acidic, varying from pH 3.67 - 5.91 (Table 8). Total exchangeable cations were high in organic horizons (highest 113 m.e./100 gm) and low in mineral horizons (10.0-20.0 m.e./100 gm) (Table 8).

Exchange calcium and potassium was low, calcium 0.3-0.5 m.e./100 gm. in mineral, 2-4 m.e./100 gm. in organic horizons. The amount of potassium was lower than clacium, 0.2 m.e./100 gm. in mineral and 1.0-2.0 m.e./100 gm. in organic horizons (Table 8).

Calcium saturation was calculated for all the soils analyzed. The value varies between 6.0-2.0 per cent. Parent materials are generally high in calcium-base saturation 4.0-15.0 per cent (Table 8).

The organic matter content of horizons shows a sudden decrease from organic to mineral horizon, from 80 per cent to 2 per cent. Occasionally a high organic matter content was found where the roots were restricted and a root mat has been developed in mineral horizons (Table 8).

Variance analyses of chemical data have shown that statistically the properties were non-significant between plots and pits, but significant between organic and mineral horizons. Soil reaction was significant between plots and horizons for solum (Table 18).

Those chemical properties of the soil (soil reaction, total cation exchange capacity, exchangeable calcium, and potassium, organic matter content) which analysed in labroatories did not show any correlation with site quality. Laboratory tests for total and available nitrogen were not carried out. Available water after being corrected for stoniness and the coarse skeleton of the various soils found related to site quality. As the amount of available water decreased site quality also decreased (Table 11).

Degree of slope and exposure did not show any correlation to site quality. Stoniness was important because of its effect on the available water as discussed previously.

Morphological futures of the profile were found most important for the evaluating of site quality (Table 5). The regression analysis was based on the data of those features. Chapter IV, sec. 5).

Among the morphological features, thickness of A_{oo}, A_o, $A_{oo} + A_o$, B_{11}, B_{12}, B_3, solum, depth to mottling, thickness of B_{11} horizon and depth to mottling were highly correlated to site quality.

Two simple linear equations were found useful for evaluation of site index.

$$Y = 100.73 + 11.35\ (X_4)$$

$$Y = 57.40 + 4.98\ (X_8)$$

Where X_4 and X_8 are thickness of B_{11} and depth to mottling. The standard error of estimate was reduced to $\pm$ 25.1 feet at the second equation.

The smallest standard error of estimate obtained (19.4 feet) when all the eight variables were used in the multiple regression equation of:

$$Y = 42.17 + 20.4\ (X_1) - 0.4\ (X_2) + 16.2\ (X_3) + 8.1\ (X_4) + 30.4\ (X_5) + 16.8\ (X_6) - 17.5\ (X_7) + 38.9\ (X_8)$$

The most practical equation for prediction of site index was found with variable of thickness of B_{11} horizon and depth to mottling. In this equation the standard error of estimate increased to $\pm$ 21.3 feet. The equation is given as:

$$Y = 15.15 + 18.4\ (X_8) + 5.22\ (X_3)$$

It was concluded from this study that available water was the most important factor as far as the soil-plant relationship was concerned. Stoniness had an important effect on the amount of available water and played an indirect role on the available water.

It was found that site index was predictable from certain soil morphological characteristics by regression equations. Two most important characteristics which were highly related to site index were the thickness of B_{11}

horizon and the depth to mottling.

Much work is still necessary to determine the relationship between soil properties and site quality.

BIBLIOGRAPHY

1. Aird, P.L., and E.L. Stone. 1955. Soil Characteristics and the Growth of European and Japanese Larch in New York. J. For. 53:6, pp. 425-429.

2. Alderfer, R.B., and F.G. Merkle. 1941. Structural Stability and Permeability of Native Forest Soils Compared with Cultivated Areas of the Same Soils Type. Soil Sci. Soc. Am. Proc. 6:98-103.

3. Aldrich, D.G., and F.M. Turrell. 1950. Effect of Soil Acidification on Some Chemical Properties of a Soil and the Plants Grown Thereon. Soil Sci. 70:83-90.

4. Allaway, W.H. 1957. pH, Soil Acidity, and Plant Growth, in Soils. Year Book of Agriculture. U.S.D.A.

5. Allen, G.S. 1942. Douglas-fir (A Summary of its Life History). B.C. Forest Service. Research Note 9.

6. _____, 1950. Applied Silviculture in the Coastal Region of British Columbia. For. Chron. 26:221-226.

7. _____, 1950. Forest Research at the University of British Columbia Faculty of Forestry. University of British Columbia Research Note 1.

8. Allison, I. 1957. Nitrogen and Soil Fertility in Soils. Year Book of Agriculture. U.S.D.A.

9. Anon. 1957. An Introduction to the Forest Soils of the Douglas-fir Region of the Pacific Northwest. Forest Soils Committee of the Douglas-fir region.

10. Armstrong, J.E. 1950. Surfacial Geology of New Estminster Map-Area, British Columbia. Geological Survey of Canada, Paper 57(5). Canada, Department of Mines and Technical Surveys.

11. Arren, J.L., and R.F. Collins. 1948. A Site Classification for Eastern Red Cedar in the Ozarks. Soil Sci. Soc. Am. Proc. 13:1, pp. 510-511.

12. Auten, J.T. 1945. Prediction of Site Index for Yellow Poplar from Soil and Topography, 43:662-668.

13. _____, 1953. Porosity and Water Adsorption of Forest Soils. Jour. Agr. Res. 46:997-1014.

14. Bayer, L.D. 1956. Soil Physics. Ed. 3, John Wiley and Sons, Inc., New York.

15. Black, C.A. 1957. Soil-Plant Relationships. John Wiley and Sons, Inc., New York.

16. Bloomfield, C. 1955. A Study of Podzolization. VI. The Immobilization of Iron and Aluminium. J. Soil Sci. 6:2, pp. 284-292.

17. Boggess, W.R. 1956, 1957. Weekly Diameter Growth of Shortleaf Pine and White Oak as related to Soil Moisture. Am. For. Soc. Proc. 83(9).

18. Broadbent. 1957. Organic Matter in Soils. Yearbook of Agriculture. U.S.D.A.

19. Bushnell, T.M. 1945. The "Catena-Drainage Profile" Key-Form as a Frame of Reference in Soil Classification. Soil Sci. Soc. Am. Proc. 9:219-222.

20. Cajander, G.K. 1926. The Theory of Forest Types. Acta Forestalia Fenica, vol. 29. 1-108.

21. Carlson, F.A. 1925. The Effect of Soil Structure on the Character of Alfalfa Root Systems. J. Am. Soc. Agron. 17:336-345.

22. Carmean, W.H. 1954. Site Quality for Douglas Fir in Southwestern Washington and its Relationship to Precipitation, Elevation and Physical Soil Properties. Soil Sci. Soc. Am. Proc. 18:3, pp. 330-334.

23. _____, 1956. Suggested Modifications of the Standard Douglas-fir Site Curves for Certain Soils in Southwestern Washington. For. Sci, 2:4, pp. 242-250.

24. Chandler, R.F., Jr. 1939. Cation Exchange Properties of Certain Forest Soils in the Adirondack Section. Jour. Agr. Res. 59:491-505.

25. Chandler, R.F., Jr. A Study of Certain Calcium Relationships and Base Exchange Properties of Forest Soils. Jour. For. 35:27-32.

26. _____, 1942. The Time Required for Podzol Profile Formation as Evidenced by the Mendenhall Glacial Deposits near Juneau, Alaska. Soil Sci. Soc. Am. Proc. 7:454-459.

27. Chandler, R.F., Jr., P.W. Schoen, and D.A. Anderson. 1943. Relation between Soil Types and the Growth of Loblolly Pine and Shortleaf in East Texas. Jour. For. 41:505-506.

28. Chapman, H.D., and W.P. Kelley. 1930. The Determination of the Replaceable Bases and the Base Exchange Capacity of Soils. Soil Sci. 30:391-406.

29. Childs, E.C. 1940. The Use of Soil Moisture Characteristics in Soil Studies. Soil Sci. 50:239-252.

30. Cline, G.M. 1949. Basic Principle of Soil Classification. Soil Sci. 67:81-91.

31. Coile, T.S. 1938. Forest Classification, Classification of Forest Sites with Special Reference to Ground Vegetation. Jour. For. 36:1062-66.

32. _____, 1942. Effect of Soil on the Development of Hardwood Understories in Pine Stands of the Piedmont Plateau. Soil Sci. 54:101-103.

33. _____, 1950. Soil and the Growth of Forests. Advances in Agronomy, vol. 4. Academic Press Inc., New York.

34. Cooper, H.P., W.R. Paden, and N.R. Page. 1948. Properties that Influence Availability of Calcium in the Soil to Plants. 65:75-96.

35. Copeland, O.L., Jr. 1958. Soil-site Index Studies of Western White Pine in the Northern Rocky Mountain Region. Soil Sci. Soc. Am. Proc. 22:3, pp. 268-269.

36. Cunningham, G.C. 1958. Forest Flora of Canada, Bulletin 121. Department of Northern Affairs and National Resources, Forestry Branch, Ottawa.

39. Day, H.J. 1959. List of Canadian Soils Names. The National Soils Surveys Committee. Canada, Department of Agriculture, Ottawa.

40. Department of Agriculture. 1956. Climate of British Columbia. Department of Agriculture Report.

41. Dimock, E.J. 1958. II. Litter Fall in a Young Stand of Douglas-fir. Northwest Sci. 32:1, pp. 19-29.

42. Duchaufour, P. 1957. L'action des divers types d'humus sur la processus d'entrainement dans le sol forestier. (The Action of Different Types of Humus on the Process of Depletion of Bases in Forest Soils.) Rev. For. Franc. 9:12, pp. 887-897.

43. Duley, F.L. 1939. Surface Factors Affecting the Rate of Intake of Water by Soils. Soil Sci. Soc. Am. Proc. 4:60-64.

44. Duncan, W.H. 1935. Wilting Coefficient and Wilting Percentage of Three Forest Soils of the Duke Forest. Soil Sci. 48:413-420.

45. Einspahr, D., and A.L. McComb. 1951. Site Index of Oaks in Relation to Soil and Topography in Northeastern Iowa. J. For. 49:10, pp. 719-723.

46. Faculty of Forestry, U.B.C. 1959. The First Decade of Management and Research, U.B.C. Forest 1949-1958.

47. Fisher, E.A. 1923. Some Factors affecting the Evaporation of Water from Soil. Jour. Agr. Sci. 13:121-143.

48. Flick, F.J. 1954. Classification Schemes for Forestry. J. For. 52:3, pp. 201-202.

49. Forristal, F.F., and S.P. Gessel. 1953. Soil Properties Related to Forest Cover Type and Productivity on the Lee Forest, Snohomish County, Washington. Soil Sci. Soc. Am. Proc. 19:3, pp. 384-389.

50. Forestry Handbook for British Columbia. 1959. The Forest Club, University of British Columbia, Vancouver 8, B.C.

51. Gaiser, R.N., and R.W. Merz. 1950. Stand Density as a Factor in Estimating White Oak Site Index. J. For. 48:572-574.

52. Gaiser, R.N. 1950. Relation Between Soil Characteristics and Site Index of Loblolly Pine in the Coastal Plain Region of Virginia and the Carolinas. J. For. 48:5, pp. 271-275.

53. _____, 1952. Readily Available Water in Forest Soils. Soil Sci. Soc. Am. Proc. 16:4, pp. 334-338.

54. _____, 1952. Root Channels and Roots in Forest Soils. Soil Sci. Soc. Am. Proc. 16:1, pp. 62-65.

55. Gessel, S.P., et al. 1935. Preliminary Report on Mineral Deficiencies in Douglas-fir and Western Red Cedar. Soil Sci. Soc. Am. Proc. 15:364-369.

56. Gessel, S.P., and Richard B. Walker. 1956. Height Growth Response of Douglas-fir to Nitrogen Fertilization. Soil Sci. Soc. Am. Proc. 20:97-150.

57. Gessel, S.P. 1949, 1950. Correlation between Certain Soil Characteristics and Site for Douglas-fir in Northwestern Washington. Soil Sci. Soc. Am. Proc. 14:333-337.

58. Gieger, R. 1957. The Climate Near the Ground, tr. N. Stewart. University Press, Cambridge, Mass., 2nd printing.

59. Goodman, R.N. 1953. Influence of Organic Mulches on Reaction and Exchangeable Calcium Content. Soil Sci. 53:459-466.

60. Greene. 1953. Soil Moisture under a Young Loblolly Plantation. Soil Sci. Soc. Am. Proc. 17:147-150.

61. Griffith, B.G. 1960. Growth of Douglas-fir at the University of British Columbia Research Forest as Related to Climate and Soil. The University of British Columbia.

62. Haig, I.T. 1929. Colloidal Content and Related Soil Factors as Indicators of the Quality. Yale University School For. Bul. 24.

63. Hansen, Henry P. 1947. Climate versus Fire and Soils as Factors in Postglacial Forest Succession in the Puget Inland of Washington. Am. Jour. of Sci. 245:265-268.

64. Heiberg, S.O., and D.P. White. 1956. A Site Evaluation Concept. J. For. 54:7-10.

65. Hill, W.W., A. Arnst, and R.M. Bond. Method of Correlating Soils and Douglas-fir Site Quality. J. For. 46:835-841.

66. Hills, G.A. 1952. The Classification and Evaluation of Site for Forestry. Res. Rep. Ont. Dept. Lds. For. 23(41).

67. _____, 1955. Field Methods for Investigating Site. Ontario, Dept. of Lands and Forests.

68. _____, 1959. Comparison of Forest Ecosystheme (Vegetation and Soils) in Different Climatic Zones. Forest Ecosystem Symposium IX. International Botanical Congress, Canada (Mimeograph).

69. _____, 1959. A Ready Reference to the Description of the Land of Ontario. Division of Research, Ontario. Dept. of Lands and Forests.

70. Holland, et al. 1958. Soil Survey of Pitt Meadows Municipality. Department of Agriculture, Kelowna.

71. Holliday, W.E.D. 1937. A Forest Classification for Canada. Canada, Department of Mines and Resources, Bull. 89.

72. Hoover, M.D., and H.A. Lunt. 1952. A Key for the Classification of Forest Humus Type. Soil Sci. Soc. Am. Proc. 16:4, pp. 368-370.

73. Ilvessaco, Y. 1929. Notes on Some of the Forest (Site) Types in North America. Acta Forestalia Fennica 34:39, pp. i-iii.

74. Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, New York.

75. Jenny, Hans, and C.D. Leonard. 1934. Functional Relationship between Soil Properties and Rainfall. Soil Sci. 38:363-381.

76. Jenny, H. 1935. The Clay Content of the Soil as related to Climatic Factors, Particularly Temperature. Soil Sci. 40:111-128.

77. Joffe, J.S. 1936. Pedology. Rutgers University Press, New Brunswick.

78. Joseph, A.F. 1925. Clay as Soil Colloids. Soil Sci. 20:84-94.

79. Kelley, C.C. and R.H. Spilsbury. 1939. Soil Survey of the Lower Fraser Valley. Dominion of Canada, Dept. of Agriculture, Pub. 650.

80. Kendew, W.G., and D. Ker. 1955. The Climate of British Columbia and the Yukon Territory. Edmund Cloutier, Queen's Printer, Ottawa.

81. Ker, J.W. 1952. An Evaluation of Several Methods of Estimating Site Index of Immature Stands. For. Chron. 28:63-74.

82. _____, 1953. Growth of Immature Douglas-fir by Tree Classes. For. Chron. 29(4):367-373.

83. Kirkham, D. 1947. Studies of Hillside Seepage in the Cowan Drift Area. Soil Sci. Soc. Am. Proc. 12:73-80.

84. Kirkham, D. and C.L. Feng. 1949. Some Test of the Diffusion Theory, and Laws of Capillary Flow, in Soils. Soil Ci. 67:29-40.

85. Koeppe, E.D. and George C. De Long. 1957. Weather and Climate. McGraw-Hill, New York.

86. Kohnke, H. 1946. The Practical Use of the Energy Concept of Soil Moisture. Soil Sci. Soc. Am. Proc. 11:64-66.

87. Kramer, P.J. 1944. Soil Moisture in Relation to Plant Growth. Botan. Rev. 10:525-529.

88. Lahee, F.H. 1931. Field Geology. New York, McGraw-Hill, 3rd ed.

89. Lamp, J. Jr., and J.C. Chapman. 1943. Effect of Surface Stone on Erosion, Evaporation and Soil Moisture. J. Am. Soc. Agron. 35:567-578.

90. Lawton, K. 1945. The Influence of Soil Aeration on the Growth and Absorption of Nutrients by Corn Plants. Soil Sci. Soc. Am. Proc. 10:263-268.

91. Leaf, A.L. and T. Keller. 1956. Tentative Technique for Determining the Influence of Soil on Growth of Forest Plantation. Soil Sci. Soc. Am. Proc. 20:1, pp. 110-112.

92. Lemmon, P.E. 1955. Factors Affecting Productivity of Some Lands in the Willamette Basin of Oregon for Douglas-fir Timber. J. For. 53:5, pp. 323-330.

93. Linteau, A. 1953. Site Classification (in the Canadian Boreal Forest). Pulp Paper Mag. Can. 54:7, pp. 147-155.

94. Long, H.D. 1955. The Site Climax as an Indication of Site Conditions. Pulp Paper Mag. Can. 54:7, pp. 155-157.

95. Loren, R.W., and J.N. Spaeth. 1945. The Growth of Conifers on Prairie Soils. J. For. 43:253-256.

96. Lull, H.W., and J.H. Axley. 1958. Forest Soil Moisture Relations in the Coastal Plain Sand of Southern New Jersey. F. Sci. 4:1, pp. 2-19.

97. Lutz, J.F., W.L. Nelson, W.C. and C.E. Scarsbrook. 1946. Effects of Cover Crops on Pore-size Distribution in a Coastal Plain Soil. Soil Sci. Soc. Am. Proc. 11:43-46.

98. Lutz, J.F. 1952. Mechanical Impedance and Plant Growth, Soil, Physical Conditions and Plant Growth. Agronomy 2. Academic Press Inc., New York.

99. Lutz, H.J., and R.F. Chandler, Jr. 1946. Forest Soils. John Wiley and Sons, Inc., New York.

100. Lyon, T.L., H.O. Buckman, and N.C. Brady. 1952. The Nature and Properties of Soils, The MacMillan Company.

101. Lyons, C.P. 1954. Trees, Shrubs and Flowers in British Columbia. 2nd ed. J.M. Dent and Sons Ltd., Vancouver.

102. Marbut, C.F. 1935. Soils of the United States. Atlas of American Agriculture, pt. III. United States Government Printing Office, Washington, D.C.

