A COMPARATIVE STUDY OF FIVE SOIL PROFILES FROM THE EAST KOOTENAY DISTRICT OF BRITISH COLUMBIA

by

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ABSTRACT

The purpose of this study was to investigate some of the properties of five soils from the East Kootenay District of British Columbia. Field observations had indicated that an investigation of this nature would assist in soil classification work and at the same time lead to a better understanding of the genesis of these soils.

The study was conducted in two parts, a field study and a laboratory study. Of the five soils examined in the field three were investigated in the laboratory.

The field study involved obtaining complete soil descriptions and data relating to the vegetation, relief, climate and geology of the area. The tests selected for the laboratory phase of the study were those thought most likely to reveal the degree of development of each profile and included mechanical analysis, apparent specific gravity, fusion analysis, cation exchange capacity, organic carbon, and soil reaction.

The results of the study indicate that the soils form a sequence of profiles showing different degrees of development. The first soil examined shows little evidence of profile development since free lime occurs right to the surface and there is no evidence of translocation of any constituents down the profile. It is suggested that this soil be treated as an Alluvial soil in classification.

The second profile, termed a Brown Wooded soil, shows slightly greater development than the Alluvial soil, but at the same time it has not reached the Grey Wooded stage of development, as represented by the

third profile. Free lime has been leached to a depth of six inches but there is no accumulation of clay or sesquioxides in the B horizon of the Brown Wooded soil. It would appear that this soil should be separated from Alluvial and Grey Wooded soils at the family level of the classification system.

The third profile has the characteristics necessary for classification as a Grey Wooded soil. The analyses show that there has been an appreciable translocation of clay and sesquioxides from the A_2 to the B_2 horizon. The apparent specific gravity and percent base saturation are also typical of Grey Wooded soils.

The fourth soil studied is a polygenetic profile having a Brown Podzolic soil in the upper part of the solum and a heavy textured clay horizon typical of Grey Wooded soils in the lower part. It would appear that a Brown Podzolic soil has developed in the A_2 horizon of a Grey Wooded due to acid leaching. This soil is considered to be a Grey Wooded-Brown Podzolic intergrade.

The fifth soil is the most mature soil in the sequence. This profile is characterized by the development of a Podzol soil in the A_2 horizon of a Grey Wooded. The laboratory analyses have confirmed field observations in this regard. There is an accumulation of sesquioxides and organic matter, typical of Podzol soils in the B_p horizon, while the lower B_{2gw} horizon shows the clay accumulation characteristic of Grey Wooded soils. The soil reaction, cation exchange capacities and percent base saturation are also in agreement with the accepted definitions of these soils. The fifth soil, therefore, is considered to be a Grey Wooded-Podzol intergrade.

In dealing with Grey Wooded - Brown Podzolic and Grey Wooded - Podzol intergrades it is suggested that a separation at the family level of classification is warranted so that the Podzol characteristics superimposed on Grey Wooded soils can be recognized.

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INTRODUCTION

Soil classification in its present form began with the work of Russian pedologists in the latter part of the nineteenth century. Since that time many modifications and improvements have been made. One of the more recent developments has been to consider the soil as a continuum rather than being made up of distinctly different units or types. This has meant that in classification greater stress must be placed on soil development and the stages through which soils pass as they develop.

During the course of soil survey operations in the East Kootenay District of British Columbia in 1952 a new and rather complex group of soils were noted in Kootenay National Park and the adjacent Columbia River Valley. It was apparent that before they could be classified by present standards a study of their properties and development would be necessary. This fact prompted the present study which involved a consideration of a sequence of five related soils.

Field and laboratory studies of the five soils are reported in this thesis, along with a discussion of the development and classification of the soils of the East Kootenay area of British Columbia.

REVIEW OF LITERATURE

Systematic soil classification had its beginning in Russia about 1870 with the work of Dokuchaiev (44). This scientist recognized that each soil has a definite morphology which is associated with a particular combination of vegetation, climate, relief, parent material, and age. He stressed the fact that soil is not a geological formation but an independent natural body.

Systematic soil classification was begun in the United States about fifty years ago. One of the pioneer workers in that country was C. F. Marbut (28) who, in 1927, published his now famous work. Marbut combined the multitude of soils into two great groups, Pedocals and Pedalfers. The Pedocals were characterized by the accumulation of carbonates in all or part of the soil solum while the Pedalfers were distinguished by an accumulation of iron and aluminum compounds.

He (28) grouped each of these great groups into six categories. The lowest category represented individual soil units or types; succeeding categories represented broader groupings from the soil series through saline, alkali, and poorly drained soils to the mature well-drained soils. Category six, the broadest group, contained the Pedocals or Pedalfers.

Marbut considered there to be eight features of the soil profile necessary to the definition of a soil type. These features were:

(1) Number of horizons in the profile.

(2) Color of the various horizons.

(3) Texture of the horizons.

(4) Structure of the horizons.

(5) Relative arrangement of the horizons.

(6) Chemical composition of the horizons.

(7) Thickness of the horizons.

(8) Geology of the parent material.

In 1938, Baldwin et al (44) published a system of classification, which embodied much of Marbut's work but at the same time introduced some new concepts. The principal change came with the introduction of zonal, intrazonal and azonal orders.

These men (44) considered the zonal soils to include those great soil groups having well-developed soil characteristics that reflect the influence of the active factors of soil genesis. These soils occur over large areas or zones and are limited by geographical characteristics.

The intrazonal soils have more or less well-developed soil characteristics that reflect the dominating influence of some local factor of relief or parent material.

The azonal soils are without well-developed soil characteristics either because of their youth or because conditions of parent material or relief have prevented the development of definite soil characteristics.

In 1952 at a meeting of the Agricultural Institute of Canada, C. E. Kellogg (16), chief of the United States Soil Survey, pointed out that recent research has shown the need for revising the system of soil classification. He stated that a new method of classifying soils would be introduced in 1954.

In Canada there are actually two systems of classification in use. A field system and a genetic system (34). The field classification recognizes the desirability of grouping the soils on a common profile basis. The system, while showing considerable geographic and genetic bias, does not require a consideration of pedological characteristics. The various categories in descending order of size are:

Soil Zones

Soil Sub-zones

Soil Catenas

Soil Series

Soil Types

The second system, the morphological classification, is necessary for the grouping of soils on the basis of common internal characteristics. The system recognizes the soil series as the basic unit of classification. The difference between the two systems lies in the grouping of the soils at the higher categories. In the morphological system, series are grouped into families, and families into great soil groups.

Recent publications by Stobbe (46), Cline (4), and a number of other workers (26), (10), (31), have stressed that soils do not occur as distinct entities with sharp breaks between them but rather as continuous bodies which gradually merge into one another.

In describing soil sequences Stobbe (46) uses two terms, intergrade and modal. He (46) uses the term intergrade in three senses. The first is used to show an intergrading of properties from one class to another. For example, where incipient gleying is superimposed upon a zonal or azonal soil. Secondly, it may be used to show the zone or zonal properties of azonal soils, or thirdly it may be used in referring to polygenetic profiles in which the characteristics of one great soil group become superimposed on a soil of an adjacent great soil group.

A modal profile, according to Stobbe (46), is an expression of the characteristic units of a great soil group. Modal classes are subdivided into maximal, medial, and minimal profiles of the zonal soils and by zones for the azonal soils. A modal profile does not partake properties of any other great soil group.

MAJOR SOILS STUDIED IN THE EAST KOOTENAY DISTRICT OF BRITISH COLUMBIA

The soils of the East Kootenay District involved in this study were related to the following soil types - Alluvial, Brown Wooded, Grey Wooded, Grey Wooded - Brown Podzolic, and Grey Wooded - Podzol. Each of these types will be reviewed in the sections which follow.

(1) Alluvial Soils.

The definition of Alluvial soils given in the U. S. D. A. Soil Survey Manual (45) is as follows: "young soils in flood plains and deltas actively in the process of construction which have no developed characteristics beyond those inherited from the alluvium itself."

Two soils related to Alluvial soils, because of their limited development, are Lithosols and Regosols. Thorp and Smith (48) define Lithosals as: " an azonal group of soils having an incomplete solum or no clearly expressed soil morphology and consisting of a freshly and imperfectly weathered mass of hard rock or hard rock fragments; largely confined to steeply sloping land."

The Regosols are defined by Thorp and Smith (48) as being: "an azonal group of soils consisting of deep unconsolidated rock (soft mineral deposits) in which few or no clearly expressed soil characteristics have developed, largely confined to recent sand dunes, and to loess and glacial drift of steeply sloping lands."

(2) Brown Wooded Soils.

Recently some workers (18), (19), (25) in Western Canada have reported a Brown Wooded which appears to vary in morphological characteristics from any presently established soil types.

Odynsky and Newton (32) describe a soil, Judah series, in the Peace River district of Alberta which appears to have some characteristics in common with the Brown Wooded soils of the East Kootenay District of British Columbia. The Judah series has a brown colored surface horizon and a brown, fairly heavy, stone-free subsoil. There is a slight greying of the lower part of the A horizon which is not typical of a distinct A_2 horizon. These men state that this soil is unlike a Degraded Black soil and more closely resembles the Brown Forest soils.

Farstad (5) makes reference to a Brown profile in the Peace River district of British Columbia which also appears to be somewhat similar to Brown Wooded soils. The soil described by him is characterized by a thick granular A_1 horizon, little or no A_2 horizon, and a strong structural B horizon.

Both the soils of Odynsky and Newton, and Farstad show little or no A_2 horizon development, this is characteristic of one of the profiles studied for this thesis.

Kelley (19) considers the Mayook soils of the East Kootenay District to be a typical Brown Wooded soil. The description of the Mayook profile is as follows:

Horizon	Depth	Description
A_0	3/4 - 0"	Forest litter of needles, twigs, grass, etc. pH 5.8
A_1	0 - 3/4"	Light brownish grey silt loam, platy structure. pH 6.6
A_2	3/4 - 2 3/4"	Pale brown, silt loam, platy. pH 6.4
A_3	2 3/4 - 8"	Very pale brown, silt loam, blocky to crumb structure. pH 6.9
B_1	8 - 10"	Light yellowish brown, silt loam, slightly calcareous, cloddy breaking to granular structure.
B_{ca}	10 - 20"	Pale yellow, silt loam, compact, pH 9.2
C	20" +	White, silt. pH 9.5

In a recent publication Leahey (25) describes a Brown Wooded soil from the Hay River District of the Northwest Territories. The description is as follows:

Horizon	Depth	Description
A_0	3 - 0"	Partly decomposed organic layer. pH 6.2
A_2	0 - 3"	Greyish brown (10YR 5/2) silt loam, weakly granular. pH 6.4

B	3 - 9"	Brown (10YR 4/3) silty clay loam, soft cloddy structure. pH 6.5
C_1	9 - 14"	Dark greyish brown (10YR 4/2) silty clay loam, granular. pH 8.0
C_2	14 - 21"	Pale brown (10YR 6/3) silty clay, massive. pH 8.2

Leahey (25) states that the profile development of this Brown Wooded soil has reached the stage where free lime and some organic matter has been lost from the upper nine inches. There is little evidence, however, of any concentration of clays in the B horizon.

The profiles described by Kelley (19) and Leahey (25) appear to exhibit about the same degree of development, in that some A_2 horizon occurs but there is no formation of a textural B horizon.

(3) Grey Wooded Soils.

One of the earliest descriptions of the Grey Wooded profile was presented by Wyatt and Newton (50) in 1927 to the 1st International Congress of Soil Science. At the same meeting Joel (13), in discussing the soils of northern Saskatchewan, made reference to a Grey "Bush" soil which is now known as a Grey Wooded.

Both these descriptions noted the presence of a leached A horizon and a B horizon which showed an accumulation of clay.

Leahey (23), in 1932, while working with Grey Wooded soils in Alberta, compared the amount of leaching taking place in Brown, Black and Grey Wooded profiles; he showed that the silica-sesquioxide ratio was fairly constant for Brown and Black soils, but in the Grey Wooded profile there was a wide spread in the ratio between A and B horizons, due to the leaching process. At this time Leahey (23) felt that the Grey Wooded soils could be classified with the Podzols, although he noted that they did vary in the B horizons, inasmuch as in Alberta soils there is a zone of carbonate accumulation which is not typical of Podzols.

Moss (30) in 1938 concluded from a study of eight profiles in Saskatchewan that the Grey Wooded soils vary considerably in morphology and composition, the variations representing different degrees of podzolization. He thought that podzolization is the dominant process in the development of wooded profiles but at the same time noted that typical Grey Wooded soils of Saskatchewan differ in several characteristics from true Podzols of more humid regions, the differences being a highly calcareous parent material, presence of carbonates in the solum, higher reaction, and a smaller unsaturation of the base-exchange complex.

Thorp and Smith (48), in discussing higher categories in soil classification, report that at the Division of Soil Survey Work-Planning Conference, March 1948, the following definitions of Grey Wooded soils was arrived at: a group of well-developed, well-drained soils having a moderately thin duff (A_0) horizon and a thin organic mineral (A_1) horizon, over a light colored bleached (A_2) horizon, over a brown, more clayey, blocky or nuciform (B_2) horizon, grading below into lighter-colored, more friable (B_3 and C) horizons. In comparing the Grey Wooded profile with a Podzol profile the committee stated that the colors resemble those of Podzols, the B horizon of the Grey Wooded, however, is generally lower in chroma; the A_2 horizon is about twice as thick as those of the Podzols in North America. Another distinction is that Grey Wooded soils develop on calcareous parent materials ranging in reaction from neutral to medium acid, many having horizons of calcium carbonate accumulation below the B_2

horizon. The name of Grey Podzolic was suggested for this group of soils at this meeting.

Williams and Bowser (49), in comparing Grey Wooded soils of Alberta and Montana with Podzolic soils, concluded that the percent base saturation in the A and B horizons of the Grey Wooded profile is two to three times that of comparable horizons in the Brown Podzolic profile, and that the B_2 is eight to ten times that of the Podzol profile.

According to Stobbe and Leahey (47), in Canada Grey Wooded soils occupy the wooded areas of the prairie provinces, central British Columbia, and the clay belt of Northern Ontario. Williams and Bowser (49) report their occurrance in parts of Montana, and McMiller and Nygard (8) have described typical Grey Wooded profiles in Minnesota. During a soil survey in the Northwest Territories, Leahey (22) found Grey Wooded profiles near Fort Simpson at Latitude N 62°.

At the Second Resources Conference of British Columbia (37) held in 1949, the Soils Committee estimated that Grey Wooded soils occupy approximately 52,100,000 acres in British Columbia. Of this acreage, 14,900,000 acres occur in the Peace River District, 18,700,000 acres in in the Central Interior and 18,500,000 in the Southern Interior area between the International Boundary and approximately the latitude of Clinton.

Several attempts have been made at correlating Grey Wooded soils of Western Canada with soils described in Europe. Leahey (23) thought they best fitted in with Glinka's Podzol group. In his opinion, they showed some of the characteristics of a Grey Forest soil but on the whole showed evidence of being too severely leached to fit the description of this European soil. Moss (30) did not think they fitted any of the great soil groups of the world, but like Leahey he believed the presence of calcium carbonate was not sufficient reason to exclude them from the Podzol group. The Division of Soil Survey (48) correlated the Grey Wooded soils with the Grey Forest soils of Russia, since they occupy a similar position between Podzols of the more humid region and the Chernozem of less humid or semi-arid regions.

(4) <u>Grey Wooded-Brown Podzolic Soils.</u>

The only reference noted in the literature pertaining to Grey Wooded-Brown Podzolic soils is made by Nygard et al (31), after conducting a study in northern Minnesota. These men found gradational soil types between Grey Wooded and Brown Podzolic and Podzol soils in which these latter two types became superimposed upon the upper part of a Grey Wooded soil.

(5) <u>Grey Wooded - Podzol Soils.</u>

This soil type was first recognized in British Columbia by Farstad (7) in the Peace River District. Kelley (18), (19), has also described them in the East Kootenay District.