103. Matiak, I.S. 1953. Influence of Soil Conditions on the Development of Root Systems of Tree and Shrub Species. Pedology J.:24-30.

104. McCalep, S.B., and M.G. Cline. 1950. Profile Studies of Normal Soils of New York: III. Physical and Chemical Properties of Brown Forest and Gray-brown Podzolic Soils. Soil Sci. 70:315-328.

105. McMinn, R.G. 1957. Soils and Forest Growth in the Douglas Fir Region on Vancouver Island. Abstract in Agricultural Institute Review 12:3, p. 44.

106. Mergen, F., and K.M. Malcolm. 1955. Effect of Hemlock (Tsuga canadensis) and Red Pine (Pinus resinosa) on Physical and Chemical Properties of Two Soils. Ecology 36:3, pp. 468-473.

107. Michail, S. 1959. A Study of the Growth of Douglas-fir (Pseudotsuga Menziesii) Seedlings. M.Sc. Thesis, University of British Columbia.

108. Mordecai, Ezekiel, and Karl A. Fox. 1959. The Methods of Correlation and Regression Analysis, Linear and Curvilinear. John Wiley and Sons, Inc., New York.

109. Muckenhirn, R.J., E.P. Whiteside, E.H. Templin, R.F. Chandler, Jr., and L.T. Alexander. 1949. Soil Classification and the Genetic Factors of Soil Formation. Soil Sci. 67:93-107.

110. Musgrave, G.W., and Free. 1936. Some Factors which Modify the Rate and Total Amount of Infiltration of Field Soils. J. Am. Soc. Agron. 28:727-739.

111. Musgrave, G.W., and M.L. Nichols. 1942. Organic Matter in Relation to Land Use. Soil Sci. Soc. Am. Proc. 7:22-28.

112. Nelson, T.C., and W.R. Beaufait. 1956, 1957. Studies in Site Evaluation for Southern Hardwoods. Soc. Amer. For. Proc.:67-70.

113. Nikiforoff, C.C. 1937. The Inversion of the Great Soil Zones in Western Washington. Geogr. Rec. 27.

114. _____, 1941. Morphological Classification of Soil Structure. Soil Sci. 52:193-211.

115. _____, 1941. Morphological Classification of Structure. Soil Sci. 52:193-211.

116. _____, 1949. Weathering and Soil Evolution. Soil Sci. 67:219-230.

117. Nygard, I.J., P.R. McMiller, and F.D. Hole. 1912. Characteristics of Some Podzolic, Brown Forest and Chernozems Soils of the Northern Portion of the Lake States. Soil Sci. Soc. Am. Proc. 16:2, pp. 123-129.

118. Olmstead, L.B., and W.O. Smith. 1938. Water Relations of Soils. Soils and Men. Yearbook of Agriculture, U.S.D.A.:897-910.

119. Page, J.B., and C.J. Willard. 1946. Cropping System and Soil Properties. Soil Sci. Soc. Am. Proc. 11:81-88.

120. Peech, M. et al. 1947. Methods of Soil Analysis for Soil Fertility Investigations. U.S.D.A., Cir. 757.

121. Ralston, C.W. 1951. Some Factors Related to the Growth of Longleaf Pine in the Atlantic Coastal Plain. J. For. 49:408-412.

122. Ralston, C.W., and R.L. Barnes. 1955. Soil Properties Related to the Growth and Yield of State Pine Plantation in Florida. Soil Sci. Soc. Am. Proc. 19:1, pp. 84-85.

123. Report on the Third Conference of the National Soil Survey Committee, Saskatoon, Sask., October 31 to November 5, 1955.

124. Report on the Meetings of the Western Section of the National Soil Survey Committee, Vancouver, June 20-21, 1957.

125. Report on the Meetings of the Western Section of the National Soil Survey Committee, Edmonton, Alta., December 8-11, 1958.

126. Richards, L.A. 1941. A Pressure-Membrane Apparatus for Soil Solutions. Soil Sci. 51:377-385.

127. _____, 1943. Fifteen Atmospheric Percentages as Related to the Permanent Wilting Percentage. Soil Sci. 51:377-385.

128. _____, 1948. Porous Plate Apparatus for Measuring Moisture Retentions and Transmission in Soil. Soil Sci. 66:105-110.

129. Richards, L.A., and C.H. Wadleigh. 1952. Soil Water and Plant Growth in Soil Physical Conditions and Plant Growth:73-251, Academic Press, New York.

130. Richards, L.A., and R.F. Chandler, Jr. 1943. Some Physical and Chemical Properties of Mature Podzol Profiles. Soil Sci. Soc. Am. Proc. 8:379-383.

131. Riecken, F.F., and D.G. Smith. 1949. Family, Series, Type, Phase. Soil Sci. 67:107-115.

132. Rowe, J.S. and E.A. Colman. 1951. Distribution of Rainfall in Two Mountain Areas of California. Tech. Bull. U.S. Dept. Agric. No. 1048.

133. Rowe, J.W. 1953. Forest Sites - A Discussion. For. Chron. 29:3, pp. 278-289.

134. _____, 1959. Can We Find a Common Platform for the Different Schools of the Forest Type Classification? Forest Ecosystem Symposium IX. National Botanical Congress, Canada. (Mimeograph).

135. Rowles, C.A. 1957. The Contribution of Soil Science. Agr. Inst. Rev. March/April.

136. Rowles, C.A., L. Farstad, D.G. Laird. 1956. Soil Resources of British Columbia. 9th British Columbia Natural Resources Conference. February 22-24, 1956. Victoria, British Columbia.

137. Russell, M.B. 1938. Physical Properties of Soils. Soils and Men. Yearbook of Agriculture, U.S.D.A.: 897-910

138. Russell, E.J. 1950. Soil Conditions and Plant Growth, 8th ed. Longmans, London.

139. Schlots, F.E., W.J. Lloyd, and C.E. Deardorff. 1959. Some Soil Characteristics which affect Root Penetration and Timber Site Quality of Douglas-fir in Western Washington. Soil Sci. Soc. Am. Proc. 20:1, pp. 101-105.

140. Schreiner, Ernst J. 1950. Genetics in Relation to Forestry. J. For. 48:33-38.

141. Scotfield, C.S. 1945. The Measurement of Soil Water. J. Agr. Res. 71:375-402.

142. Shaw, C.F. 1927. The Normal Capacity of Soils. Soil Sci. 23:303-317.

143. Sisam, J.W.B. 1938. Site as a Factor in Silviculture. Dominion Forest Service Research Note 54, Ottawa, Canada.

144. Smith, G.D., and H.R. Aandahl. 1957. Soil Classification and Surveys. The Yearbook of Agriculture, U.S.D.A.

145. Smith, R.M., and D.R. Browning. 1947. Soil Moisture Tension and Pore Space Relations for Several Soils in the Range of the "Field Capacity." Soil Sci. Soc. Am. Proc. 12:17-21.

146. Snedecor, George W. 1949. Statistical Methods, 4th ed. The Iowa State College Press.

147. Soils and Men. 1938. Yearbook, U.S. Dept. of Agriculture.

148. Soil Survey Manual. 1951. U.S. Dept. of Agriculture. Soil Survey Staff. Agricultural Handbook 18.

149. Starr, W.A., and L.C. Wheeling. 1950. Land Capability Methods for Conserving Washington Soils. Popular Bulletin 200. Institute of Agricultural Sciences, State College of Washington, Pullman, Washington.

150. Steinbrenner, E.C. 1955. The Effect of Repeated Tractor Trips on the Physical Properties of Forest Soil. Northern Sci. 29:4, pp. 155-159.

151. Steinbrenner, E.C., and S.P. Gessel. 1955. The Effect of Tractor Logging on the Physical Properties of Some Forest Soils in Southwestern Washington. Soil Sci. Soc. Am. Proc. 19:3, pp. 772-776.

152. Stephenson, R.E., and C.E. Shuster. 1937. Physical Properties of Soils that Affect Plant Nutrition. Soil Sci. 44:23-46.

153. Storbe, P.C. 1945. Suggested System of Field Classification for Canadian Soils. Proceedings of the First Conference of the National Soil Survey Committee, Ottawa, Ont.

154. Storie, R.E. 1938. Effect of Claypan on the Growth and Production of Apples in California. Soil Sci. Soc. Am. Proc. 3:317-322.

155. Storie, R.E., and H.E. Weisland. 1948, 1949. Rating Soils for Timber Sites. Sci. Soc. Amer. 13: 499-509.

156. Stout, B.B. 1952. Species Distribution and Soils in the Harvard Forest. Harv. For. Bull. 24.

157. Tarrant, R.F. 1949. Douglas-fir Site Quality and Fertility. J. For. 47:716.

158. Tarrant, R.F. 1949-1950. The Role of Organic Matter as a Source of Nitrogen in Douglas-fir Forest Soils. Forest Abstract 11:38.

159. Thorp, J.D. 1931. The Effect of Vegetation and Climate upon Soil Profiles in Northern and Northwestern Wyoming. Soil Sci. 32:283-297.

160. Thorp, J.D., and G.D. Smith. 1949. Higher Categories of Soil Classification: Order, Suborder, and Great Soil Groups. Soil Sci. 67:117-129.

161. Travernier, R., and G.D. Smith. 1957. The Concept of Braunerde (Brown Forest Soil) in Europe and the United States. Advances in Agronomy, vol. IX: 217-289. Academic Press Inc., New York.

162. Trimble, G.R., Jr., and Sidney Weitzman. 1956. Site Index Studies of Upland Oaks in the Northern Appalachians. For. Sci. 2:3, pp. 162-173.

163. Turner, L.M. 1937. Some Soil Characters Influencing the Distribution of Forest Types and Rate of Growth of Trees in Arkansas. Jour. For. 35:5-11.

164. Tyner, E.H. 1940. The Use of Sodium Metaphosphate for Dispersion of Soils for Mechanical Analysis. Soil Sci. Soc. Am. Proc. 4:106-113.

165. Van Doren, C.A., and A.A. Klingebiel. 1945. Permeability Studies on Some Illinois Soil. Soil Sci. Soc. Am. Proc.:51-55.

166. Weaver, R.A., T.M. Bushnell, and G.D. Scarseth. 1948. Correlative Studies of Indiana Soils. Soil Sci. Soc. Am. Proc. 13:484-493.

167. Weaver, J.E., and F.E. Clements. 1938. Plant Ecology, 2nd ed. McGraw-Hill, New York.

168. Weihmeyer, F.J., and A.H. Hendrickson. 1931. The Moisture Equivalent of a Measure of the Field Capacity of Soils. Soil Sci. 32:181-183.

169. _____, 1946. Soil Density as a Factor in Determining the Permanent Wilting Percentage. Soil Sci. 62:451-456.

170. _____, 1948. Soil Density and Root Penetration. Soil Sci. 65:487-493.

171. Wheeling, L.C. 1936. Shot Soils of Western Washington. Soil Sci. 41:35.

172. White, D.P., and R.S. Wood. 1958. Growth Variations in a Red Pine Plantation Influenced by a Deep-lying Fine Soil Layer. Soil Sci. Soc. Am. Proc. 22:2, pp. 174-175.

173. Wilde, S.A. 1949. Glinka's Later Ideas on Soil Classification. Soil Sci. 67:411-414.

174. Wilde, S.A., E.D. Steinbrenner, R.S. Pierce, R.C. Dosen, and D.T. Pronin. 1953. Influence of Forest Cover on the State of the Ground Water Table. Soil Sci. Soc. Am. Proc. 17:1, pp. 65-67.

175. Wilde, S.A. 1954. Reaction of Soils: Facts and Fallacies. Ecology 35:1, pp. 89-92.

176. Wilde, S.A., and A.L. Leaf. 1955. The Relationship Between the Degree of Soil Podzolization and the Composition of the Ground Cover Vegetation. Ecology 36:1, pp. 19-22.

177. Willis, L.G., and J.R. Piland, 1931. Ammonium Calcium Soil Sci. 31:5-23.

178. Yoder, R.E. 1957. The Signification of Soil Structure in Relation to the Tilth Problem. Soil Sci. Soc. Am. Proc. 21:21-23.

179. Young, Harold E. 1954. Forest Soils-site Index Studies in Maine. Soil Sci. Soc. Am. Proc. 19:1, pp. 85-87.

180. Youngberg, C.T., and H.F. Scholz. 1949, 1950. Relation of Soil Fertility and Rate of Growth of Mixed Oak Stands in the Driftless Area of Southwestern Wisconsin. Soil Sci. Soc. Am. Proc. 14:331-332.

181. Zahner, R. 1954. Estimating Loblolly Pine Sites in the Gulf Coastal Plain. J. For. 52:6, pp. 448-449.

182. Zinke, P.J. 1959. Site Quality of Douglas-fir and Ponderosa Pine in Northwestern California as Related to Climate, Topography and Soil. For. Soc. Amer. (65) Proc.:167-171.

A P P E N D I X

PLOT #1 - PLOT #8

PLOT #1

PARENT MATERIAL:

Soil is developed on hard glacial till. Texture is coarse sandy loam. Moderately stony, but these pits have poorer drainage than the others. Bedrock was not encountered and it is assumed that the till is deeper in this location. The soil is not quite so stony as in the other plots.

TOPOGRAPHY:

Slopes to the southwest at approximately 13 per cent. The micro-topography is very hummocky. Hummocks vary from 1 to 5 feet high.

MOISTURE RELATIONSHIPS:

These pits have moderate surface drainage, but profile drainage is restricted. Drainage appears to be the poorest of all the plots examined. There appears to be considerable lateral movement of water along the upper surface of the till.

VEGETATION:

Site index is "180". Trees are mainly Douglas fir. The forest on this plot consists of the biggest and the best trees of all the plots. Ground cover is shaded down and consists mainly of sword fern. This is the most luxuriant

growth of sword fern noted on ths plots. On the surface there is 5-10 per cent cover wood.

STONINESS:

Light stones and boulders. Not as stony as the other plots. Fine to medium gravel scattered throughout the profile.

GREAT SOIL GROUP:

Concretionary Brown.

PROFILE PIT 1

Lowest in Elevation.

Horizon	Depth	Description
A_{00}	2¼-2"	Needles, twigs, mainly coniferous needles. Thickness varies just a little.
A_0	2-0"	Thickness varies from 1 inch to 3 inches. Dark brown black. Consists of partially decomposed organic matter with numerous fine angular granitic rock fragments. Some charcoal and rotting wood, numerous fine roots, mycelium. Soft and fluffy.
A_2	trace	Just trace. 2.5Y 5/2 to 4/2 grayish brown. Discontinuous horizon. It varies up to 1 inch thick in very local spots. Sandy loam texture. Weak medium sub-angular blocky structure. Friable, non-sticky, non-plastic, numerous roots, fine gravel. This horizon is so incipient. Sampled for pH only.
B_{11}	0-6"	Minimum thickness 2 inches and maximum 8 inches. 10YR 3/4 "very dark yellowish brown" to "dark reddish brown" 5YR 3/3-3/5. Coarse sandy loam, fine gravel. Strong coarse angular blocky structure Consistence firm to hard. Non-sticky,

Horizon	Depth	Description
		non-plastic. Numerous roots. Angular granitic stones cobbles and medium gravels. This horizon consists of some charcoal. Considerable orstein also some white mycelium.
B_{12}	6-18"	7.5YR 4/2 "brown to dark brown" to 7.5 YR 4/4 which is "brown to dark brown". Some of soil 5YR 5/8 yellowish red. Coarse sandly loam. Thickness varies from 4 to 16 inches. Weak medium to coarse subangular blocky. Consistence slightly firm non-sticky, non-plastic, considerable numerous roots, angular stones, cobbles. Medium gravels and some weak orstein in places.
B_3	18-28"	Varies from 21 inches to 31 inches to the C_1 horizon. Light color 5Y 6/1 "gray to brown to dark brown" 7.5YR 4/4 which is "brown to dark brown" (moist). Some dark areas 5YR 4/4 which is reddish brown. Highly mottled coarse sandy loam structure; from weak coarse subangular blocky breaking to weak subangular blocky. Consistence slightly firm to firm. Non-sticky, non-plastic, stones, cobbles and

Horizon	Depth	Description
		gravels but not numerous. Few roots. Thin root mat on the C_1. Very wet, some decaying roots.
C_1	28"+	Varies from 21 to 31 inches from the surface, 2.5Y 7/2 light gray with mottles to reddish brown 5YR 4/4 which is reddish brown, some yellowish brown mottles 10YR 5/8. Main color yellowish brown. Matrix is light gray color. Coarse sandy loam fine gravel, angular stones and cobbles. Massive, very hard and compact. Impermeable to water penetration. No roots.

PROFILE PIT 2

Approximately same elevation as pit number 1. This is most southerly pit. Till varies from 24 to 26 inches from the surface. This solum slightly shallower than pit number 1. More boulders and also this pit has rotted logs which are 25 inches wide and 10 inches thick. This pit is similar to profile number 1, except the horizons are shallower and they have less orstein.

Horizon	Depth	Description
A_{00}	2¼-2"	This profile same as profile pit number 1. Only thin in some places.
A_0	2-0"	Minimum ¼ inch, maximum thickness 5 inches, rotted logs as above. Moss, charcoal in this zone.
A_2	trace	Up to ½ inch under logs. Very incipient. Sampled for pH only under the logs.
B_{11}	0-6"	Minimum 3 inches maximum 8 inches. It is not quite as strong developed. Orstein as in profile pit number 1. Some shot.
B_{12}	6-18"	Minimum 8 inches thick. Maximum 18 inches. Same as in profile 1. Some mottling. There is no orstein.
B_3	18-24"	Minimum 2 inches, maximum 9 inches. Some decayed roots in all horizons exceot C_1.

Horizon	Depth	Description
C_1	24-27"	24 - 27 inches from the surface. Some hard compact till, same as profile number 1. Water moving on top of till. Moving down slope. Collected in bottom of the pit. Large boulders embedded in the till.

PROFILE PIT 3

Highest pit in elevation at east. Deepest solum about 30 inches. Also has the best drainage of the three pits of this plot. There is lateral movement of water off surface on the till about 30 - 33 inches deep.

Horizon	Depth	Description
A_{00}	1¼-1"	Varies up to ½ inch. Minimum 0 inches, especially in the hummocks.
A_0	1-0"	Minimum ¼ inch. Maximum 2 inches. This A_0 is thinner than pit number 1 and 2. It is in part covered by mineral soil as a result of erosion. Average 1 inch.
A_2	trace	Varies from 0 to trace. Too thin to sample.
B_{11}	0-6"	Minimum 2 inches, maximum 8 inches. Similar to number 1. Some orstein but not as good as pit 1. Orstein just in pockets.
B_{12}	6-18"	Minimum 7 inches, maximum 17 inches; mottles, roots; just trace orstein in some places. Fairly firm and yellowish red color. Otherwise is same as other pits.
B_3	18-29"	Minimum 5 inches, maximum 13 inches. Otherwise same as the other pits.
C_1	29"+	Gray mottled, very hard compact, no root penetration and not much water penetration. Large boulder in one

Horizon	Depth	Description
		end of the pit. Drainage slightly better than pits number 1 and 2.

PLOT #2

PARENT MATERIAL:

Mantle of till (probably Alderwood type) over bedrock. Depth of till is unknown, but is generally over 4 feet. Gravelly sandy loam till and appears to be more stony than at pits 3 and 4.

TOPOGRAPHY:

About ¼ - ½ mile of slope above the plot. Slope gradient of macro-topography is 10-15 per cent towards the south-southwest. Micro-topography is hummocky. Hummocks 20-30 feet apart and 2-4 feet high. Pits are located about 50-75 feet from edge of steep bluff into Blaney Creek.

MOISTURE RELATIONSHIPS:

Surface runoff is moderate. Internal drainage is moderate to rapid. Very little water in the profile pits and probably not too much lateral water movement over the till surface.

VEGETATION:

Fir, cedar and hemlock coming in. Stumps and odd old cedar snags. A large number of small 2-6 inches windfall logs. Some ground cover of bracken fern and salal. Feather moss relatively abundant.

STONINESS:

Very stony on surface subangular to rounded cobbles and stones. Stones in the parent till material are angular to subangular.

GREAT SOIL GROUP:

Podzol (minimal).

PROFILE PIT 1

Most southerly and lowest of 3 pits.

Horizon	Depth	Description
A_{00}	3½-2"	Varies up to 2½ inches thick. Mainly dead fir and cedar needles; branches and twigs; low density.
A_0	2-0"	Thickness varies from 1 - 3 inches. Charcoal wood chips. White and yellow mycelium. Humified partially, few recognizable plant remains. Odd fine angular gravel.
A_2	0-½"	Thickness varies from nill to 1½ inches. 10YR 7/2 light gray to 5Y 6/1 gray (moist), sandy loam. Fine angular gravel. Very weak coarse subangular blocky breaking to medium weak granular. Non-sticky and non-plastic, friable. Soft numerous fine roots.
B_{11}	½-1½"	Thickness varies from ½ to 2 inches. 7.5YR 5/6 strong brown to 5YR 3/4 dark reddish brown. Coarse sandy loam. Very weak subangular blocky. Much fine angular gravel and some shot. Massive to structureless. Breaking to weak granular.

Horizon	Depth	Description
B_{12}	1½-16"	Gradual boundary to B_3. 7.5YR 6/4 light brown (moist) to 7.5 YR 4/4 brown to dark brown, mottles, sandy loam. Much fine angular gravel and shot. Massive to structureless breaking to weak granular.
B_3	16-28"	2.5Y 4/4 brown. Mottles 7.5YR 4/4 brown to dark brown (moist) similar to B_{12} above.
Orstein	28-36"	Discontinuous. Light yellowish brown to dark brown, mottled, strongly cemented gravel and sandy material. Massive.
C_1	36"+	2.5Y 6/2 - 5/2 light brown gray to brownish gray (mottles). Extremely hard. Moist, mottling strong brown around stones. No roots. Very slowly permeable. Sampled only near the top of the horizon.
	NOTE:	Entire profile is extremely cobbly and subangular.

PROFILE PIT 2

Horizon	Depth	Description
A_{00}	1½-1"	Thickness varies up to 2 inches. Similar to pit 1. Much moss and twigs.
A_0	1-0"	Thickness up to 3 inches. Similar to pit 1. Partially decomposed wood.
A_2	0-½"	Thickness varies from nil to 2 inches. Similar to pit 1.
B_{11}	½-2½"	Thickness varies from 1 - 3 inches. Similar to pit 1. Moderately firm in places. Moderate coarse blocky.
B_{12}	2½-17"	Thickness varies from 13 to 20 inches. Strong coarse blocky, pockets of orstein; coarse around cobbles and between cobbles. Very firm. Few roots and less roots in bottom flat. Highly mottling. Similar to pit 1. Otherwise, small thin root mat at the bottom.
B_3	17-40"	Stronger and yellowish mottling and firmer than pit 1. Very few roots.
C_1	40"+	Similar to pit 1. Till is drier than in pit 1. Sampled only near the top of the horizon.

PROFILE PIT 3

Most easterly pit. Same slope as the other pit. Solum varies from 8 inches to 28 inches above hard compat till. Hummocky micro-topography. A_0 is developed but A_2 is not.

Horizon	Depth	Description
A_{00}	1½-1"	Same as in previous pits.
A_0	1-0"	Thickness up to 4 inches. Stick same as in the other pits.
A_2	trace	Discontinuous. Appears to be buried in spots as a result of erosion or turbulence within the profile as uprooting of trees. Too small to sample.
B_{11}	0-3"	Discontinuous, varies up to 6 inches in places, same as the other pits.
B_{12}	3-18"	Varies from 12 to 30 inches. Average 15 inches thick.
B_3	18-28"	Discontinuous, similar to pit 1 and 2. There is root mat at the bottom of this horizon.
C_1	28"+	Till varies from 8 inches to 28 inches from the surface. Very hard and compact, solum is moist but till is dry. Sampled on top of the horizon only. No orstein observed in this pit.

PLOT #3

PARENT MATERIAL:

Thin mantle of till (probably Alderwood) varying from 1 inch or 2 up to 4 feet thick, in pit observed, lying over bedrock which appears to be mainly granite. Till is a gravelly sandy loam texture, weathered to the bedrock.

TOPOGRAPHY:

Slope from 25-35 per cent towards south-southeast. Elevation approximately 1,200 feet. Pit No. 1 is 15-20 feet lower than pit number 2. Pit number 3 is about 4 feet higher than pit number 1. Micro-topography consists of many small depressions up to 2 feet deep. Around each tree there is an accumulation of soil up to 1 foot high.

MOISTURE RELATIONSHIPS:

Surface drainage is rapid. Internal drainage of solum is good, but water is moving laterally along the bedrock; except for that which is trapped in pockets in the bedrock.

VEGETATION:

Douglas fir (moderately dense), cedar with hemlock coming in. Ground cover is very light. Feather moss and some salal and bracken fern.

STONINESS:

Very strong numberous angular cobbles and some angular boulders on the surface and some throughout the profiles. All fragments are very angular.

GREAT SOIL GROUP:

Podzol (minimal podzol).

PROFILE PIT 1

Most southerly and lowest in elevation.

Horizon	Depth	Description
A_{00}	2¼-2"	Mainly dead coniferous needles, cedar, Douglas fir, twigs, barks. White and yellow mycelium in patches at the bottom of this horizon. Feather or step-ladder moss grows in abundance in top of this horizon and is included in the sample. Thickness varies from 1/8 to 3/4 inches. Very few seed cones, fluffy, low density. Moist.
A_0	2-0"	Varies from a trace to 3 inches in thickness. Mainly unrecognizable vegetative remains. Decayed needles, twigs, barks, wood bits, charcoal pieces. Wet, many small roots, white and yellow mycelium penetrate this horizon. Some small rock fragments 1/8 - ½ inch in diameter.
A_2	0-3"	Thickness varies from trace to 3 inches. Many places absent. Some pockets up to 7 inches thick associated with a thick A_{00} and A_0 and also depression in micro-topography. 10YR

Horizon	Depth	Description
		5/2 grayish brown (moist) sandy loam to loamy sand (wet). Massive to very weak medium angular blocky. Non-sticky, non-plastic, friable. Organic matter appears to be low. Numerous roots, large, extending through the horizon. Much fine angular gravel. Odd pits of charcoal in thicker portions. Some white and yellow mycelium in thicker portion. Horizon sampled only in portions ½ inch or more thick.
B_{11}	3-7"	Discontinuous horizon ¼ to 5 inches thick. 5YR 4/4 - 3/4 reddish brown to dark reddish brown (moist). Not associated with depth of A_2. Thicker B_{11} seems to occur at higher points of micro-topography. Sandy loam, much fine gravel. Very weak subangular coarse blocky breaking, shotty and crumb. Friable, soft. Non-sticky and non-plastic. Numerous roots, large and small. Angular cobbles and stones through horizon. No mycelium. Pockets of 5YR 4/6 yellowish red loam which may have been burnt by forest fires. Some occasional charcoal bits.

Horizon	Depth	Description
B_{12}	7-20"	Thickness varies from 10 to 13 inches. 10YR 4/4 dark yellowish brown (moist). Coarse sandy loam, fine angular gravels. Small mottles some shotty concretions up to ¼ inch in diameter. Wet, very weak subangular blocky breaking to fine to coarse shotty. Friable, non-sticky and non-plastic. Main concentration of roots ends at the bottom of this horizon. Odd bit of charcoal along root channels. Extremely permeable to water movement.
B_3	20-46"	Thickness varies with depth to bedrock or 4 to 40 inches. 5Y 5/3 olive (moist) mottles colored 5YR 4/4 reddish brown sandy loam, fine angular blocky. Fine angular gravel. Very wet. Few roots. Moderately permeable. Weak angular coarse blocky to weak angular fine blocky. Non-sticky, slightly firm, non-plastic.
Root Mat	46-48"	Thickness from 2½ inches to 3 inches. Dark reddish brown. Water saturated loam. Appears to be high in organic matter.

PROFILE PIT 2

Most northerly pit in plot #3. Approximately 25 feet higher than profile pit 1.

Horizon	Depth	Description
A_{00}	2¼-2"	Mainly dead coniferous needles. Cedar leaves. Sparse moss cover, twigs, white mycelium growth. Very few fir cones. Fluffy, low density, moist.
A_0	2-0"	Maximum of 5 inches minimum of ¼ inch. 5YR 3/6, 10YR 2/2 black to reddish brown (moist). Numerous bits of charcoal, bits of wood to numerous fine roots, some white mycelium, some small granitic rock fragments.
A_2	0-1	Discontinuous, up to 4 inches thick in places. 2.5Y 5/2 to 4/2 grayish brown to 5Y 4/1 dark gray, moist. Sandy loam, some fine angular gravel, weak medium angular blocky structure, friable, non-sticky, non-plastic. Numerous large and small roots. A few small angular cobbles, a few bits of charcoal.
B_{11}	1-1½"	Discontinuous, varies in thickness from ¼ to 2 inches, average 1 inch. 5Y 3/4 dark reddish brown. Seems to occur mainly

Horizon	Depth	Description
		where A_2 is best developed. Sandy loam, fine angular gravel, very weak subangular blocky gravel, breaking to shot. Numerous shotty concretions. Friable, non-sticky and non-plastic, small angular granitic stones, numerous roots.
B_{12}	1½-17½"	Varies from 8 to 24 inches thick. Faintly mottled. 10YR 4/4 dark yellowish brown mottles to 7.5YR 4/4 strong brown (to 7.5YR 5/6). Coarse sandy loam, vary weak coarse subangular blocky structure, highly aggregated. Some fine to coarse shotty concretions friable, non-sticky and non-plastic. Numerous roots. Small angular granitic cobbles.
B_3	17½-28"	At north end of pit only. At south end of pit horizon stops at 10 inches to bedrock. Very wet. 5Y 5/3 olive to 5/4 dark olive, dark reddish brown to strong brown mottles. Coarse sandy loam. Weak coarse angular blocky breaking to weak fine angular blocky structure. Slightly firm, non-sticky and non-plastic, small angular granitic cobbles and angular gravel roots present but not as numerous as in B_{12}.

Horizon	Depth	Description
Root Mat	28"+	½ - 1 inch thick. Same as in profile pit 1. Water seeping over bedrock. Water collected in north end of pit.

PROFILE PIT 3:

Most easterly pit. Approximately 10 feet higher than profile pit No. 1, and 15 feet lower than profile pit No. 2.

Horizon	Depth	Description
A_{00}	1¼-1"	Same as in profile pit number 2.
A_0	1-0"	Varies from ½ to 4 inches thick. Same as in profile pit No. 2.
A_2	0-½"	Varies from 0 to 1 inch thick. Discontinuous. This horizon has its poorest representation in this pit.
B_{11}	½-1"	Discontinuous. Varies from ¼ to 1 inch thick.
B_{12}	1-16"	Varies from 10 to 15 inches thick. Same as in profile pits 1 and 2.
B_3	16"+	Shallowest depth to bedrock is 20 inches and deepest is 28 inches. Horizon varies from 4 - 12 inches. Same as in profile pits 1 and 2. Very wet. Seepage.

PLOT #4

PARENT MATERIAL:

Thin mantle of till (probably Alderwood) and is found in profile 3 and 4. Profiles 1 and 2 are very thin deposits over bedrock but material is derived from the till. Bedrock appears to be mainly granitic. Till is gravelly sandy loam weathered to a depth of 4 feet.

TOPOGRAPHY:

Slopes to the east at 10 - 15 per cent, average with short local slopes up to 30 per cent. Elevation is first over 1,200 feet, above sea level. Plot 4 is about 50 feet higher than plot 3. Hummocky micro-topography, with hummocks up to 6 feet high and 20 feet apart. Roots of trees sit about 6-7 inches above soil surface indicating that soil material has been eroded away from them.

MOISTURE RELATIONSHIP:

Surface drainage is medium to rapid. Internal drainage is good until it becomes restricted in the parent material. Water moves laterally when the bedrock is encountered. Plot #4 is about 50 feet from the crest of the ridge, hence not much water storage to seep down.

VEGETATION:

Moderately dense stand of small Douglas fir, with some cedar and hemlock coming in. Ground cover is shaded down and consists mainly of moss.

STONINESS:

Very stony on the surface and throughout the profile. Mainly angular granitic boulders and angular cobbles. Bedrocks come to the surface occasionally. Very rocky.

GREAT SOIL GROUP:

Podzol (minimal podzol).

PROFILE PIT 1:

This pit is most north easterly in this plot. It is lowest. There is a bedrock on the bottom (all the bottom). Pit slopes from 24 inches to 17 inches; from north to south. There is a few roots on the bedrock.

Horizon	Depth	Description
A_{00}	2¼-2"	Dead hemlock, cedar, fir needles, leaves and twigs. Very few granitic fragments. Much roots. Some charcoal present. Some hemlock cones. Much moss, a few mycelium.
A_0	2-0"	Minimum thickness 1/8 inch, maximum 3 inches. Numerous fine roots, some charcoal. White mycelium present. Moderately decomposed. Color 2.5Y 2/10 black to 10YR 2/1 black (moist).
A_2	trace	Just trace. Some pockets up 3/4 inch. Sampled for pH only.
B_{11}	0-2¼"	Minimum thickness 1/2 inch maximum 3 inches. Color 5YR 3/4 dark reddish brown (moist) coarse sandy loam. Weakly angular and subangular blocky. Some shot. Non-sticky, non-plastic, numerous roots. Permeable to water movement.

Horizon	Depth	Description
B_{12}	2¼-10"	Thickness varies up to 12 inches. 2.5Y 4/4 olive. Coarse sandy loam, much fine angular and subangular gravel. Some shot, weak. Non-sticky and non-plastic. Numerous roots and cobbles. Permeable to water movement.
B_3	10-20"	Minimum 12 to 20 inches. 2.5Y 4/4 olive brown to 7.5YR 4/4 brown to dark brown, coarse sandy loam. There is much gravel subangular up to 1 inch. Non-sticky non-plastic. Several roots present.
		Only bedrock all the bottom of pit. Some root mats present on the bedrock (about 20 inches deep from the surface).

PROFILE PIT NO. 2

Most easterly pit in this plot. All the bottom is bedrock. Shallowest pit. Depth of the pit varies from one inch to 8 inches. There are many roots on the bedrock.

Horizon	Depth	Description
A_{00}	1-1/8-1"	Same as profile pit No. 1.
A_0	1-0"	Same as profile pit No. 1.
A_2	trace	Same as profile pit No. 1. Sampled only for pH.
B_{11}	0-1½"	Minimum ¼ maximum 1 inch. Color 7.5YR 3/2 dark brown to 4/4 brown to dark brown. Otherwise same as profile pit No. 1.
B_{12}	1½-5"	Minimum 2 inches, maximum 6 inches. Color 7.5YR 3/2 dark brown. No B_3 horizon.
Bedrock		Hard granitic rocky layer.

PROFILE PIT NO. 3

Most north westerly pit and about 5 feet above profile pit 4. This pit is situated on the small knoll in one and a slight depression on the other end. This profile is moist whereas profile pit 4 and 1 are not.

Horizon	Depth	Description
A_{00}	1¼-1"	Absent in places. Similar to that of profile pit 4.
A_0	1-0"	Varies in thickness from ½ to 3 inches. Similar to that of profile pit 4.
A_2	0-1/8"	Thickness up to ½ inch, absent in most places. Similar to that of profile pit 4.
B_{11}	1/8-4"	Thickness varies up to 7 inches. Similar to that of profile pit 4.
B_{12}	4-18"	Thickness varies from 4 - 24 inches. Similar to that of profile pit 4.
B_3	18-24"	Thickness varies from 5 to 8 inches. Similar to profile pit 4.
C_1	24-36"	Average thickness of C_1 is 5 inches. Similar to that of profile pit 4.
Orstein	36-43"	Thickness varies from 0 - 8 inches, occurs in pockets 5YR 4/8 yellowish red to 5YR 3/3 dark reddish brown (moist) to 7.5Y 6/6 reddish yellow. Coarse

Horizon	Depth	Description
		sandy loam, massive, breaking to strong large blocky. Non-plastic, non-sticky, compact to indurated. Wet, fine angular granitic gravel. Very few roots.
Root Mat	43-45"	Varies from 1 inch to 4 inches. Very wet and spongy 5YR 3/3 - 3/1 dark reddish brown coarse gravelly sandy loam. Very weak medium subangular blocky. Friable, non-sticky, non-plastic. High in roots and organic. Odd fine angular gravel.

PROFILE PIT 4

Most north-easterly pit in Plot #4 and also the deepest soil to bedrock--42 inches. It is second highest pit in Plot #4.

Horizon	Depth	Description
A_{00}	1½-1¼"	Dead fir and cedar needles and leaves, barks, twigs, occasional granitic fragments. 5 to 10 per cent of pit area is covered by decaying logs. Mycelium, some charcoal present. Moderate density.
A_0	1¼-0"	Ranges up to 4 inches in places, firm 10YR 2/1 to 2/2 (moist), Many fine roots. Moderately well decomposed. Mycelia concentrated in woody portions. Some charcoal, some granitic rock fragments. Dense, some charcoal present, numerous fine roots present.
A_2	0-¼"	Discontinuous, varies up to 2 inches thick. 2.5Y 5/2 grayish brown (moist), sandy loam, numerous granitic fragments. Structure: weak, medium blocky breaking to medium granular. Consistence, non-sticky thin horizon. Stoniness, fine angular gravels.