Odynsky et al (33) noted the occurrance of Podzolized Grey Wooded soils in the Peace River District of Alberta. These men give the following description of the Heart Series, a Podzolized - Grey Wooded intergrade.

A_0 Horizon - $\frac{1}{2}$ inch in thickness, brown organic debris. pH 6.0

A_{2p} Horizon - 3 inches in thickness, white to pinkish white in upper portion, grading to light grey in lower portion, fine sand, loose but held together by plant roots. pH 5.6

B_p Horizon - 7 inches in thickness, pale brown in upper portion grading to brownish yellow in lower portion, fine sand, slight evidence of compaction. pH 5.4

C_p Horizon - 6 inches in thickness, light yellowish brown fine sand, weakly blocky. pH 5.6

$A_3(B_1)$ Horizon - 10 inches in thickness, very pale brown fine sand, weakly blocky with occasional soft spheroidal aggregates of loamy sand to sandy loam. pH 5.7

B_2 Horizon - 13 inches in thickness, very pale brown fine sand to loamy fine sand with strong brown clusters of soft spheroidal aggregates of loamy sand to sandy loam. Lime flecks are sometimes found in the lowest part of this horizon. pH 5.4

Generally more pronounced evidence of lime accumulation is found at depths of about 48 inches.

In discussing the above profile, Odynsky et al (33) state that the upper portion of this profile has the characteristics of a Podzol profile while the lower horizons appear to be heavier textured remnants of a former Grey Wooded B horizon.

(6) Brown Podzolic Soils.

Brown Podzolic soils were first introduced into the soil classification system by Baldwin, Kellogg, et al (44) in 1938. The definition of Brown Podzolic soils given by these men is as follows:

"a zonal group of soils with a thin mat of partly decayed leaves over a very thin dark greyish-brown humus mineral soil and a trace of pale grey leached A_2 horizon over a brown or yellowish brown B horizon heavier in texture than the surface soil; developed under deciduous or mixed deciduous and coniferous forest in temperate or cool-temperate humid regions."

Baldwin, Kellogg, et al (44) considered Brown Podzolic soils to be restricted in extent to the New England States but later investigations have shown them to be of fairly widespread occurrance in both eastern and western North America. A recent publication (8) issued by the Soil Survey Laboratory, Beltsville, Maryland lists Brown Podzolic Soils from many localities in the United States including Connecticut, New Hampshire, Minnesota, Idaho and Washington States. In discussing Brown Podzolic soils in Canada, Stobbe (46) reports that in Ontario and Quebec twenty-seven soil series belonging to this great soil group have been classified. In British Columbia, Brown Podzolic soils have been reported as occurring on Vancouver Island (7) and in the Peace River District (7).

Stobbe (46) states that profiles of Brown Podzolic soils vary considerably in morphology but gives the following description as being fairly typical of this great soil group in Eastern Canada. There is an A_0 horizon of one-half to two inch thickness at the surface which may or may not be underlain by a friable, crumb structured A_1 horizon which is on the average one-half to two inches in thickness. A thin discontinuous A_2 horizon may be present beneath the A_0 or A_1.

The B horizon forms the major part of the solum, averaging twenty to thirty inches in thickness. This horizon is yellowish to reddish brown, friable, and generally has a fine crumb structure. The B_3

horizon is more firm and the structure more variable than the B_2. The reaction of the B horizon varies from strongly to moderately acid.

Almost without exception the parent material is of a non-calcareous nature and is usually of a medium or light texture.

(7) Podzol Soils.

Baldwin, Kellog, et al (44) define Podzol soils as: "a zonal group of soils having an organic mat and a very thin organic-mineral layer above a grey leached layer which rests upon an illuvial dark-brown horizon, developed under coniferous forest, or under heath vegetation in a temperate to cold moist climate. Iron oxide and alumina, and sometimes organic matter, have been removed from the A and deposited in the B horizon."

According to Joffe (15) Podzol soils cover the largest habitable area of the earth's land surface. Glinka's "Soil Map of the World" shows Podzol soils extending from the subarctic region through the temperate zone to a few degrees north of the Mediterranean in Europe, to about 50° north latitude in Asia and to 40° north latitude in North America.

A great deal has been written on Podzol profiles since they were first described by Sprengel (14) about 1837. Jenny (12) offers the following generalized description as being typical of a Podzol profile:

A_0 Horizon - varies in thickness from 1 to 5 inches, consisting mainly of forest litter and leafmold.

A_1 Horizon - varies in thickness from 1 to 6 inches, consisting of a dark-brown humus layer, mixed with mineral soil. The reaction is highly acidic.

A_2 Horizon - 1 to 8 inches thick, which is greyish-white in color. Zone of maximum eluviation.

B Horizon - 2 to 15 inches thick, rust-brown to chocolate colored. The B horizon is thicker than the other layers and in most cases is divided into B_1 and B_2. The lower boundary of the B_2 is irregular and frequently forms pocket-like intrusions into the substratum. If the sand grains are cemented together by colloidal sesquioxides (Fe_2O_3 plus Al_2O_3) into a hardpan, the zone is called orstein.

C Horizon - Parent material, mostly light textured.

The above description of a Podzol profile is very general but serves to demonstrate the sequence of horizons usually found in this type of soil.

Recently Nygard et al (31), in discussing Podzol soils in the northern Great Lake States of the United States, suggests that the morphological characteristics are (a) an A_0 horizon of undecomposed or partially decomposed organic matter rich in organic acids, and (b) a platy ashy grey A_2 horizon rich in silicates because of the removal of humus, bases and sesquioxides; an illuviated B horizon which is generally compact and colored brown, yellowish brown, or reddish brown by iron compounds and organic matter. They suggest further that in most Podzols a very thin, almost imperceptible, dark-colored humus layer (A_1) of low base status occurs between the A_0 and the A_2. The important chemical characteristics of these soils are a highly acid reaction and high percentage of exchangeable hydrogen.

Regarding Brown Podzolic and Podzol soil profiles a difference of opinion exists among some soil scientists (4), (26), as to the importance of separating these two great soil groups in soil classification work. Cline (4) considers Brown Podzolic soils as merely being weakly expressed Podzol profiles and suggests that in soil classification there is no need to separate them as distinct great soil groups. On the other hand, Lyford (26) feels that due to certain differences in morphological and chemical properties between the two profiles, a separation at the great soil group level is justified. Lyford (26) came to this conclusion after comparing a number of analyses of Brown Podzolic and Podzol soils. He noted a striking difference in the total base-exchange capacity and content of organic carbon. Brown Podzolic soils showed a maximum of these in the surface organic horizon with a gradual decrease with depth, while the Podzol exhibited a second maximum in the orterde (B horizon). Lyford also found that the iron and aluminum contents of the orterde of Podzols is higher than in the B_{21} horizon of Brown Podzolic soils.

SOIL SEQUENCES

Soil sequences have been described through a series of climatic regions ranging from the work of Sherman (42) in Hawaii, to Stobbe (46) and Cline (4) and others (10), (26), in the temperate zone to the polar regions where Kellogg and Nygard (17) have described a sequence of profiles which appear to form a continuum in Alaska.

Sherman (42) recently investigated a sequence of soil profiles in Hawaii which show successive stages of weathering or development. The soils selected for study by this worker were: (a) a youthful soil containing most of its primary minerals; (b) the peak of clay formation - kaolinization; (c) the stage showing the cessation of clay formation and the increasing oxide formation or clay mineral decomposition; and (d) the final end-product of weathering - the free oxide soil. Sherman states that these stages of soil weathering are found under increasing rainfall or a shorter drought period.

The analytical data provided by this worker (42) shows a steady decrease in silica content of the A horizon, from the initial stage, due to the advancement of weathering. In the second stage where clay formation is at a peak the alumina content increases sharply but falls off in the third stage where clay decomposition is active. Iron and titanium oxides begin to accumulate as the soil weathering increases and in the final stage they constitute almost 80 percent of the soil. It is interesting to note that as the weathering progresses the silica content decreases from a maximum of about 45 percent in the youthful soil to about 5 percent in the final stage.

In regard to soil weathering Semb (41) and Richard and Chandler (36) have noted a difference between the mineralogical content of Brown Forest and Podzol soils. Semb (41) found that in Brown Forest soils, where leaching is not too intense, the mineral composition of the various horizons tends to be nearly the same. Richard and Chandler (36) reported that in the A horizon of Podzols there is a definite reduction in some of the heavy minerals, particularly horneblende, indicating the effect of greater leaching.

In the temperate zone Stobbe (46) and Cline (4) have described similar soil sequences involving Brown Forest, Grey-Brown Podzolic, and Brown Podzolic soils. In this sequence the modal Brown Forest soil represents the least developed profile which is typified by a neutral solum, a thick granular A_1 horizon, and a B horizon that is transitional to the parent material. There is no concentration of clays or sesquioxides in any horizon.

The modal Grey-Brown Podzolic profile of this sequence shows evidence of greater development than the Brown Forest soil due to the presence of an eluviated A_2 horizon, a B horizon that contains more clay than either the A or the C, and a solum that is generally thicker and slightly more acidic than the Brown Forest soil.

Between these two modal profiles there occurs a profile which is structurally typical of Grey-Brown Podzolic soils but has the reaction and textural properties of Brown Forest soils. This soil remains about neutral in reaction but a thin A_2 horizon develops below the accumulation of organic matter. The B horizon takes on the well-developed nuciform structure of the Grey-Brown Podzolic soils but is not distinctly heavier in texture from the A horizon. These men (46), (4) regard this soil as being an intergrade between the modal Brown Forest and modal Grey-Brown Podzolic soils in Ontario and Quebec and in New York State.

These workers, Stobbe (46) and Cline (4) have described two soils, which appear to be intergrades between the modal Grey-Brown

Podzolic soils and modal Brown Podzolic and Podzols. One of these soils, the Grey Brown Podzolic - Brown Podzolic intergrade, is characterized by the development of a Brown Podzolic profile in the A_2 horizon of a Grey - Brown Podzolic soil. Below this Brown Podzolic profile the heavier textured B horizon of the Grey - Brown Podzolic profile occurs above the calcareous parent material. Cline (4) states that in some cases the B horizon of the Grey Brown Podzolic, although distinguished on the basis of color, does not differ greatly in texture from the horizon above, suggesting that the former clayey B horizon is losing its clay under the influence of acid leaching. Cline (4) concluded that with the disappearance of the textural B horizon the profile will fit the accepted definition of a modal Brown Podzolic soil since in the most developed profiles in the area the depth to free carbonates was eight feet or more.

Besides the Grey - Brown Podzolic - Brown Podzolic intergrade, Stobbe (46) has noted a profile which he refers to as a Grey - Brown Podzolic - Podzol intergrade. This soil shows a Podzol profile development in the A_2 horizon of a Grey - Brown Podzolic soil which is underlain by the textural B horizon of a Grey - Brown Podzolic soil. Stobbe (46) considers this profile to be an intergrade between a modal Grey - Brown Podzolic and a modal Podzol soil. The main difference between the Grey - Brown Podzolic - Brown Podzolic intergrade and the Grey - Brown Podzolic Podzol intergrade being the development of a bleicherde or podzol - like A_2 horizon in the latter. Stobbe (46) postulates that with time the intergrade characteristics will disappear and this soil will be replaced by a modal Podzol profile.

Regarding disintegration of the clayey B horizons of Grey - Brown Podzolic soils, Frei and Cline (9) report, following a petrographic study of this horizon, that there is distinct evidence of clay destruction in the topmost part of the B horizon which extends deeply into the B horizon of the intergrades. They found, too, evidence of clay remnants in the lower horizons of well-developed Brown Podzolic soils. These men interpret this evidence as indicating a Brown Podzolic profile will develop in a former Grey - Brown Podzolic soil.

Stobbe (46) has also reported a sequence of profiles which represent a transition between Brown Forest and Brown Podzolic soils in Eastern Canada. These soils which he calls Brown Forest - Brown Podzolic intergrades have developed from mixed calcareous and non-calcareous materials and are usually found in transition areas between highly calcareous and non-calcareous surface deposits. He states that the gradual change from calcareous to non-calcareous parent materials is associated with a gradual transition in type of profile from modal Brown Forest through Brown Forest - Brown Podzolic intergrade and Brown Podzolic - Brown Forest intergrade to modal Brown Podzolic.

Lyford (26) has noted the occurrence of Podzol - Grey - Brown Podzolic intergrades in the Northeastern United States. This worker oonsiders there to be two types of Podzol soils in that area. One type has no horizons below the orterde or B horizon of the Podzol, and a second type that has horizons below the orterde which are similar to those found in Grey - Brown Podzolic and Red - Yellow Podzolic soils.

Lyford advances several theories attempting to explain the genesis of double or intergrade profiles. He first suggests, as did Cline (4), that they were originally Grey - Brown Podzolic soils and later developed into Podzols due to a gradual leaching of carbonates. He notes, however, that south of the Wisconsin terminal moraine they develop on acid sandstone which suggest that a diminishing base status may not be the controlling factor. Lyford is also of the opinion that the profiles may have always been Podzols and that the texture B may have developed concurrently with the bleicherde (A_{2p}) and orterde (B_p), this being a maximal Podzol. Those soils, therefore, now considered to be modal Podzols which do not have a texture B horizon would actually be young in comparison.

A further suggestion made by Lyford (26) is that the Grey - Brown Podzolic or Red - Yellow Podzolic soils develop first in a warmer climate or under a different vegetation than now exists and later the Podzol profiles develop.

In 1952 Gardner and Whiteside (10) reported on the occurrence of Podzol - Grey Brown Podzolic intergrades in the Thumb Region of Michigan. These men studied a sequence of seven profiles, the parent materials of which ranged in texture from sand to silty clay loam. According to Gardner and Whiteside the soil development on the sandy parent materials shows a typical Podzol profile with only the slightest suggestion of lower horizons below the orterde. On the heaviest parent material, the silty clay loam, the soil profile is that of a Podzol - Grey - Brown Podzolic intergrade. They note that in many places on the heavier textured parent materials the A_{2p} horizon is discontinuous and the upper profile suggests that of a Brown Podzolic soil. This latter type of development would correspond to the Grey - Brown Podzolic - Brown Podzolic intergrade described by Stobbe (46) and Cline (4).

In conclusion, Gardner and Whiteside (10) summarize the theories postulated by different workers for the development of Grey - Brown Podzolic - Brown Podzolic and Grey - Brown Podzolic - Podzol intergrades. These suggestions are as follows:

(1) It has been suggested that the upper profile is the result of weathering of a more recent geological deposit on the lower profile.

(2) A theory has been advanced suggesting that the upper profile is a Ground - water - Podzol formed due to drainage being restricted by the lower B horizon.

(3) A genetic theory suggesting that the upper Podzol profile is the younger, having formed in the acid relatively siliceous A_2 horizon of an older Grey - Brown Podzolic soil.

(4) Another theory points out that the B horizons of the Podzol and the Grey - Brown Podzolic soils are quite different, and suggests that the processes active in forming these two kinds of B horizons are operating at the same time on the climatic border between the Podzols and Grey - Brown Podzolic soils.

In 1951, Smith (43) in describing the soils of Clallam County, Washington, noted the occurrence of a sequence of profiles involving Grey Podzolic, Brown Podzolic and Brown Lateritic soils. These soils, although varying widely in character, occur within a distance of fifty miles. In this short distance the annual rainfall ranges from sixteen inches northeast of the Olympic Mountains to one hundred and fifteen inches on the western windward side of the mountains.

According to Smith (43), in the area of lowest rainfall the soils are predominately Grey Podzolic in character. They range in reaction from pH 6.0 at the surface to pH 7.5 in the substratum. Under virgin forest conditions about two inches of dark greyish-brown highly organic loam occurs under the forest litter, but there is little evidence of sesquioxide or organic matter eluviation in the profile. Smith notes that in some places a half-inch or more of sandy or ashy material may occur, which suggests that a podzolized A_2 horizon may be in the process of forming.