Horizon	Depth	Description
B_{11}	¼-2"	This horizon is discontinuous. Varies from 0 to 3 inches thick. 5YR 3/4 dark reddish brown (moist) coarse sandy loam. Weak subangular medium blocky, breaking to medium granular shotty concretions structure. Non-sticky, non-plastic friable. Numerous roots, fine angular gravels some angular cobbles (over 3 inches). Permeable water movement.
B_{12}	2-13"	Varies up to 23 inches thick. 2.5Y 4/4 olive brown (moist) with some strong brown mottling. Coarse sandy loam with fine angular gravel. Some shots. Very weak subangular medium blocky breaking to weak fine blocky. Non-plastic, non-sticky, friable. Numerous roots. Angular stones and cobbles permeable to water movement.
B_3	13-23"	Varies from 5 inches to 10 inches. 2.5Y 6/2 light brownish gray to 2.5Y 4/4 olive brown (moist). Highly mottled 5YR 4/3 reddish brown. Coarse sandy loam. Moderately strong subangular coarse blocky. Consistence is firm. Non-

Horizon	Depth	Description
		sticky non-plastic. Numerous roots with several root mats in the lower portions.
C_1	23"+ to bedrock	Bedrock occurs from 42 to 50 inches. Color 2.5Y 7/2 light gray to 5YR 4/7 yellowish red. Coarse sandy loam. Non-sticky. Non-plastic. Very firm and compact. Very few roots occurring as mats in top of the horizon, stoniness same as that of the other horizons.

PLOT #5

PARENT MATERIAL:

Cobbles, sandy loam till. Angular and subangular cobbles.

TOPOGRAPHY:

10 - 15 per cent slopes to the south. Micro-topography hummocky and hollowy, about 2 to 4 feet range in elevation.

VEGETATION:

Site index 155-160 (approximate). Cedar, fir, hemlock coming in. Many small windfalls. Ground cover is tall blue huckleberry, bracken fern, salal moss. Twin flowers moderately dense.

MOISTURE RELATIONSHIPS:

Moisture holding capacity of this soil is probably high as compared to plot 7 and 8, because solum is deeper. Surface runoff is moderate to rapid. Internal drainage is rapid.

STONINESS:

Moderate stoniness. Mainly subangular cobbles.

GREAT SOIL GROUP:

Intergrade between Concretionary Brown and Podzol.

PROFILE PIT 1

Most north-easterly pit.

Horizon	Depth	Description
A_{00}	1½-1¼"	Similar to those of plot 7 and 8.
A_0	1¼-0"	Varies from ½ to 3 inches thick. It is made up of some wood and logs and charcoal. Odd bit of fine gravel, friable. Many fine roots. Some yellow and white mycelium.
A_2	0-¼"	Very discontinuous varies up to 2 inches thick. 10YR 4/2 dark gray brown (moist) sandy loam, massive, wet, friable, fine roots, some fine angular gravel. Sampled only for pH.
B_{11}	¼-2"	Varies from ½ to 4 inches with some tongues extending to 6 inches. 7.5YR 4/4 brown to dark brown, mottle very dark brown. Sandy loam, subangular blocky breaking to granular and shotty. Compact cemented in the thicker portions which occur around cobbles, many large and small roots.
B_{12}	2-20"	Varies from 18 to 20 inches thick. 10YR 4/4 dark yellow brown. Slightly mottled, sandy loam. Fine gravel, very

Horizon	Depth	Description
		weak subangular coarse blocky breaking to granular and shotty. Some tongues of A_2 and B_{11} extend into this horizon. Some roots.
B_3	20-36"	Fairly uniform thickness. 2.5Y/5/4 light olive brown. Mottles 10YR 5/6 yellow brown (moist). Sandy loam weak subangular coarse blocky, few roots. Friable, non-sticky, non-plastic.
C_1	36-42"	Numerous large mottles, 2.5Y 6/2 light brown gray, mottles 7.5YR 5/6 strong brown (moist) sandy loam, massive very compact, non-sticky and no roots.
C_2	42"+	Unmottled sandy loam. Very compact.

PROFILE PIT 2

Horizon	Depth	Description
A_{00}	2¼-2"	Similar to that of Pit 1.
A_0	2-0"	Similar to that of pit 1. Mycelium, fine granitic fragments.
A_2	0-1"	Discontinuous thickness varies from 0 to 3 inches. Fine angular gravel, similar to that of pit 1.
B_{11}	1-4"	Varies in thickness from 1 to 6 inches. Sometimes extending to 12 inches. Compact, and cemented. Numerous large shots. Shots up to ½ inch in diameter.
B_{12}	4-14"	Varies from 8 to 12 inches thick. Tongues of A_2 and B_{11} extend into this horizon otherwise similar to that of pit 1.
B_3	14-26"	Boundary in this B_{12} and C_1 are distinct. Otherwise similar to pit 1. It is very shallow on the end of the pit.
C_1	26-34"	Similar to pit 1.
C_2	34"+	Bottom C_1 too small root mats. Otherwise similar to that of profile pit 1.

PROFILE PIT 3

Horizon	Depth	Description
A_{00}	2¼-2"	Similar to that of pit 1.
A_0	2-0"	Thickness varies from 1 to 6 inches. Contains some partially decomposed logs. Similar to that of pit 1.
A_2	0-1"	Nearly continuous horizon. Thickness varies from ¼ to 4 inches with occasional tongue down to 8 inches. Similar to that of pit 1.
B_{11}	1-5"	Quite variable thickness from ½ to 8 inches. Nearly continuous tongues to 12 inches. Similar to that of pit 1.
B_{12}	5-18"	Thickness varies from 1 to 21 inches. Similar to that of pit 1.
B_3	18-30"	Thickness varies from 8 to 18 inches. Similar to that of pit number 1.
C_1	30-36"	Similar to that of pit number 1.
C_2	36"+	Hard, compact sandy glacial till. Similar to that of pit 1.

PLOT #6

PARENT MATERIAL:

Soil derived from the same glacial till as we have found on the area. Hard, compact, sandy loam, stony.

TOPOGRAPHY:

Slopes 14 per cent to the southwest. Micro-topography extremely hummocky about 1-4 feet high. There is just a small gully on the east side of the plot.

MOISTURE RELATIONSHIPS:

Surface drainage is moderately rapid. Profile drainage is moderate in the solum but restricted by parent material. Water moves laterally on the till surface, which occurs 24 to 30 inches from the surface.

VEGETATION:

Mainly Douglas fir, thin ground cover of fern and moss.

STONINESS:

Moderately severe stoniness some big boulders numerous stones and cobbles, medium size gravels.

GREAT SOIL GROUP:

Intergrade between Concretionary Brown and Podzol.

PROFILE PIT 1

This is the lowest and shallowest of the three pits of plot #6. Also it is the most southwest pit.

Horizon	Depth	Description
A_{00}	2-1¼"	Dead needles, moss, wood, twigs. Some mycelium, some charcoal and fine granitic rock fragments.
A_0	1¼"-0"	Minimum ½ inch, maximum 3 inches. Numerous roots, fine granitic rock fragments, charcoal. Soft, some mycelium but not very much.
A_2	trace	Minimum 0 inches, maximum 1 inch. Discontinuous 5Y 5/1 which is gray. Coarse sandy loam. Fine gravels, medium fine subangular blocky structure. Soft and friable. Non-sticky, non-plastic. Numerous roots, fine granitic rock fragments. Sampled only for pH.
B_{11}	0-6"	Minimum 2 inches, maximum 10 inches. Color: 7.5YR 5/6 strong brown to 5YR 3/3 dark reddish brown coarse sandy loam texture. Moderately strong to medium fine subangular blocky structure. Firm consistence, some orstein developed. Roots, angular granitic stones,

Horizon	Depth	Description
		granitic gravels, shotty concretions present.
B_{12}	6-18"	7.5YR 5/6 strong brown faintly mottled. Minimum 10 inches, maximum 16 inches. Coarse sandy loam. Weak moderate medium to fine subangular blocky. Friable and firm. Numerous roots, numerous stones, cobbles, fine gravels.
B_3	18-24"	Varies from 0 to 8 inches. 5YR 6/1 gray also 7.5YR 5/6 strong brown, 4/4 is yellowish red. Coarse sandy loam texture to loamy sand. Weak, medium to fine blocky. Slightly firm. Non-sticky and non-plastic, very few roots, except some thin root mats just about on the till. Numerous stones, cobbles, gravels.
C_1	24"+	Very stony. 2.5Y 5/2 which is grayish brown. Some slightly mottled coarse sandy loam to loamy sand. Very hard compact. Impermeable for moving of water. Massive, no roots.

PROFILE PIT 2

This is the highest pit in Plot #6. It is central.

Horizon	Depth	Description
A_{00}	2¼-2"	Similar to profile pit 1.
A_0	2-0"	Minimum 1 inch, maximum 3 inches. Otherwise same as profile pit 1.
A_2	trace	Not enough to sample.
B_{11}	0-6"	Minimum 2 inches, maximum 12 inches. This horizon is the same as profile pit 1, except a little better developed orstein.
B_{12}	6-18"	Similar to profile pit 1 except thicker horizon. It contains pockets of orstein and there is a weak iron pan forming at the bottom of this horizon directly above the till. This pan is not continuous. N.B. Two samples taken from this horizon. One of them mottled to B_2, the other from orstein formation both in the topsoil and in the subsoil.
B_3	18-40"	Similar to that of profile pit 1.
C_1	40"+	It is the same as in the other pit, except the till occurs at a greater depth from the surface than in profile pit 1.

PROFILE PIT 3

Most westerly pit. This pit represents a poor soil in comparison with the other two pits.

Horizon	Depth	Description
A_{00}	2¼-2"	Thickness varies from 1/8 to 1 inch. Many twigs. Few mosses. Very thin in some places. Very loose. Many dead fir and hemlock, cedar needles. Granitic fragments and some fine gravels. Some barks, bits of wood.
A_0	2-0"	Thickness varies from 1/8 inch to 3 inches. Many granitic fragments. Some charcoal. Some fungi. White and yellow mycelium. Some roots. There are pockets of A_0 in B_{11}, around roots.
A_2	0-½"	Discontinuous. Thickness varies from 0 to 1½ inches. There are some pockets under the pockets of A_0. Otherwise same as that of profile pit 1. Sampled only for pH.
B_{11}	½-4½"	Thickness varies from 5½ to 15 inches. Similar to that of profile pit 1.
B_{12}	4½-20"	Thickness varies from 7 to 25 inches. No orstein. Similar to that of profile pit 1.

Horizon	Depth	Description
B_3	20-26"	Thickness varies from 4 to 15 inches. Similar to that of profile pit 1.
C_1	26-32"	Thickness varies from 2 inches to 5 inches. Similar to that of profile pit 1.

PLOT #7

PARENT MATERIAL:

30 to 40 inches of till (probably Alderwood type) over bedrock which consists mainly of granite and argillite. Till contains many large stones and cobbles which are angular to subangular, some rounded. Stones are over 2 feet in diameter. Till may be weathered.

TOPOGRAPHY:

Slopes 10 per cent to south. Steep bluff into Blaney Creek 200 to 300 feet to the east. Land also slopes off gradually to the west, beyond the plot. Micro-topography is pronounced hummocks and all elevation varying from 3 to 4 feet. Slopes uphill to the north, continuing some distance.

MOISTURE RELATIONSHIPS:

Moderate to rapid on surface. Internal drainage is rapid in the solum. Moisture holding capacity is similar to that of Plot #8, because the impermeable layers are nearly in the same depth in both profiles.

VEGETATION:

Similar to that of Plot #8.

STONINESS:

Moderate to severe. Stones occupy 10 per cent of the surface area.

TENTATIVE GREAT SOIL GROUP:

Concretionary Brown and Podzol.

PROFILE PIT 1

Most northerly pit.

Horizon	Depth	Description
A_{00}	1¾-1½"	Dead fir cedar, hemlock needles, feather moss growing in this horizon, hemlock cones scattered on the surface.
A_0	1½-0"	Decayed forest litter. Many roots. Thickness varies from 1 to 4 inches. Some bits of charcoal and wood. Friable. Black to dark brown.
A_2	0-1/8"	Discontinuous and absent in many places. It is not enough to sample. 10YR 5/2 gray brown (moist) sandy loam. Friable massive, non-sticky and non-plastic.
B_{11}	1/8-1½"	Thickness varies from ½ to 2 inches with some tongues extending to 6 inches. 7.5YR 4/6 very strong brown. Slightly mottled, friable very weak subangular blocky. Very few shots, fine subangular gravel. Non-sticky, non-plastic. Coarse sandy loam texture. Numerous roots.
B_{12}	1½-22"	Varies from 16 to 25 inches thick. 10YR 5/6 yellowish brown slightly mottled. Sandy loam, friable. Very

Horizon	Depth	Description
		weak subangular blocky, breaking to granular and shots. Non-sticky and non-plastic.
B_3	22-36"	Varies from 10 to 20 inches thick. 2.5Y 5/6-5/4 light yellow brown to light olive brown. Slightly mottled sandy loam to loam. Very weak subangular blocky breaking to granular. Friable compact in low part in some places. Non-sticky, non-plastic. This horizon sits on the bedrock (D). Some root mats on the bottom of this horizon. Very wet. Some roots.
Stoniness:		Subangular to rounded cobbles and stones through profile. Entire profile appears to be low in organic matter.

PROFILE PIT 2

Most easterly pit. Not much plant cover. Bottom bedrock.

Horizon	Depth	Description
A_{00}	2-1/8-2"	Not much moss and plant life. Otherwise the same as profile pit 1.
A_0	2-0"	Much more charcoal than in the others. Some rotting wood. Dense white and yellow mycelium. Thickness varies from ¼ to 4 inches. Otherwise the same as pit 1.
A_2	0-1"	Not continuous. Varies from 0-3½ inches. Similar to that of pit 1. Some pockets.
B_{11}	1-2½"	Thickness varies from ½ to 4½ inches. Tongues up to 8 inches. Similar to that of pit 1.
B_{12}	2½-19"	Thickness varies from 10 inches to 25 inches. Otherwise the same as profile pit 1.
B_3	19-30"	Minimum thickness 6 inches. Maximum 15 inches. Similar to that of pit 1.
Orstein	30-33"	Up to 3 inches. Cemented. Massive. Discontinuous.
C_1	33"+	Very thin over the bedrock.

PROFILE PIT 3

The most southerly pit and also the deepest. 50 inches to 30 inches slope. Bedrock bottom.

Horizon	Depth	Description
A_{00}	2¾-2½"	Not much moss and plants on the surface. Much twigs. Otherwise the same as profile pit 1 and profile pit 2.
A_0	2½-0"	Thickness varies from ½ to 4 inches. Mycelium white and yellow. Some granitic fragments. Otherwise same.
A_2	0-½"	Not continuous. Thickness minimum 0 inches and maximum 1½ inches. Sampled for pH only. Otherwise the same as profile pit 1.
B_{11}	½-3"	Thickness varies from 0 to 5 inches. Tongues down to 12 inches. Similar to that of others.
B_{12}	3-20"	Minimum thickness 3 inches maximum 25 inches. Otherwise the same as profile pit 1 and profile pit 2.
B_3	20-35"	Thickness varies from 2 to 10 inches. Otherwise the same as profile pit 1 and profile pit 2.

PLOT #8

PARENT MATERIAL:

Glacial till over bedrock (Alderwood till probably). Till is over 4 feet thick. Bedrock.

TOPOGRAPHY:

Micro-topography, uniform slope from 5 - 10 per cent. Sloping towards the south. Plot is situated about 100 feet west of Blaney Creek. There is a steep bluff about 50 feet high between plot and Blaney Creek. Topography slopes down, west of the plot. Micro-topography consists of minor undulations about 1-2 feet high and 10-15 feet apart.

MOISTURE RELATIONSHIPS:

Profile was wet at the time of observation. Surface runoff is moderate. Moisture holding capacity of the soil profile will be similar to that of plot #2. Internal drainage will be moderate because of cemented till in the C horizon.

VEGETATION:

Mainly cedar, second growth Douglas fir, ground cover is light, consisting of bracken fern and salal. Some tall blue huckleberry. Moderate cover, feather moss.

STONINESS:

Moderate stoniness. Stones mainly granitic angular to subangular.

GREAT SOIL GROUP:

Intergrade Concretionary Brown and Podzol.

PROFILE PIT 1

Most southerly. This pit sits on a knoll.

Horizon	Depth	Description
A_{00}	3¼-3"	Similar to that of profile pit 3 and 2.
A_0	3-0"	Similar to that of profile pit 3.
A_2	0-¼"	Absent in many places. Varies from nil to 1 inch. Similar to that of profile pit 5. Sampled only for pH.
B_{11}	¼-2"	Thickness varies 0 to 3 inches. With the odd tongue extending to 6 inches. Similar to that of pit 3. Deeper tongues are cemented.
B_{12}	2-25"	Varies from 16 to 25 inches thick. Similar to that of pit 3. With some tongues of C_1 extending into it.
B_3	25-27"	Discontinuous horizon. Similar to that of pit 3.
C_1	27-40"	Similar to that of pit 3.
C_2	40"+	Similar to that of pit 3.

PROFILE PIT 2

Horizon	Depth	Description
A_{00}	3¼-3"	Thickness varies from 1/10 to ½ inch. Similar to pit number 3.
A_0	3-0"	Thickness varies from 1½ to 6 inches. In the thicker portions there are decomposed woods. Otherwise similar to pit number 3.
A_2	0-¾"	Almost continuous horizon. Thickness varies ¼ to 5 inches. Otherwise similar to the other pit.
B_{11}	¾-2½"	Continuous horizon varies from ½ to 3 inches. Except for occasional tongues which may occur down to 12 inches thickness. Thicker portions occur under thick A_2 horizon. Slightly more cemented than that of pit 3.
B_{12}	2½-22"	Varies from 16 to 20 inches thick. It is quite similar to profile pit 3. Except it is slightly cemented. Occasionally there are root mats. Root mats occur near the bottom. Numerous loose pockets probably along old root concentrations.
B_3	22-25"	Nearly uniform thickness boundary between B_3 and B_{12} is somewhat indistinct

Horizon	Depth	Description
		except that B_3 is more cemented.
		Similar to that of pit 3.
C_1	25-32"	Thickness varies 5 to 10 inches.
		Similar to that of profile pit 3.
C_2	32"+	Similar to that of profile pit 3.