To the west, where the annual rainfall is twenty to twenty-five inches, the Grey Podzolic soils grade into Brown Podzolic on the same type of parent materials. The Brown Podzolic soils, according to Smith (43), lack the light grey horizon of the Grey Podzolic but appear to have a greater accumulation of iron and alumina in the subsoil. Also, the reaction of the solum indicates greater leaching ranging from pH 5.0 at the surface to 6.0 in the substratum.

West of the zone of Brown Podzolic soils, and in the area of highest rainfall along the coast, Smith (43) considers the soils to be Brown Laterites. The typical Brown Lateritic profile in this area ranges from pH 4.5 to 5.0 throughout the solum. The organic litter, which varies from a few inches to several feet in thickness underlain by about twelve inches of dark brown, loose, granular mineral soil containing numerous hard aggregates. The subsoil is a granular clay in which there is a fairly high content of aggregates, chiefly iron concretions and decomposing gravel. According to Smith (43) these soils are similar to Brown Lateritic soils with regard to granules, texture, permeability, and reaction.

In 1952 Geracimov (11) reported on a sequence of Russian soils. This worker sub-divides Podzol soils into weakly podzolic, medium podzolic, strongly podzolic and Podzol soils. He also describes mull podzolic soils which apparently show different degrees of development; a similar breakdown is given for Grey Forested soils. Although the exact meaning of the scheme outlined by Geracimov (11) is somewhat obscure, it does convey the idea that the Russian views on certain soils are somewhat similar to those of workers in North America at the present time.

In 1953 Leahey (25) described a sequence of soils occurring in the Hay River District of Alberta at N. Latitude 60° 00'. He studied three soils, the first called Wooded Calcareous shows little profile development except that free lime has been leached out of the upper five inches of mineral soil. A second profile which he called a Brown Wooded soil shows slightly greater development than the Wooded Calcareous; free lime has been leached from the upper nine inches and there is evidence of some loss of organic matter from the profile. The most mature or most developed profile in the sequence described by Leahey (25) is a Grey Wooded soil. This soil is lower in organic matter than the Brown Wooded; free lime has been leached to a depth of fourteen inches, and some clay has been moved down the profile. All three soils occur on silty clay alluvium.

Still another sequence of soil profiles has been reported by Kellogg and Nygard (17) after studying the soil groups of Alaska. These workers state that the Subarctic Brown Forest soils resemble the Podzols in some features but note that transitional soils occur between them and the Podzols. The Subarctic Brown Forest soils develop on low lime parent materials and may or may not be underlain with permafrost. They have an organic A_0 horizon at the surface which is slightly to strongly acid, while the lower layers are slightly acid to neutral. Usually the Subarctic Brown Forest soils are leached of free carbonates. Nygard and Kellogg (17) note that the Subarctic Brown Forest soils lack the ashy A_2 horizon characteristic of the Podzols, although near the margins of the transition to Podzols some suggestion of it is evident.

These workers (17) feel that it is not possible to say definitely that the Subarctic Brown Forest soils are younger than the Podzols simply because they are less mature. They state further that the Brown Forest soils appear to be fairly stable in this polar region and it is not possible to postulate that they will become Podzols with time.

EXPERIMENTAL

(1) Field Study

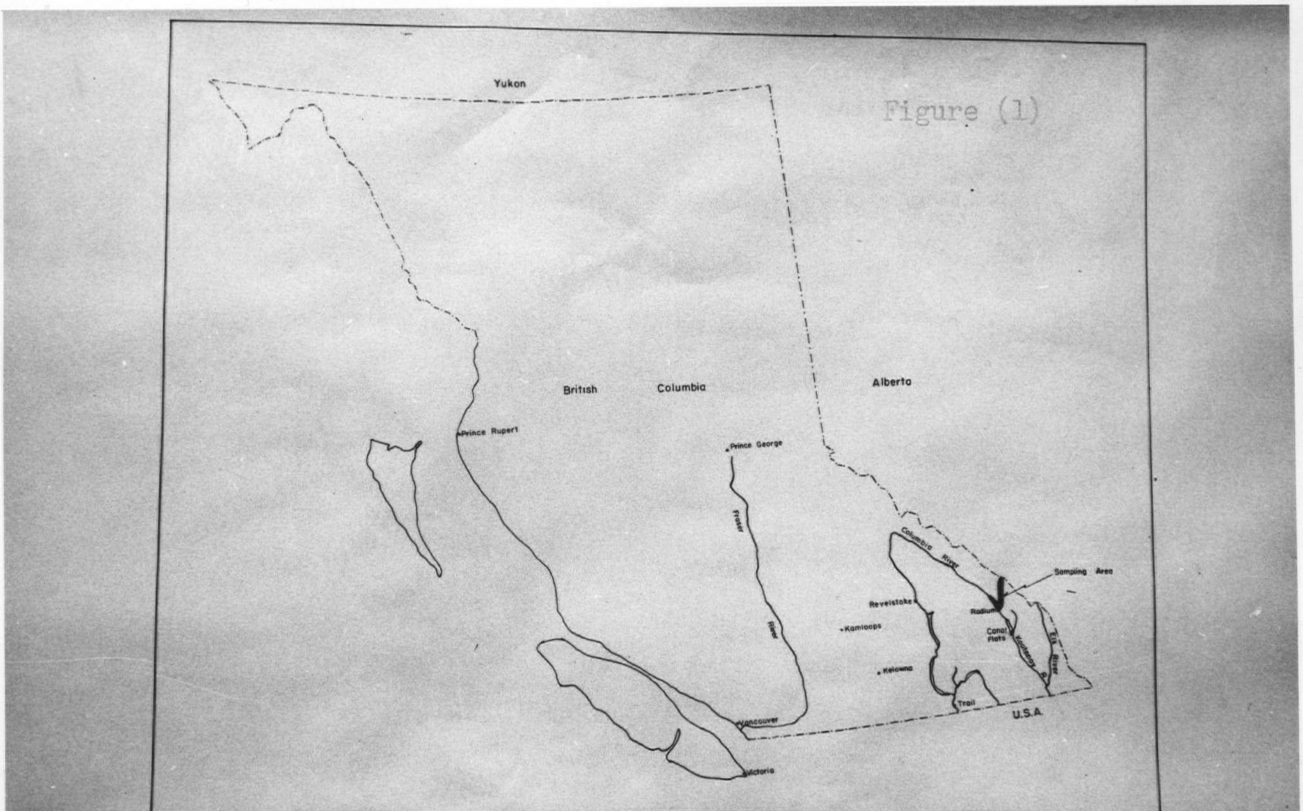
Location of Soil Sampling Area.

The soils included in the study occur in Kootenay National Park and the adjacent Columbia River Valley in the East Kootenay District of British Columbia. The area is located between latitudes N 50° 19' and N 51° 00', the mean longtitude being approximately 116° 00'. The range in elevation for the complete series of soils studied is from 3,170 to 4,290 feet above sea level.

Four of the soils, i.e., profiles number one, two, four and five occur in Kootenay National Park while number three is found in the Columbia River Valley.

The location of the sampling area in southeastern British Columbia is shown in Figure (1).

Figure (1)



Map of British Columbia Showing Location of Soil Sampling Area

Geography of the Area.

The valleys of the Kootenay and Columbia Rivers lie in a north-south direction and have the typical U-shape of glaciated mountain valleys. The soils are formed from a variety of materials which occupy the valley floor and line the valley sides to a height of a thousand feet or more.

The centers of the valleys are occupied by relatively slow moving rivers which are fed by numerous fast flowing tributary streams entering from the valley sides. The main rivers have built a series of terraces along their edges. These terraces vary in texture from coarse gravelley outwash to fine stone-free silts and clays. The tributary streams have deposited alluvial material in the form of fans in the valley bottom. The fan material is for the most part coarse textured but provides one of the principal soil forming materials in the area.

The greatest part of the valley fill consists of glacial till. The till plains, which lie above the terraces, have a variable rolling topography and are dotted in some areas with oval-shaped till heaps or drumlins.

Above the till the mountains rise to alpine ridges and summits, ranging from 8,000 to 10,000 feet elevation. The Columbia River Valley is situated between two mountain systems and has the Purcell Mountains to the west and the Rocky Mountains to the east. The Kootenay River Valley, in Kootenay National Park, is situated wholly in the Rocky Mountain system, having the Stanford Range to the west and the Mitchell Range to the east.

The rock formations contained in the Purcell and Rocky mountains are principally limestones; consequently the soil parent materials, glacial till and the till derivatives, are of a calcareous nature. This feature plays an important role in the type of soil development in the area.

Climate of the Area.

The climatic data (2) available for Canal Flats and Brisco in the Columbia River Valley and Sinclair Pass in Kootenay National Park is shown in Table (1).

Generally there is an increase in precipitation and lowering of mean annual temperature in a south to north direction. The driest part of the area occurs in the vicinity of Canal Flats where the annual precipitation amounts to 16.2 inches. At Sinclair Pass in Kootenay National Park the annual precipitation is 21.4 inches; the higher precipitation at this station is undoubtedly associated with the higher elevation.

It is to be noted that at Canal Flats the precipitation is slightly higher than at Brisco even although this latter station lies to the north. It is possible, however, that the humidity is greater at Brisco due to a higher elevation. At Golden, some 100 miles north of Canal Flats, the annual precipitation is eighteen inches.

Field observations have indicated that the degree of soil development in the East Kootenay District is related to humidity. Around Canal Flats the dominant soils are of the Brown Wooded type which exhibit minimum development under the dry climate. Around Brisco the soils exhibit greater development, being Grey Wooded. The maximum development, Grey Wooded - Podzol soils, occur in the area of highest precipitation around Sinclair Pass.

Of the soils studied, profile numbers one, two, four and five occur in Kootenay National Park under approximately twenty-one inches of precipitation. The older soils in this area show the type of development exhibited by profiles four and five. The less mature soils, profiles one and two, are younger soils and their development, therefore, cannot be correlated with climate.

Profile number three occurs in the Columbia River Valley where the climate is similar to that at Brisco.

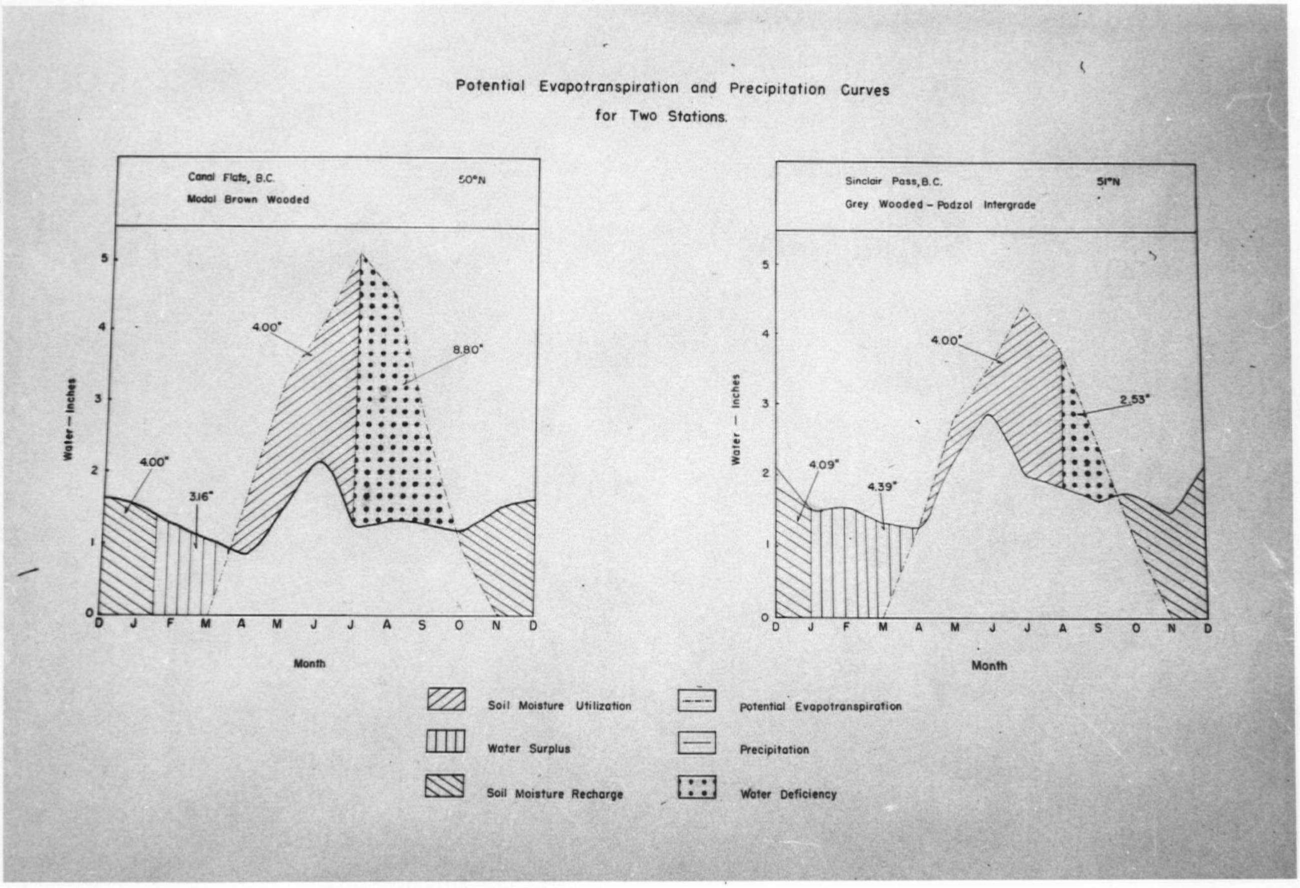
TABLE I
Mean Monthly and Annual Precipitation and Temperature Data for Three Stations

	Canal Flats		Brisco		Sinclair Pass	
	Altitude 2653'		Altitude 3000'		Altitude 3840'	
	Average Annual Pption. (inches)	Mean Annual Temp. °F.	Average Annual Pption. (inches)	Mean Annual Temp. °F.	Average Annual Pption. (inches)	Mean Annual Temp. °F.
Jan.	1.51	-3	1.44	-	1.46	11
Feb.	1.25	20	.99	-	1.52	17
March	1.03	30	.82	-	1.30	27
April	.84	43	.77	-	1.24	38
May	1.48	52	1.39	-	2.16	46
June	2.13	57	1.76	-	2.88	51
July	1.22	63	1.16	-	1.99	57
Aug.	1.30	62	1.35	-	1.83	55
Sept.	1.23	53	1.25	-	1.64	48
Oct.	1.18	40	1.23	-	1.85	39
Nov.	1.46	32	1.25	-	1.42	23
Dec.	1.61	22	1.93	-	2.11	16
Yearly	16.24	39	15.34	-	21.40	36

That sharp changes in climate should occur in such short distances is not unusual in narrow mountain valleys, as in the East Kootenay District. Sudden changes in elevation in relatively short distances often occur; this factor coupled with the nature of the topography tends to alter the climate regularly.

The potential evapotranspiration and precipitation curves, according to the Thornethwaite method (38), for the stations at Canal Flats and Sinclair Pass are shown in Figure (2).

Figure (2)



It can be seen that in the relatively humid Grey Wooded - Podzolic zone the water deficit is only 2.5 inches as compared to the more arid Brown Wooded zone where the annual deficit is 8.8 inches. There is a significant difference, too, in the length of period during which the soil moisture level is deficient. At Canal Flats this period extends from late June to late September, while at Sinclair Pass it begins around the first of August and lasts until late September. During this dry period soil development will be progressing at a minimum rate.

The amounts of water surplus, moisture utilization, water deficit, and potential evapotranspiration are computed in inches; the basis for all calculations being that every soil is capable of storing four inches of precipitation.

Description of Soils.

Field Descriptions.