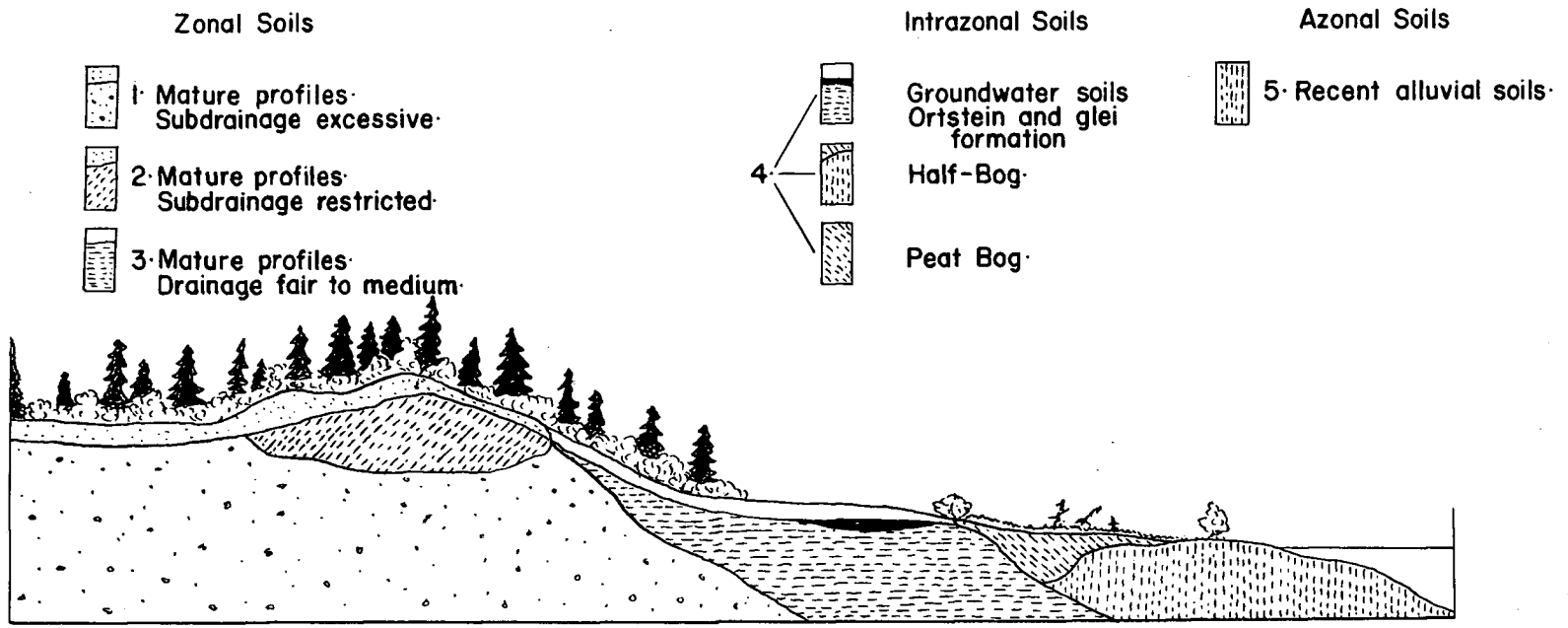
PROFILE PIT 3

This is most northerly pit.

Horizon	Depth	Description
A_{00}	2¾-2½"	Mainly dead fir needles, some cedar needles, feather moss growth on this horizon. Loose, non-compact, some twigs, bits of wood. Some white mycelium. Fine granitic fragment.
A_0	2½-0"	Thickness varies from 1 inch to 4 inches. Black to very dark brown (moist color). Some charcoal, spongy, many fine roots, very few recognizable plant remains some bits of wood, friable.
A_2	0-½"	Discontinuous thickness varies ¼ to 3 inches. Thick parts in this horizon occur under thick A_0 horizon. Coarse sandy loam. 10YR 5/2 to 4/2 gray brown to dark gray brown (moist). Very weak medium subangular blocky, wet consistence friable. Few bits of charcoal, non-sticky and non-plastic. Many large and small roots.
B_{11}	½-2"	Thickness varies from ½ to 3 inches. 7.5YR 4/4 - 3/6 brown to dark brown (moist) coarse sandy loam. Very weak to

Horizon	Depth	Description
		massive, many large concretionary shots. (½ - ¼ inch) friable, non-sticky and non-plastic. Some places the shots appear to be weakly cemented together. Some bits of charcoal.
B_{12}	2-15"	Thickness varies from 10 inches to 18 inches. Slightly mottled, 7.5YR 5/6 strong brown. The mottles 7.5YR 3/6 dark brown (moist) coarse sandy loam. Structure very weak subangular blocky, breaking to very weak granular and shot. This shot is less than ¼ inch. Some fine angular gravel, non-sticky, non-plastic friable. Numerous roots. Small tongues of A_2 and C_1 occur, occasionally throughout horizon. Orstein-like occurs around some of the stones.
B_3	15-18"	Quite uniform, thickness. 7.5YR 4/4 brown to dark brown (moist). Slightly mottled. Coarse sandy loam. Moderate subangular coarse blocky. Some shot, compact, non-sticky and non-plastic, slightly cemented. Few roots.
C_1	18-36"	Thickness varies about from 12 to 24 inches. 2.5Y 8/2 - 5/2 light gray to

Horizon	Depth	Description
		light brownish gray. Mottles. 7.5Y 5/8 - 6/8 strong brown to reddish yellow (moist), loam to sandy loam. Massive to coarse angular blocky. Compact very few roots. Non-sticky, non-plastic. Root mat occurs discontinuously at the bottom of this horizon.
C_2	36"+	2.5Y 5/4 light olive brown (moist). Some mottling loam to sandy loam. Massive. Very compact and moist. No roots. Throughout whole profile some angular to subangular gravel and cobbles occur. Organic matter below A_0 appears very low except in orstein-like formations.



Fig· I Illustration (after Kelley & Spilsbury) showing the general features of the soil zone and its associates in the lower Fraser Valley (79)·

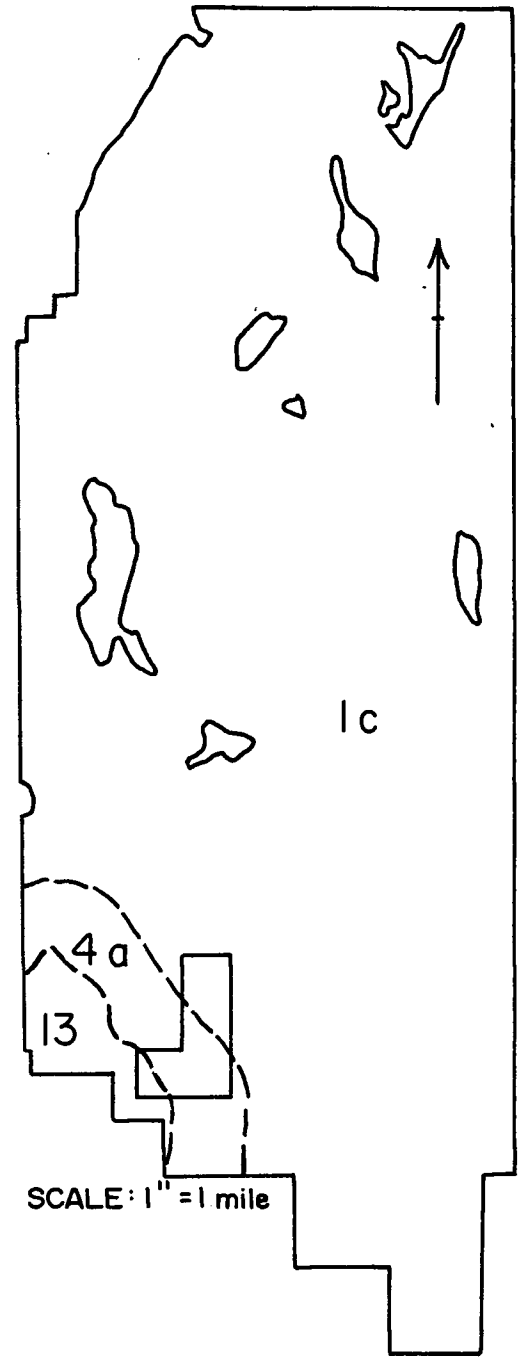


Fig. 2 University Research Forest showing the Surficial Geology according to Map 16-1957 of the Geological Survey of Canada, Dept. of Mines & Technical Surveys.

Legend:

Ic, rough mountainous country in which granitic and associated rock types occur at or near surface. Commonly overlain by till and outwash sand, gravel, and silt.

4 Surrey Till (glacial deposits): 4a, sandy to silty till and minor sub-stratified drift up to 75 feet thick but generally less than 25 feet.

13 Whatcom Glacio-Marine Deposits: stoney clayey silt and silty clay, clay, silt, and sand 25 to 300 feet thick.

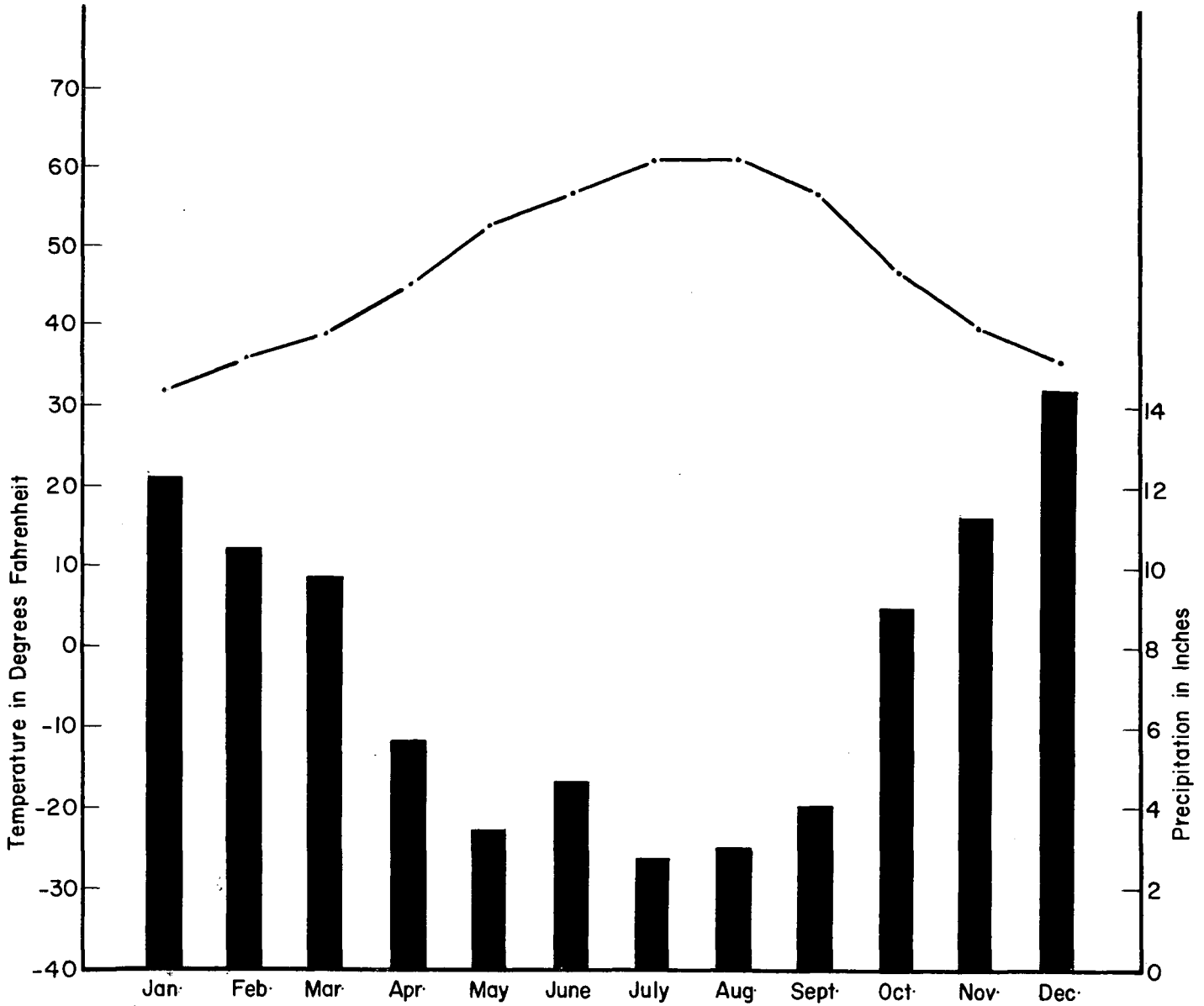


Fig. 3 Average monthly precipitation and temperature at Haney, 1946-1958

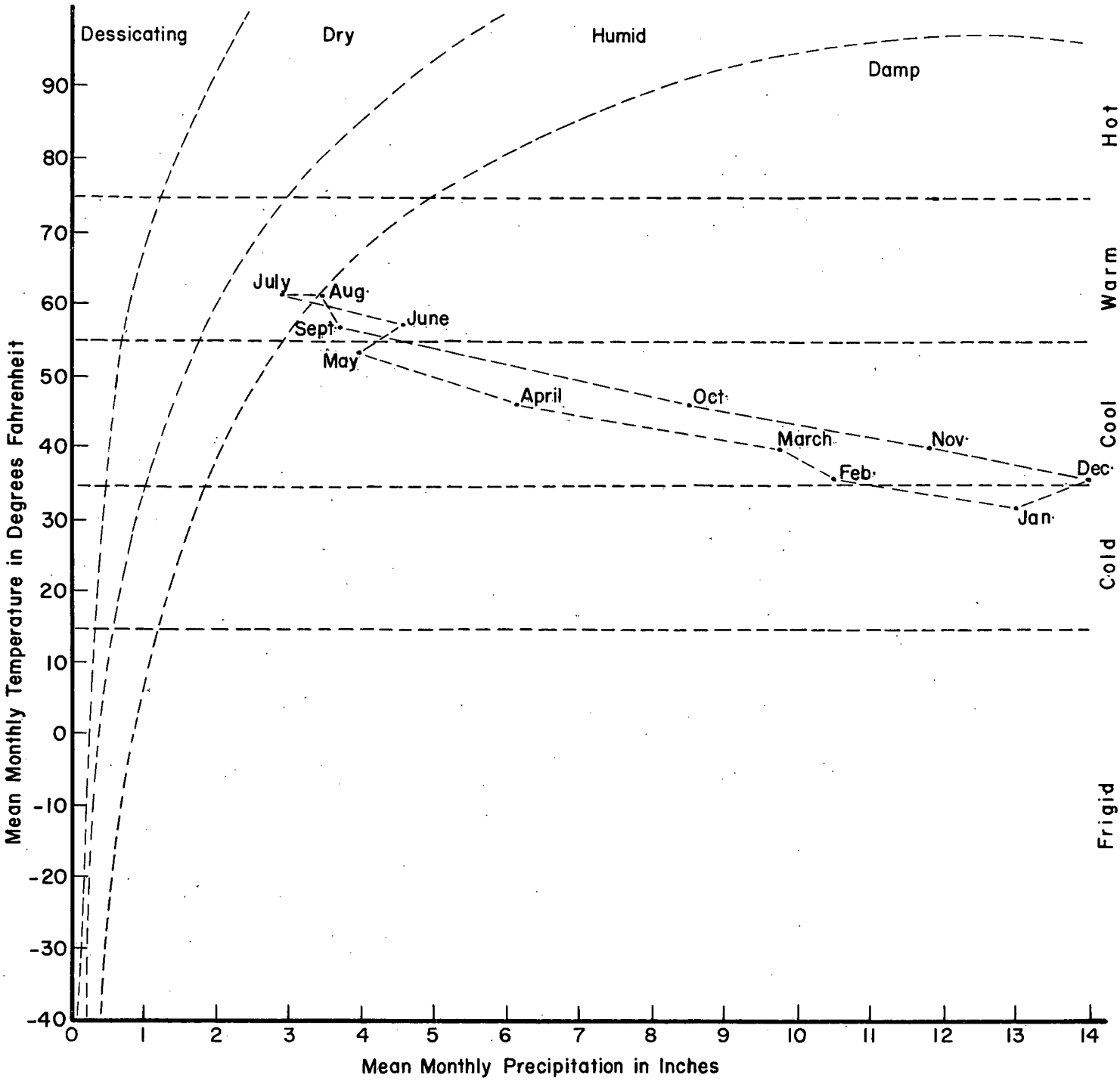


Fig. 4 Climograph (after Koeppe) showing the climatic pattern of Haney

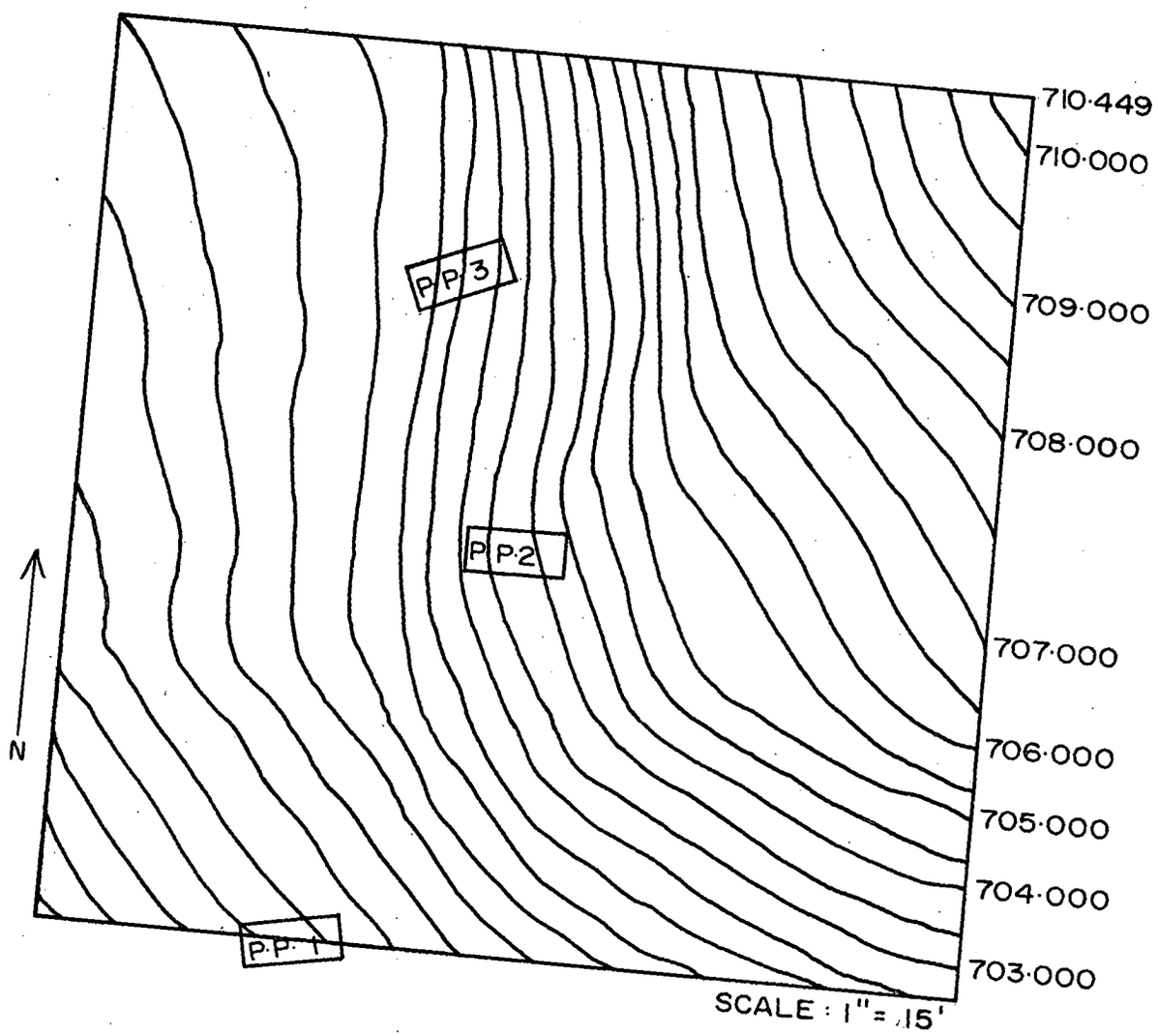
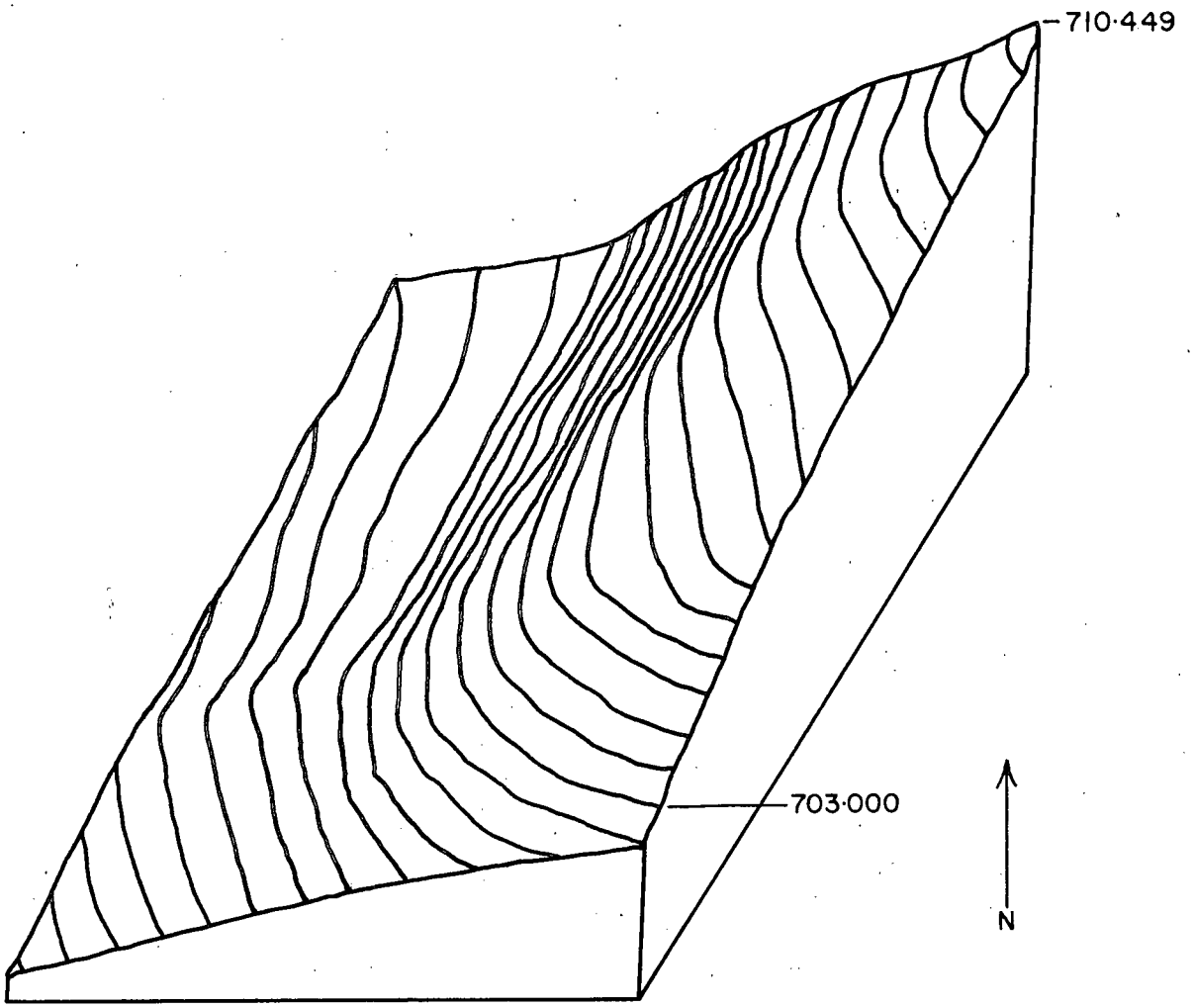
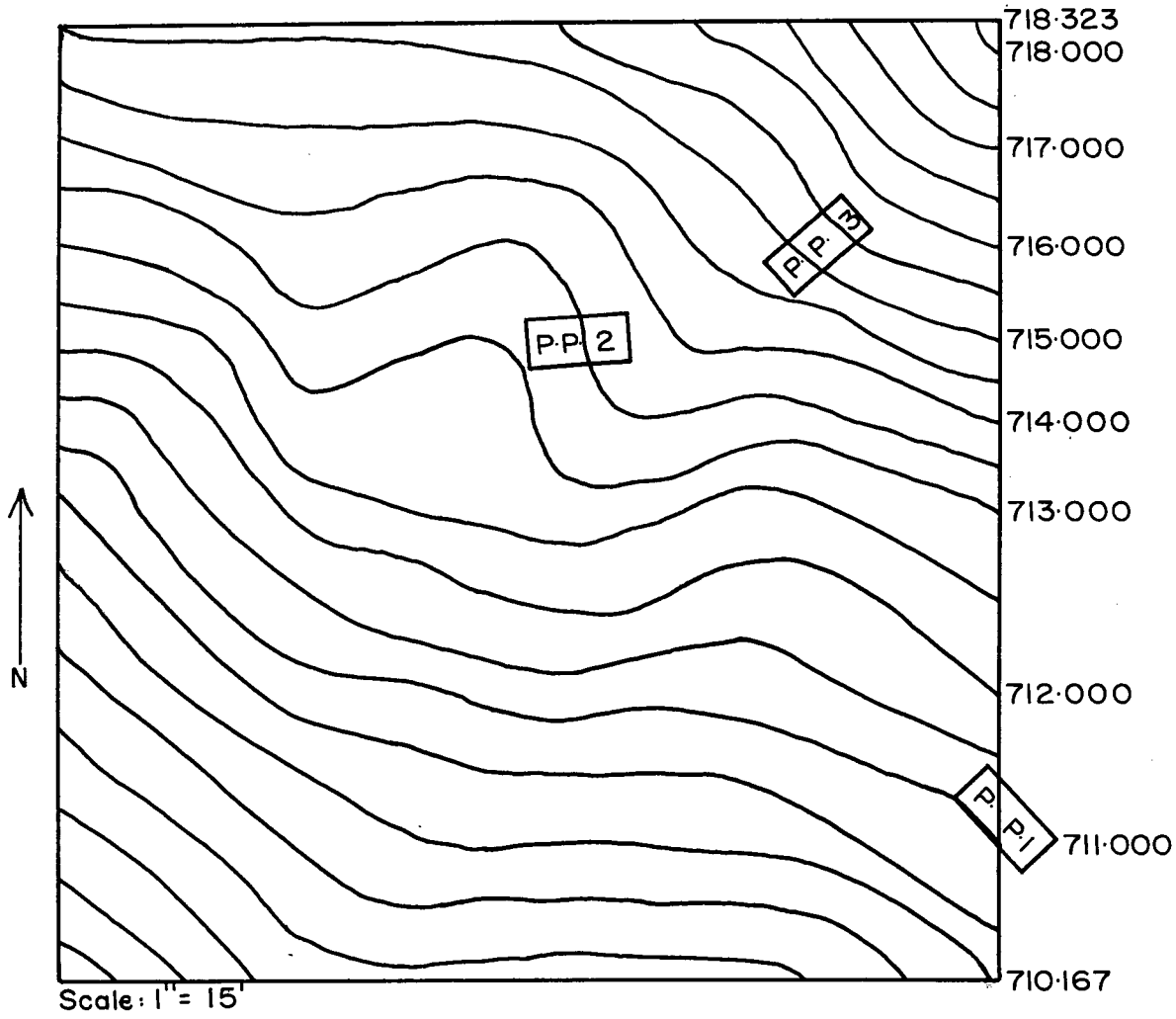


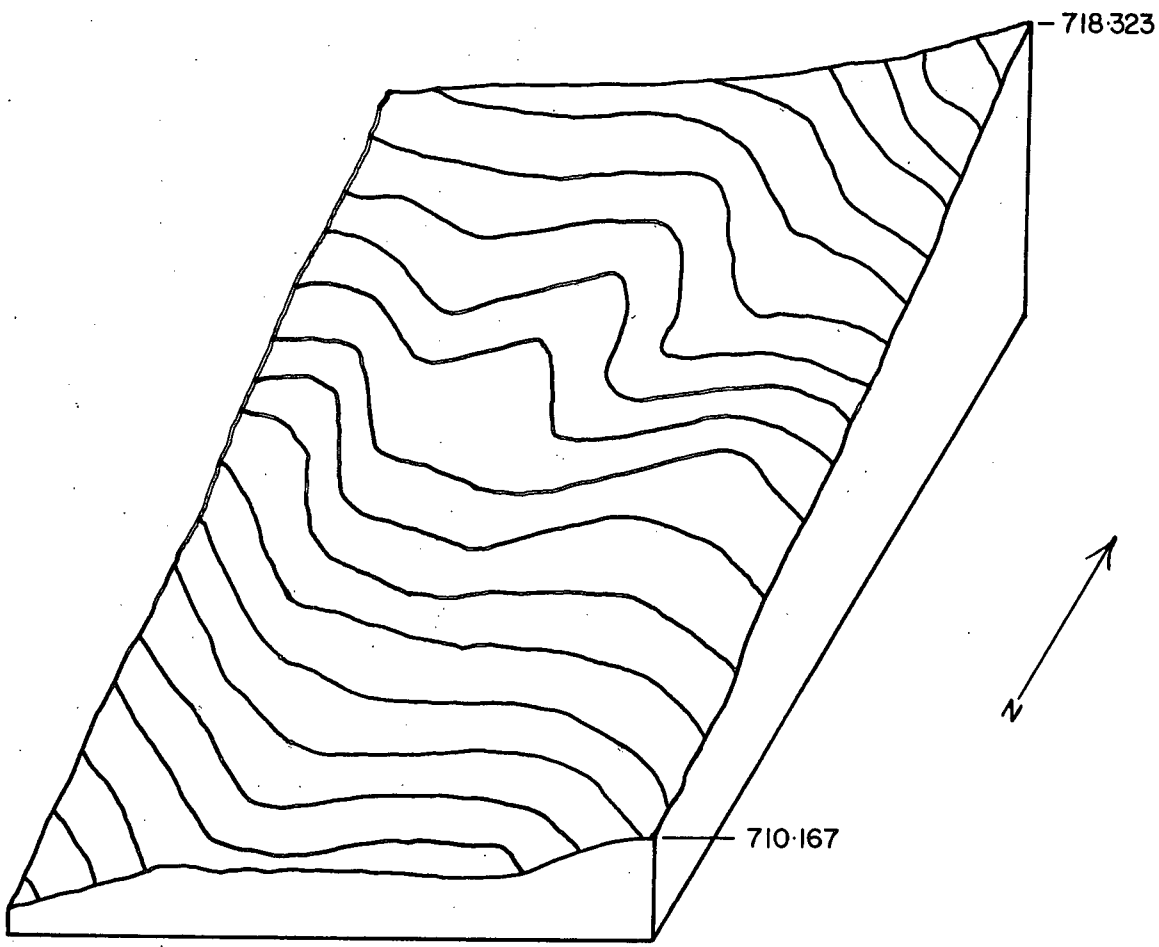
Fig. 6 Topographic map of plot 1.



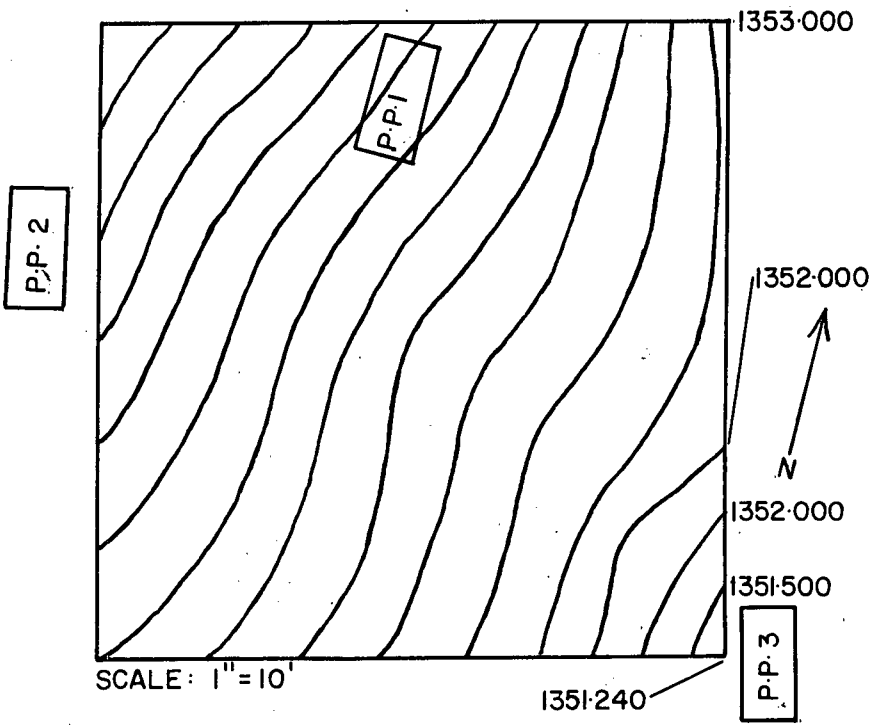
Fig· 7 Topographic projection of plot I·



Fig·8 Topographic map of plot 2·



Fig· 9 Topographic projection of plot 2·



Fig· 10 Topographic map of plot 4·

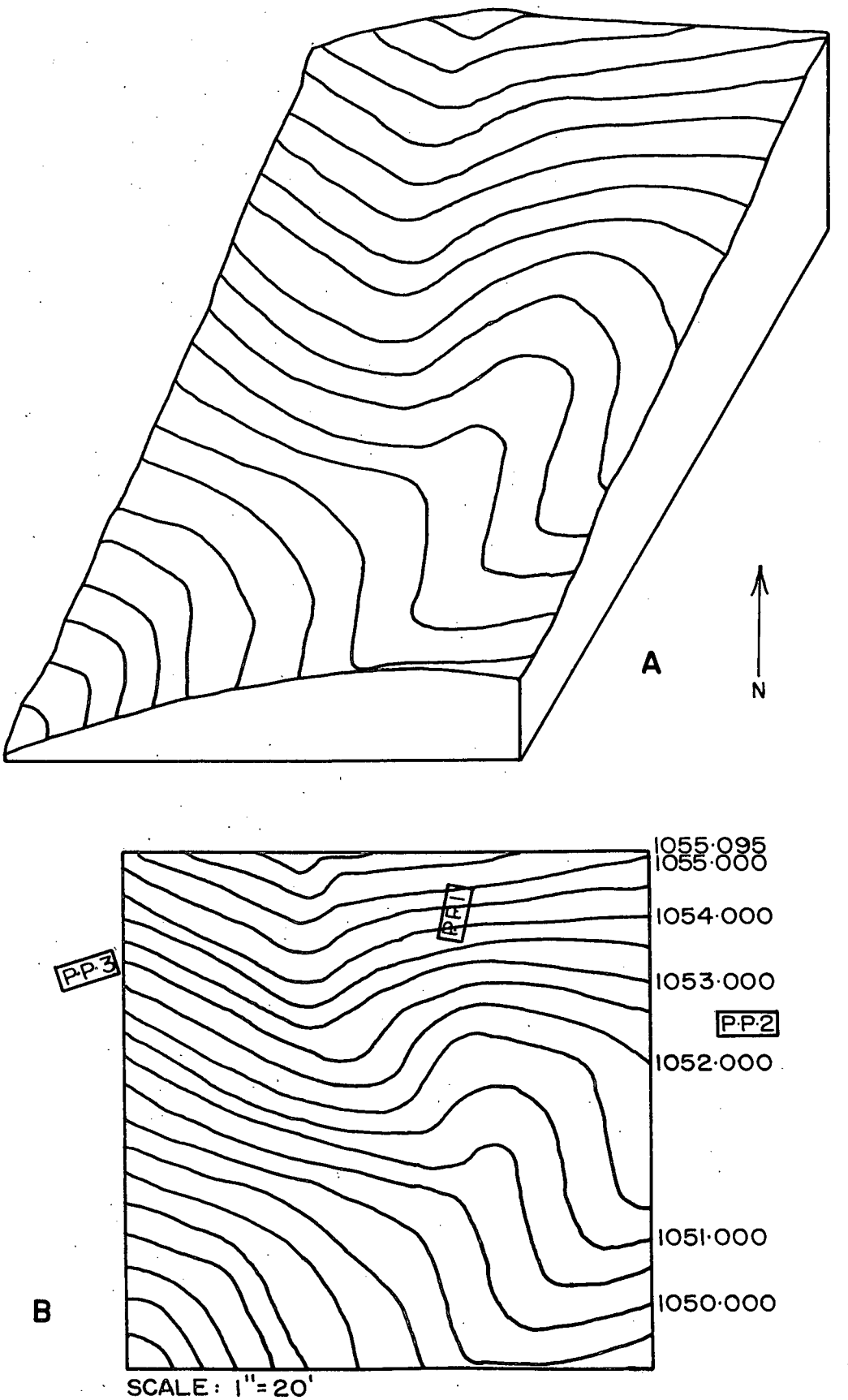
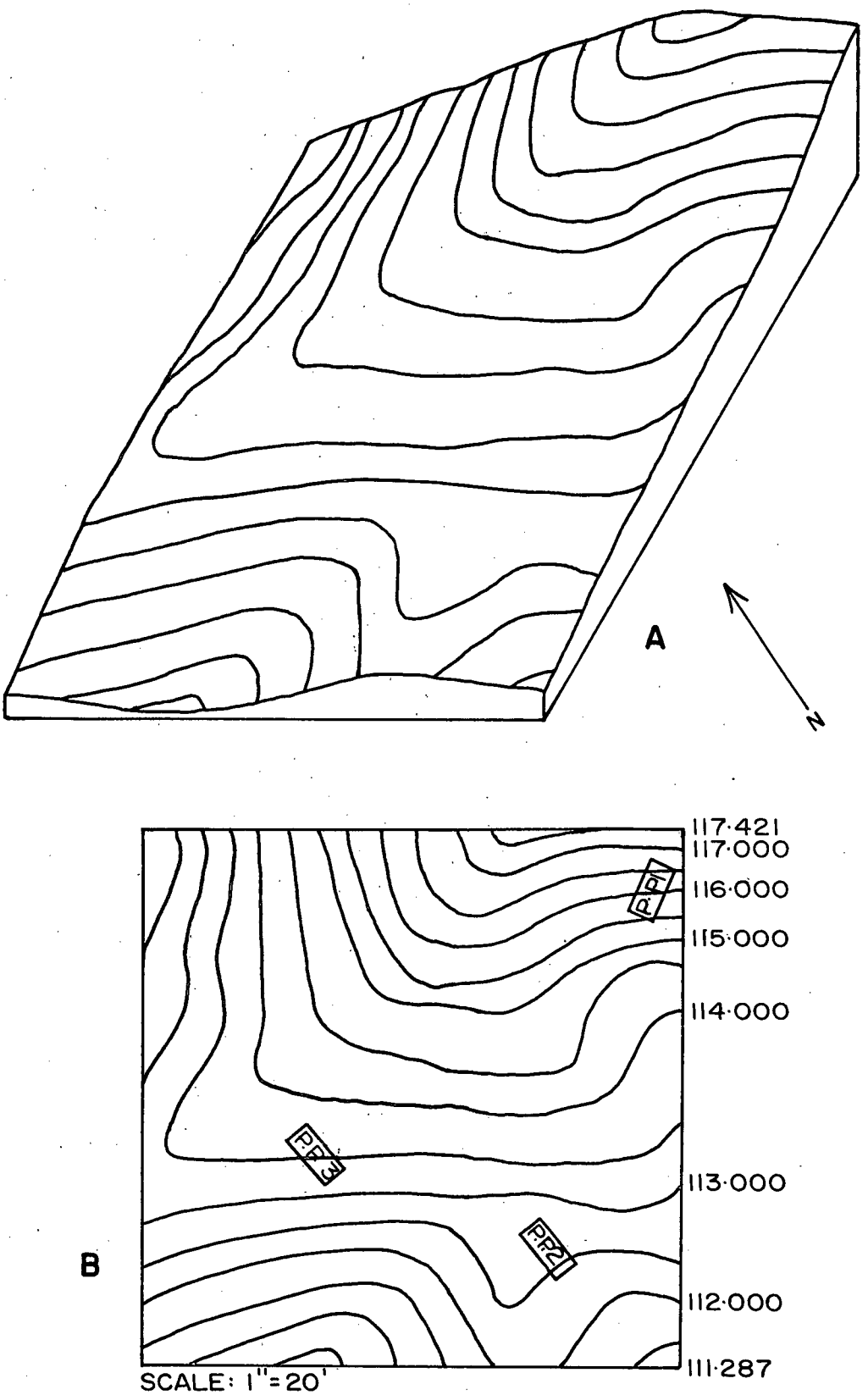