During the course of the Soil Survey in the East Kootenay area many soil profiles were examined. Some rather interesting and complex relationships were observed that made classification difficult. It appeared that some of the soils might fit into a sequence such as the one described by Stobbe (46). These soils were selected for further careful study in the field and for laboratory examination.

Profile descriptions were taken from the surface (A_0 horizon) to the parent material (C horizon) according to the procedure outlined in the Soil Survey Manual (45). Notes were taken on texture, structure, depth, consistence, color according to Munsell Color charts, and the reaction using a pH field kit. A record of the topography, drainage, native vegetation, stoniness, and elevation was also taken. Soil samples were obtained from each horizon for laboratory analysis. The samples taken were of two types, bulk samples for chemical and physical analyses and core samples for determining apparent specific gravity.

Soil Profile Descriptions.

Five profiles were examined in the field; three of these being selected for laboratory analysis. The profile descriptions are as follows:

Profile No. 1

The first profile chosen for study is located in Kootenay National Park, 13.5 miles from the west entrance to the park at Radium. It occurs on a flat, low-lying river terrace along the Kootenay River, at an elevation of 3,780 feet above sea level. The profile is approximately ten feet above the present Kootenay River level.

The area has been burned over recently, the vegetation (27) now consisting of second growth Englemann Spruce (Picea englemanni), and Lodgepole Pine (Pinus contorta latifolia). The ground cover is made up of Pine Grass (Calamagrostis rubescens), Wild Strawberry (Fragaria glauca), Kinnikinnick (Arctostaphylos Uva-ursi), Fireweed (Epilobium angustifolium), Soopolalli (Shepherdia canadensis), and small Aspen (Populus tremuloides).

The parent material is a highly calcareous alluvial sand which is underlain by gravel.

The description of the profile is as follows:

Horizon	Depth	Description
A_0	$1\frac{1}{2}$ - 0"	Coniferous needle mat, some mosses, cones, and twigs. The reaction is slightly acid.

C	0 - 14"	Light brownish grey (10YR 6/2) dry and dark greyish brown (10YR 4/2) moist, very fine sandy loam with crumb to single grain structure and a soft consistence. This horizon is highly calcareous giving a strong effervescence with weak hydrochloric acid. The reaction is moderately alkaline (45).
D	14 - 20"	Coarse sand with single grain structure and soft consistence. This horizon is highly calcareous, the reaction being moderately alkaline.

It is apparent from this description that very little leaching has occurred in the profile for the mineral soil is calcareous right to the surface. Also there is no evidence of downward movement of clay or other material. Therefore, on the basis of field observations it must be concluded that the soil is very youthful and may be classed as an Alluvial soil (45).

Profile No. 2

The second soil studied was examined and sampled in Kootenay National Park at a point 13.2 miles from the west entrance to the park at Radium.

This profile occurs on a terrace of the Kootenay River at an elevation of 3,840 feet above sea level, and about 60 feet above the present Kootenay River level.

The tree cover at the point of sampling consists of a dense stand of Lodgepole Pine (Pinus contorta latifolia) with an occasional Englemann Spruce (Picea englemanni). The pine trees average about three to four inches in diameter at breast height, and stand approximately fifty feet high. Indications are that this area has been burnt-over recently.

The ground cover is principally Pine Grass (Calamagrostis rubescens), Wild Strawberry (Fragaria glauca), Fireweed (Epilobium angustifolium), Yellow Columbine (Aquilegia Flavescens), Dwarf Rose (Rosa gymnocarpa), Soopolalli (Shepherdia canadensis), and Dwarf Juniper (Juniperus communis).

The parent material of this soil is fairly heavy, being of silty clay loam texture. The area appears to lie on the inner edge of a terrace, at this point the water may have been slow moving or even ponded resulting in the deposition of fine sediments.

The profile description is as follows:

Horizon	Depth	Description
A_0	1 3/4 - 0"	Coniferous needle mat, cones, twigs, etc., partly decomposed in lower portion.
A_2	0 - 1"	Very Pale Brown (10YR 7/3) dry and brown (7.5 YR 5/4) moist, clay loam with weak platy to subangular blocky structure and a slightly hard consistence. There is a concentration of roots in this horizon. The depth is variable, being absent in some places and showing an inch of development in others. The reaction is medium acid.
B	1 - 6"	Pale yellow (2.5Y 7/4) dry and light yellowish brown (2.5YR 6/4) moist, clay loam to clay with medium blocky structure and a slightly hard consistence. An occasional stone and a few roots are present. There is only slight evidence of clay accumulation in this horizon. The reaction is neutral.
C	6" +	Pale yellow (5Y 8/3) dry and moist, silty clay loam with crumb structure and a slightly hard

consistence. There are a few stones and roots present. This horizon effervesces when dilute hydrochloric acid is applied, the reaction is moderately alkaline.

A comparison of the above description with that of the soil previously described shows that they differ distinctly in morphological characteristics. The differences serve to indicate that the latter soil is more mature, or in a more advanced stage of development than the former.

In support of this suggestion it should be noted that the first profile contained free calcium carbonate in all parts of the solum, while the second soil has been leached of carbonates to a depth of six inches. This leaching process has resulted in a lowering of the soil reaction.

There is also a suggestion of a B horizon in the second profile. This horizon, although lacking in textural properties, does show a more intense color and a slightly firmer consistence than the parent material.

The differences between the alluvial soil and the second type may be due in part to a difference in age. The position of the first profile, about ten feet above the present river level, indicates that the parent material for this soil was laid down in comparatively recent geological time. On the other hand, the second type occupies a position some sixty feet above the present river level. This difference suggests that the parent material for the second type was deposited some time earlier and consequently the processes of soil formation have been operating over a much longer period.

On the basis of the profile description it would appear that this soil may be a member of a recently described group known as Brown Wooded soils (25).

Profile No. 3

The third profile studied may be classed as a modal Grey Wooded soil (48). The best examples of this great soil group in the area occur in the Columbia River Valley near the town of Edgewater. The profile selected to represent this type of development was obtained at a point approximately seven miles north of Edgewater in the Columbia River Valley.

In the Soil Survey Report of the Upper Columbia River Valley, Kelley (18) refers to this particular soil as Kinbasket Silt Loam.

Kinbasket Silt loam is derived from a silty clay glacial till. The till contains a moderate amount of stones, the majority of which are limestones, consequently the parent material is of a calcareous nature.

The topography is typical of the till plain in the area, it tends to vary from gently to steeply rolling. The elevation at the point of sampling is 3,170 feet above sea level.

The tree cover consists of an open stand of Lodgepole Pine (Pinus contorta latifolia) and Douglas Fir (Pseudotsugo taxifolia). The ground cover is made up of Kinnikinnick (Arctostaphylos Uva-ursi), Soopolalli (Shepherdia canadensis), Dwarf Rose (Rosa gymnocarpa), and Pine Grass (Calamagrostis rubescens).

The profile description is as follows:

Horizon	Depth	Description
A_0	3/4 - 0"	Coniferous needle mat, twigs, grass, cones. Slightly decomposed in lower portion. The reaction is medium acid.
A_{21}	0 - 2"	Light grey (10YR 7/2) dry and brown (10YR 5/8) moist, sandy loam with platy structure and a

		soft consistence. There is a fairly high concentration of roots and few stones occur. The reaction is neutral.
A_{22}	2 - 9"	Very Pale Brown (10YR 7/3) dry and yellowish brown (10YR 5/4) moist, platy to weak subangular blocky structure and a soft to slightly hard consistence. A few roots and some stones occur in this horizon. The reaction is neutral.
B_{22}	9 - 14"	Brownish yellow (10YR 7/6) dry, yellowish brown (10YR 5/8) moist, clay loam with subangular to small blocky structure and a hard consistence. A few stones and some roots are present. This horizon shows definite clay accumulation, it is compact and somewhat impermeable. The reaction is neutral.
C	14" +	Pale yellow (5Y 7/3) dry and light yellowish brown (2.5Y 6/3) moist, silty clay loam glacial till. The material effervesces with dilute hydrochloric acid. The reaction is moderately alkaline.

It is evident that the morphological description is that of a modal Grey Wooded soil which has reached a greater stage of development than either of the two soils previously described.