Fig. 11 Topographic projection (A) and map (B) of plot 5.



Fig· 12 Topographic projection (A) and map (B) of plot 7·

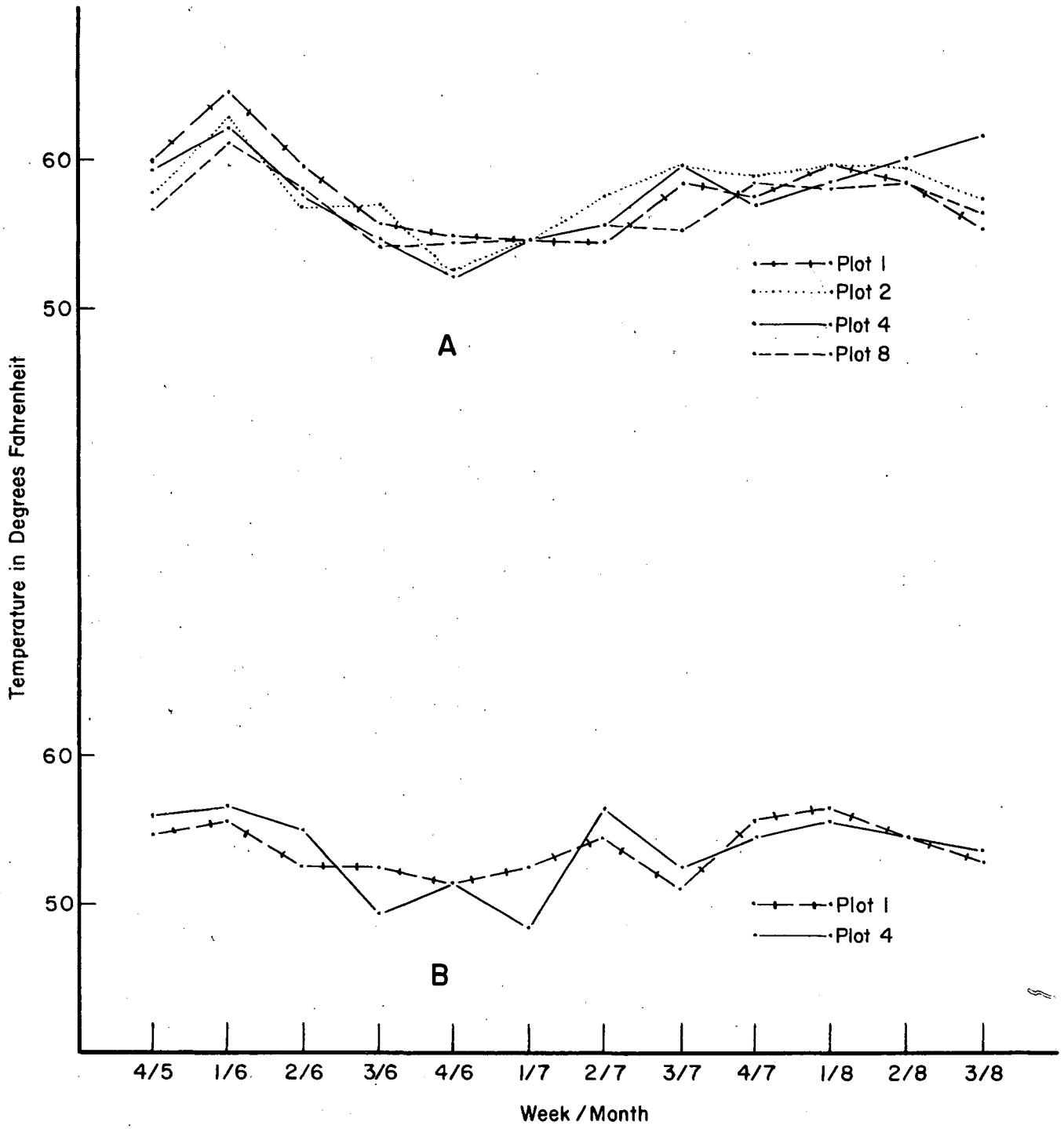


Fig. 13 A - Average weekly atmospheric temperatures for the period May 21 to August 15, 1957 for plots 1, 2, 4, and 8.
B - Average dew points for the same period for plots 1 and 4.

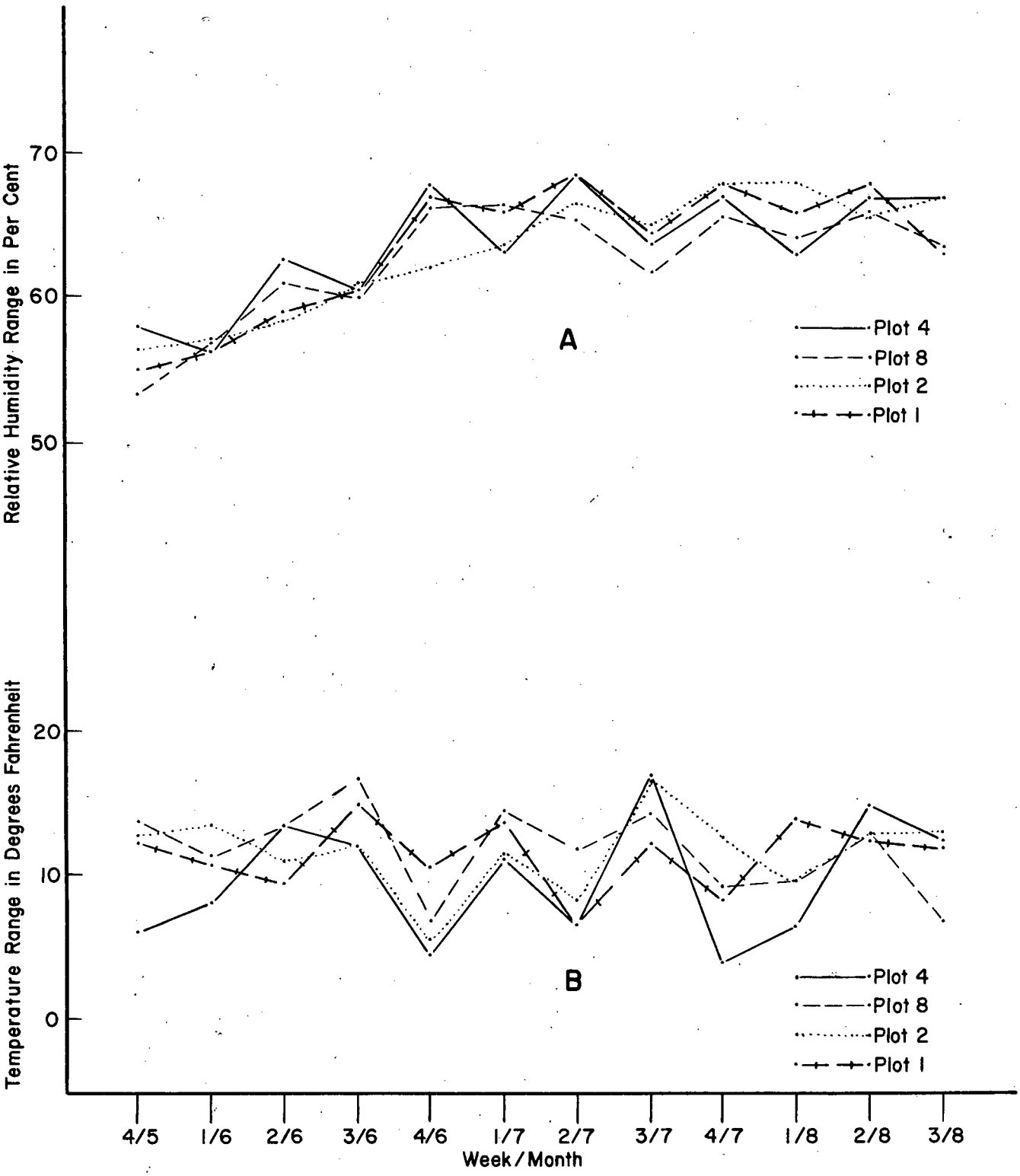


Fig. 14 Average weekly relative humidity (A) and temperature (B) ranges for the period May 21 to August 15, 1957 for the plots 1, 2, 4, and 8.

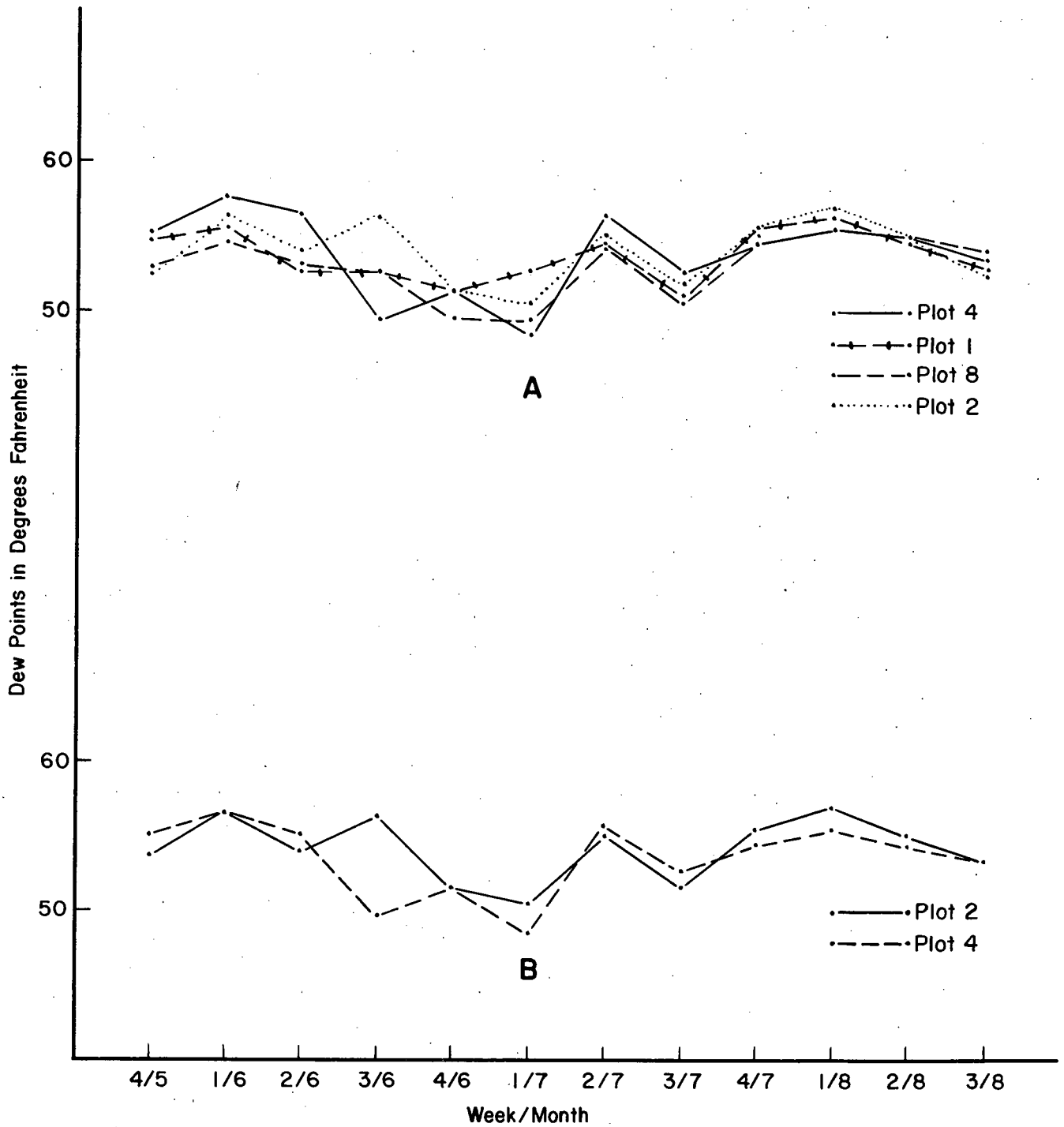


Fig. 15 Weekly average dew points for (A) plots 1, 2, 4, and 8; and (B) plots 2 and 4; for the period May 21 to August 15, 1957.

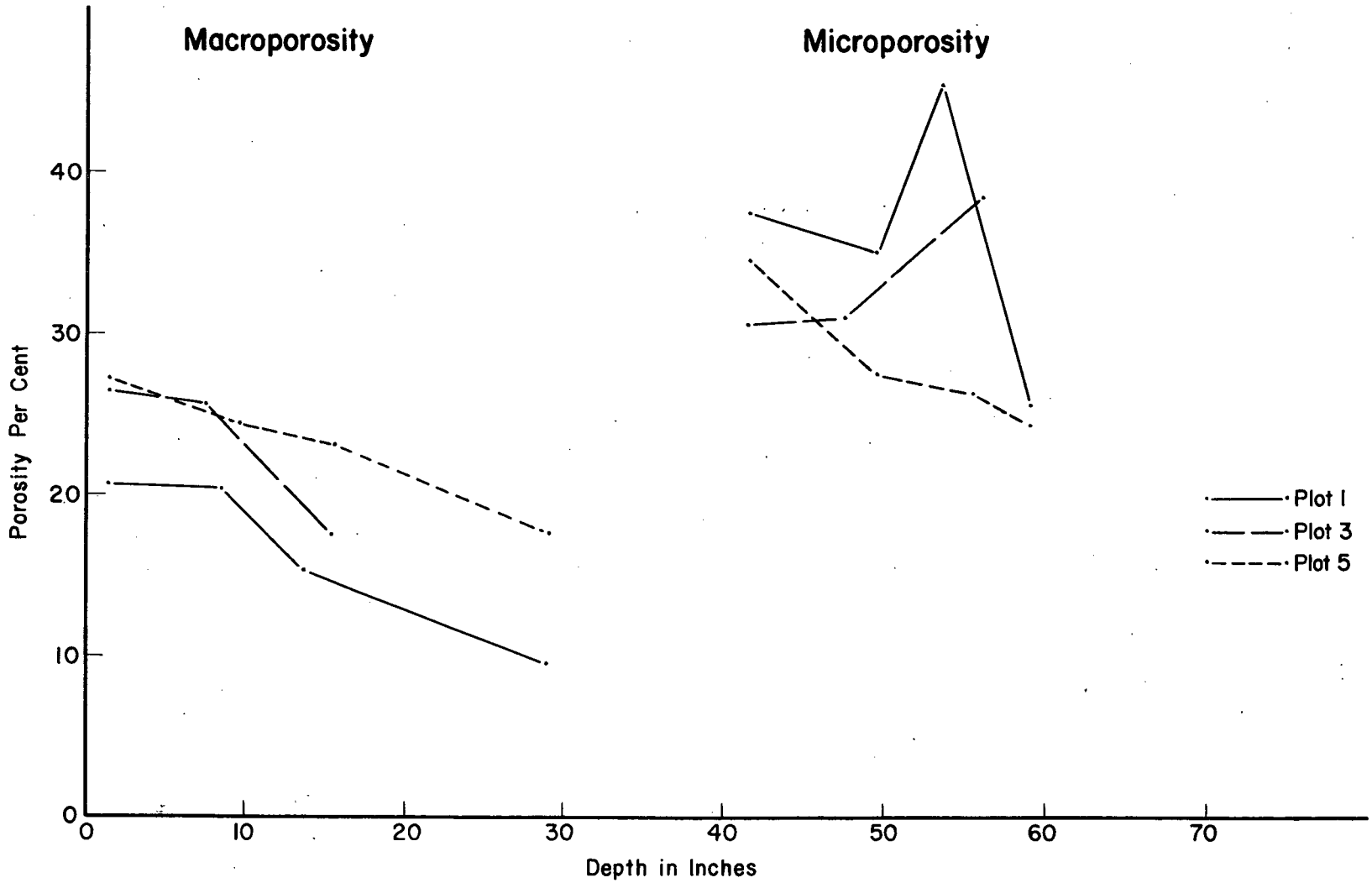
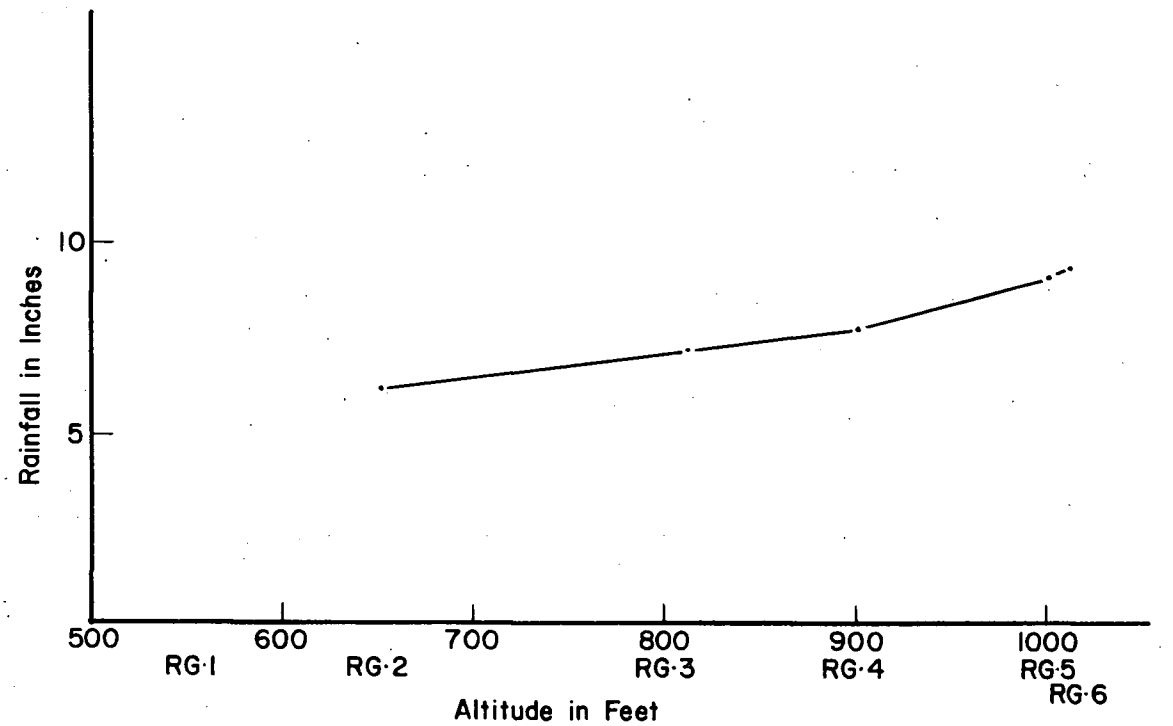


Fig. 17 Changes in soil porosity with soil depth for plots 1, 3, and 5.



Fig· 18 Rainfall at several different elevations for July and August, 1957·

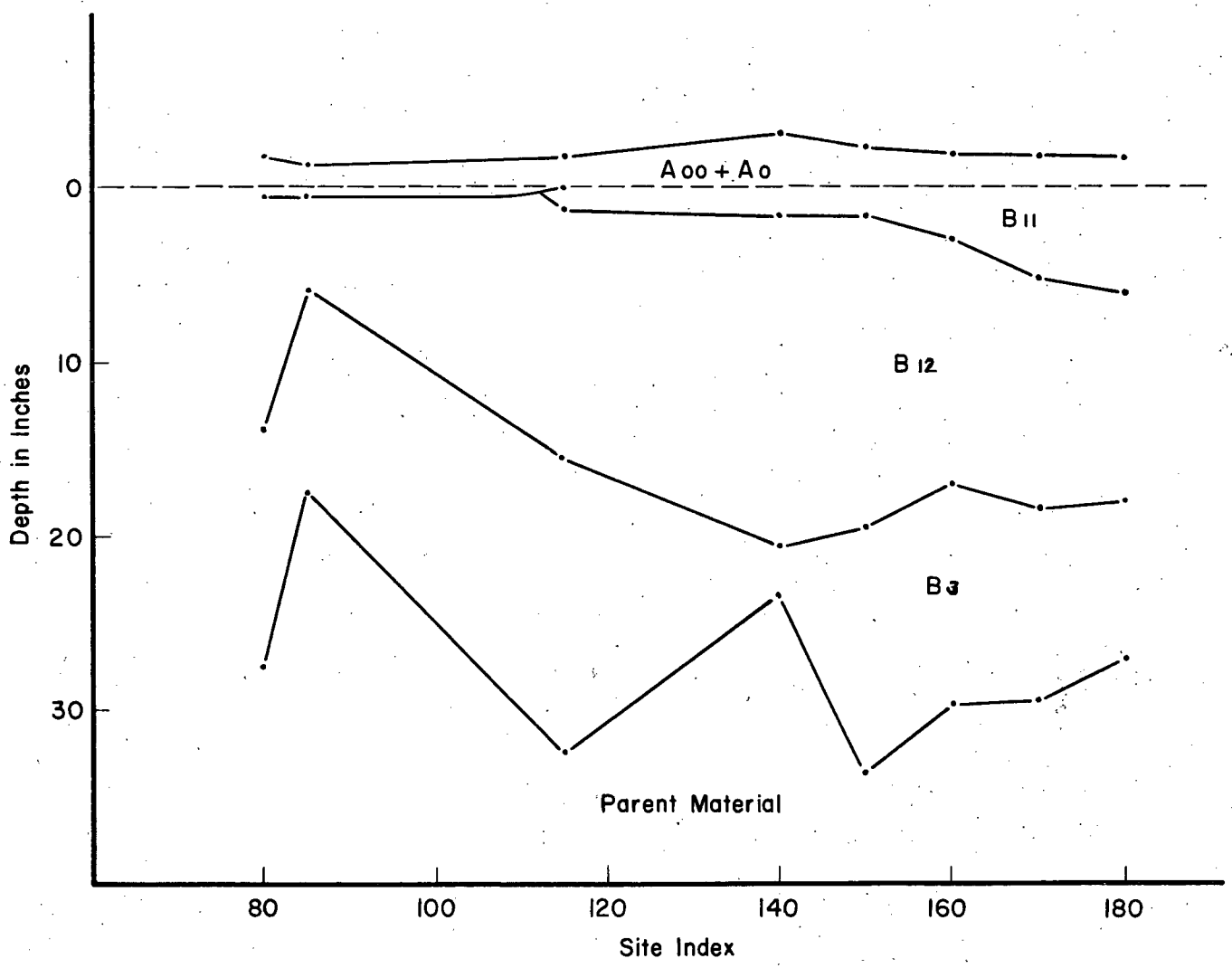


Fig. 19 Average depth of soil horizons for plots 1, 2, 3, 4, and 5 in relation to site index.

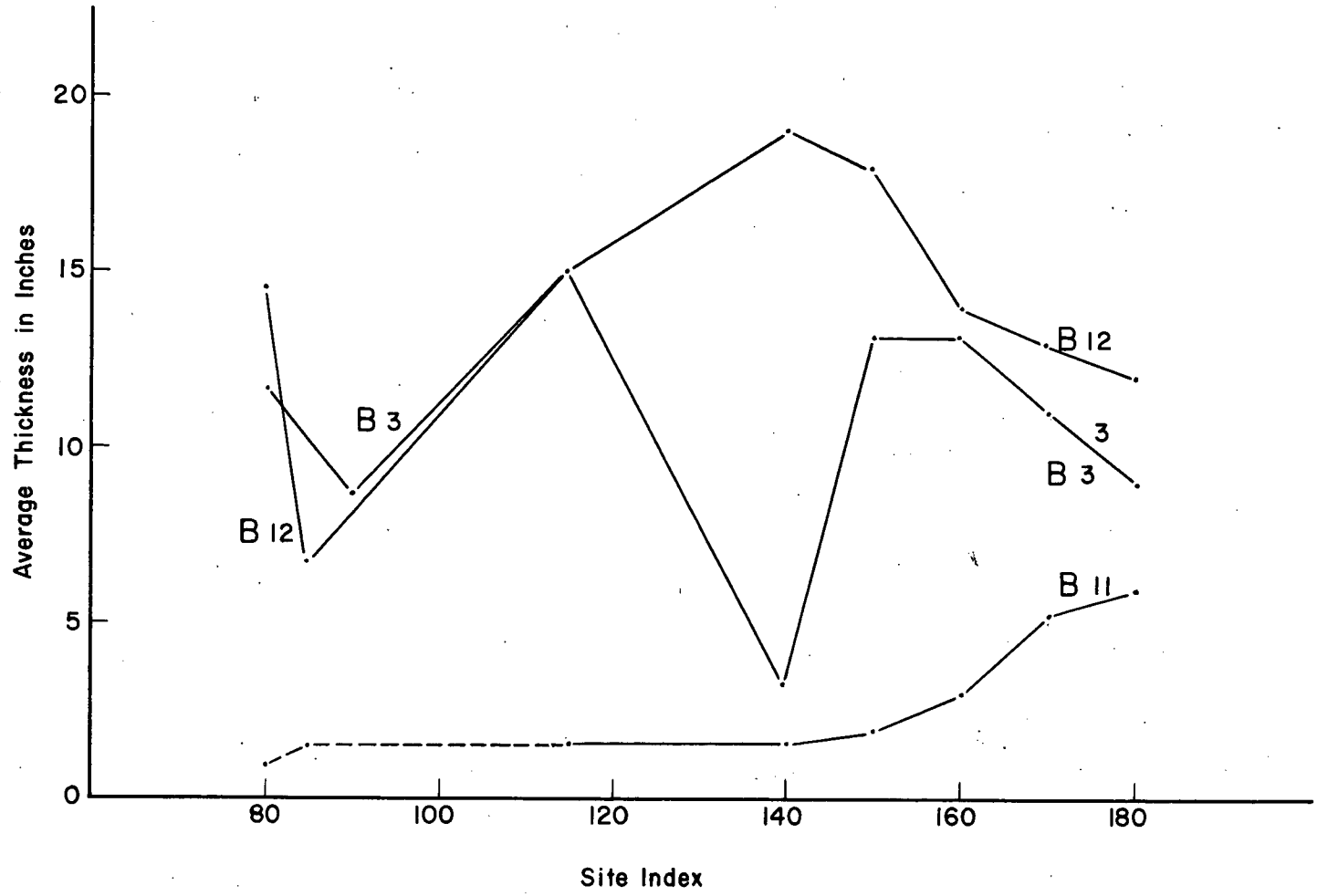


Fig. 20 Average thickness of B 11, B 12, and B 3 horizons for plots 1, 2, 3, 4, 5, 6, 7, and 8 in relation to site index.

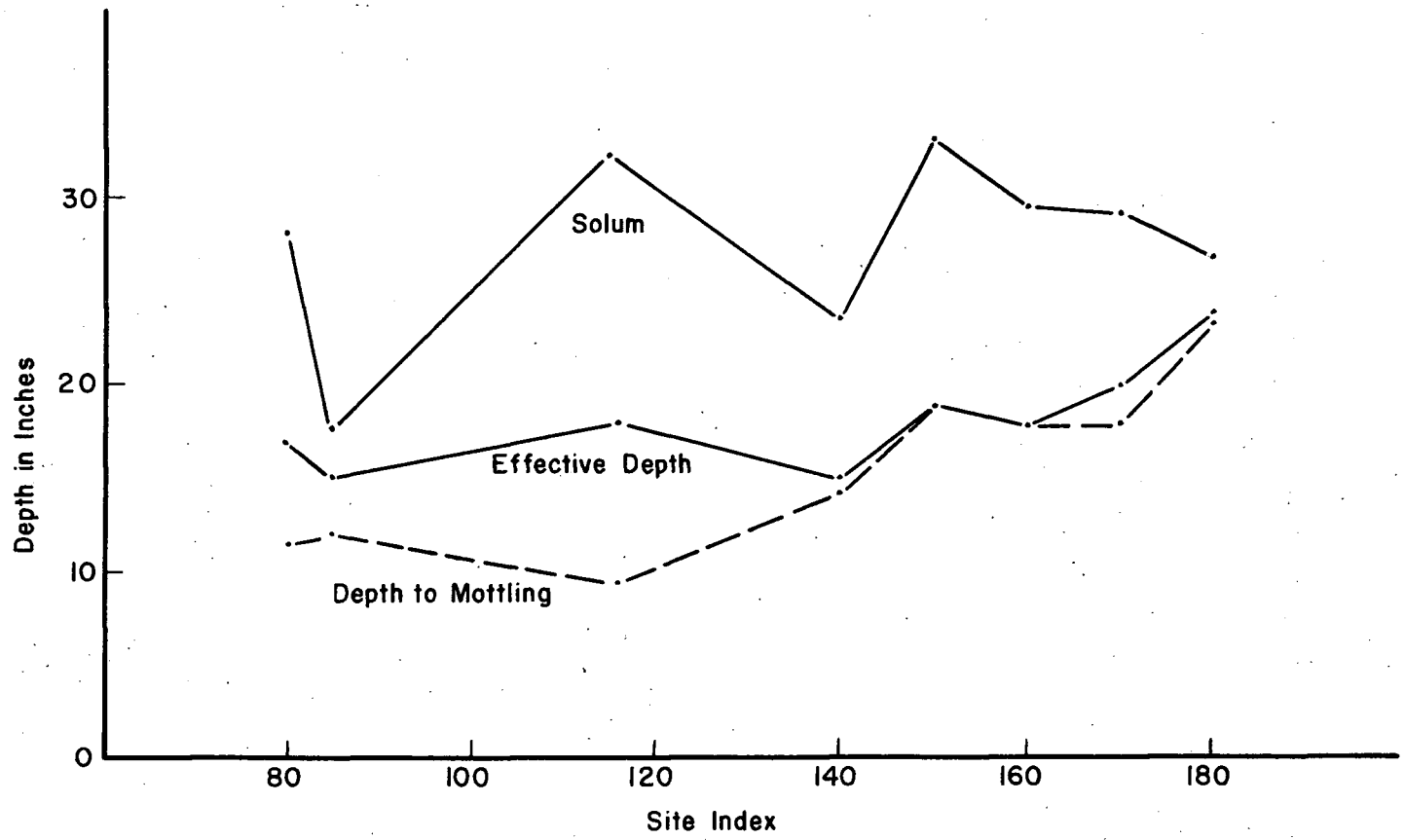


Fig. 21 Depth of solum, effective depth, and depth to mottling in relation to site index.

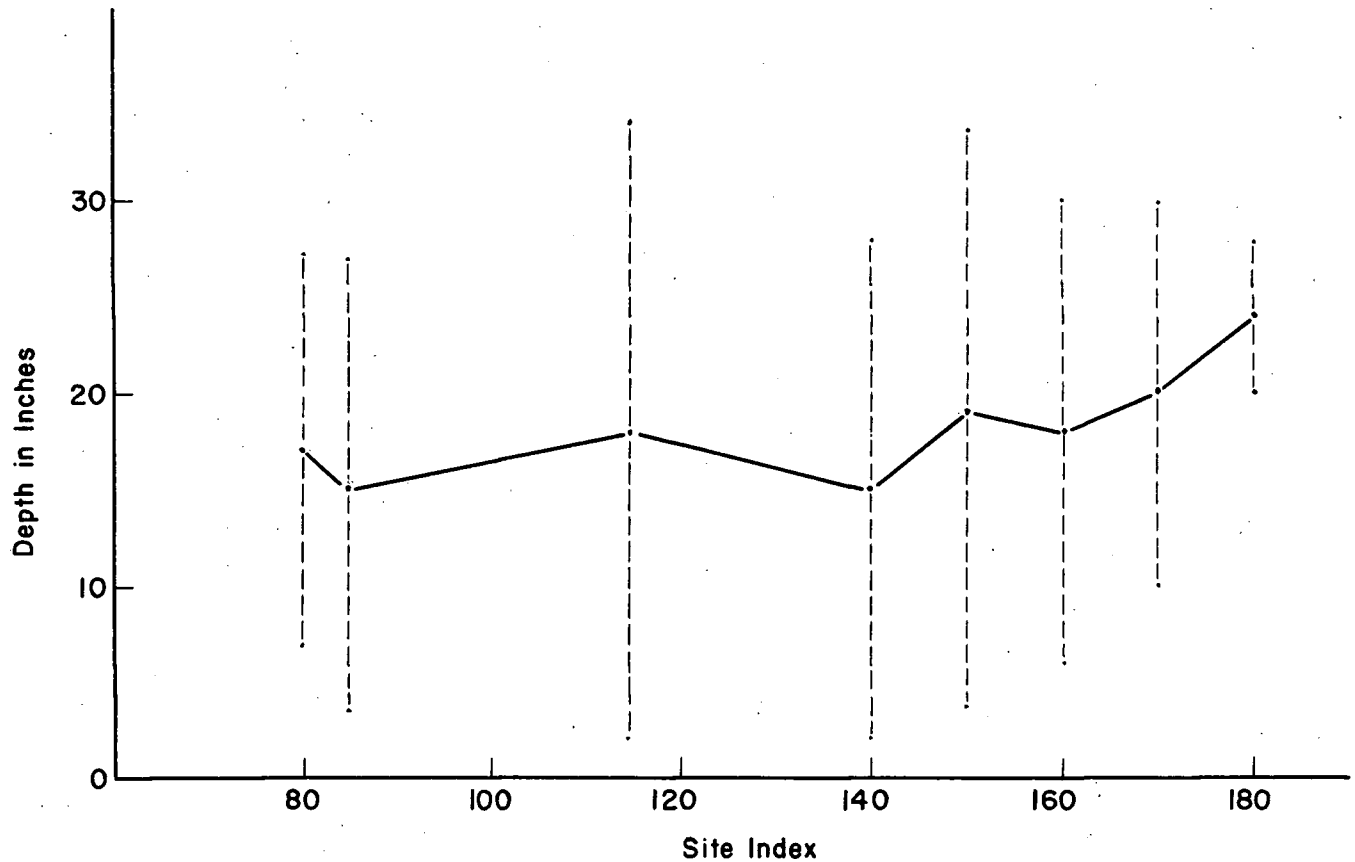


Fig. 22 Maximum, minimum, and average effective depth for all plots in relation to site index.