The major features exhibited by the Grey Wooded Profile which point to greater development are a deeper solum, thicker horizon of eluviation, and a definite horizon of clay accumulation. In the Grey Wooded profile unweathered parent material occurs at a depth of fourteen inches, whereas in the Brown Wooded soil the parent material is reached at a six inch depth. Similarly, the Grey Wooded soil has an A_2 horizon of nine inches as compared to a maximum of one inch in the Brown Wooded. The B_{22} horizon of clay accumulation, which occurs in the Grey Wooded profile, can be easily distinguished by ordinary field texturing methods; this feature is not evident in the Brown Wooded profile.

The difference in development between these two soils appears to be due to a difference in age. Since the parent materials are of similar texture, one cannot account for it on the basis of greater leaching or deep percolation; differences in climate do not appear to be the cause either, since the Brown Wooded soil occurs in an area of greater precipitation than the Grey Wooded soil. Age, however, does seem to suggest an explanation.

The Grey Wooded profile occurs on glacial till and the Brown Wooded soil on alluvial material. It seems likely that the glacial till pre-dates the alluvial material which would be deposited sometime after the ice had withdrawn from the area.

Profile No. 4

The fourth profile was examined and sampled in Kootenay National Park at a point 41.2 miles from the Radium entrance to the park. The elevation at the profile site is 4,290 feet above sea level.

This soil occurs on an alluvial river terrace about 100 feet above the present river level.

The vegetation consists of Douglas Fir (Pseudotsugo taxifolia), Balsam Fir (Abies amabilis), Englemann Spruce (Picea englemanni). The ground cover is principally Kinnikinnic (Arctostaphylos Uva-ursi), Soopolalli (Shepherdia canadensis), Dwarf Rose (Rosa gymnocarpa), Yellow Columbine (Aquilegia flavescens) and mosses.

The profile description is as follows:

Horizon	Depth	Description
A_0	2 - 0"	Coniferous needle mat, twigs, cones, etc. Decomposed in lower portion.
A_{2p}	Absent	
B_p	0 - $3\frac{1}{2}$"	Brownish Yellow (10YR 6/6) dry and yellowish red (5YR 4/8) moist, sandy loam to light loam with single grain structure and soft consistence. A few roots but no stones occur in this horizon.
C_p or A_{22gw}	$3\frac{1}{2}$ - 8"	Light yellowish brown (10YR 6/4) dry and pale yellow (2.5Y 7/4) moist, loam with weak crumb or single grain structure and soft consistence. A few roots and stones occur in this horizon.
B_{22gw}	8 - 10"	Light olive brown (2.5Y 5/6) dry and light olive brown (2.5Y 5/4) moist, clay loam with subangular blocky to blocky structure. The consistence is slightly hard. The aggregates appear to be coated with a thin waxy film. This horizon tends to become "wavy" in places and occurs at varying depths from the surface.

B_{cagw}	10 - 14"	Brownish yellow (10YR 6/6) dry and yellowish (10YR 5/8) moist, clay loam with small blocky structure and a slightly hard consistence. Some stones and roots occur in this horizon. There is effervescense when dilute acid is applied, indicating presence of free lime.
C_{gw}	14" +	Light olive brown (2.5Y 5/4) dry and light olive brown (2.5Y 6/4) moist, sandy clay loam outwash material of a calcareous nature.

In the above description the subscript "p" is used to indicate that a particular horizon belongs to the Brown Podzolic profile while the subscript "gw" is used to denote a horizon of the Grey Wooded soil.

The above profile appears to be that of a Brown Podzolic profile which is underlain by a heavy textured horizon typical of the Grey Wooded soils. On the basis of field observations and material reported in the literature (31), (46) it is concluded that this soil is a Grey Wooded - Brown Podzolic intergrade; the Brown Podzolic soil having formed in the A_2 horizon of the Grey Wooded.

The greater development exhibited by the above profile over the previously mentioned Grey Wooded soil may be associated with a more humid climate. Since the Grey Wooded - Brown Podzolic profile occurs at an elevation of 4,290 feet above sea level, some 1,200 feet above the site of the Grey Wooded profile, it can be safely assumed that due to lower temperatures and perhaps higher precipitation the climate would be more humid. This would result in a greater amount of leaching and consequently greater profile development.

The Brown Podzolic profile development in the upper part of the solum is morphologically typical of this great soil group. The colors and texture are similar to those of Brown Podzolic profiles described in different parts of North America.

The reactions of the various horizons were not included in the profile description due to possible sample contamination, however similar profiles have been noted in which the B_p and C_p horizons ranged from mildly to moderately acid. Since an acidic parent material is one of the criteria necessary for inclusion of a profile in the Brown Podzolic great soil group, the acidic C_p horizon of this intergrade fits the accepted definition.

Profile No. 5

The profile pit for the fifth soil examined is located in Kootenay National Park at a point approximately 11.2 miles from Radium. The elevation at the site of sampling is 4,010 feet above sea level.

The profile occurs on a terrace of the Kootenay River about 200 feet above the present river level. The parent material is of a coarse nature, consisting of coarse sand and gravel outwash.

Lodgepole Pine (Pinus contorta latifolia), Douglas Fir (Pseudotsugo taxifolia), and Englemann Spruce (Picea englemanni) make up the forest cover in the vicinity of the profile pit. The ground cover consists of Pine Grass (Calamagrostis rubescens), Dwarf Rose (Rosa gymnocarpa), Soopolalli (Shepherdia canadensis), and Kinnikinnick (Arctostaphylos Uva-ursi).

The profile description is as follows:

Horizon	Depth	Description
A_0	2 - 0"	Coniferous needle mat, cones, twigs, etc. Slightly decomposed in lower part. The reaction is medium acid.

A_{2p}	0 - 2"	White (10YR 8/1) dry and pinkish grey (7.5YR 6/2) moist, sandy loam with platy structure and a soft consistence. There are no stones but a fairly high concentration of roots in this horizon. The depth is variable, it may occur in pockets or extend down in a tongue-like fashion to a depth of four inches. The reaction is extremely acid.
B_p	2 - $6\frac{1}{2}$"	Brownish yellow (10YR 6/6) dry and yellowish red (5YR 4/8) moist, the texture is sandy loam and the structure single grain. It has a soft consistence. There are no stones but a few roots occur in this horizon. The distinctive feature of this horizon is the bright reddish color when moist due to accumulation of sesquioxides. The reaction is medium acid.
C_p or A_{22gw}	$6\frac{1}{2}$ - 14"	Pale yellow (2.5Y 7/4) dry and light yellowish brown (10YR 6/4) moist, the texture is sandy loam with single grain structure. The consistence is soft to slightly hard. An occasional stone occurs and roots penetrate this horizon. The reaction is medium acid.
B_{22gw}	14 - 17"	Light yellowish brown (10YR 6/4) dry and yellowish brown (10YR 5/4) moist, the texture is clay with small blocky structure. The consistence is slightly hard to hard. Stones and roots occur in this horizon. This horizon varies in thickness and does not follow a

straight line but tends to be wavy in nature. The heavy texture is typical of Grey Wooded B_2 horizons. The reaction is neutral.

C_{gw} 17" + Light brown grey (2.5Y 6/2) dry and olive grey (5Y 4/2) moist. The texture is a sandy loam. It is a calcareous mixture of sand and gravel, a few roots have penetrated to this horizon. The reaction is moderately alkaline.

The above described soil shows the development of a Podzol profile within the A_2 horizon of a Grey Wooded soil. In many respects it is morphologically similar to the Grey Wooded - Brown Podzolic soil, the major difference being the development of a bleicherde or A_{2p} horizon. Like the Grey Wooded - Brown Podzolic soil, however, this profile has the remnants of a former Grey Wooded soil in the lower part of the solum in the form of a heavy textural B_2 horizon and a calcareous parent material. Field observations indicate that this soil is a Grey Wooded - Podzol intergrade (33), (46).

The Grey Wooded - Podzol profile is considered to be zonal for Kootenay National Park. That is, under the existing climate and vegetation, the majority of the soils exhibit this type of development.

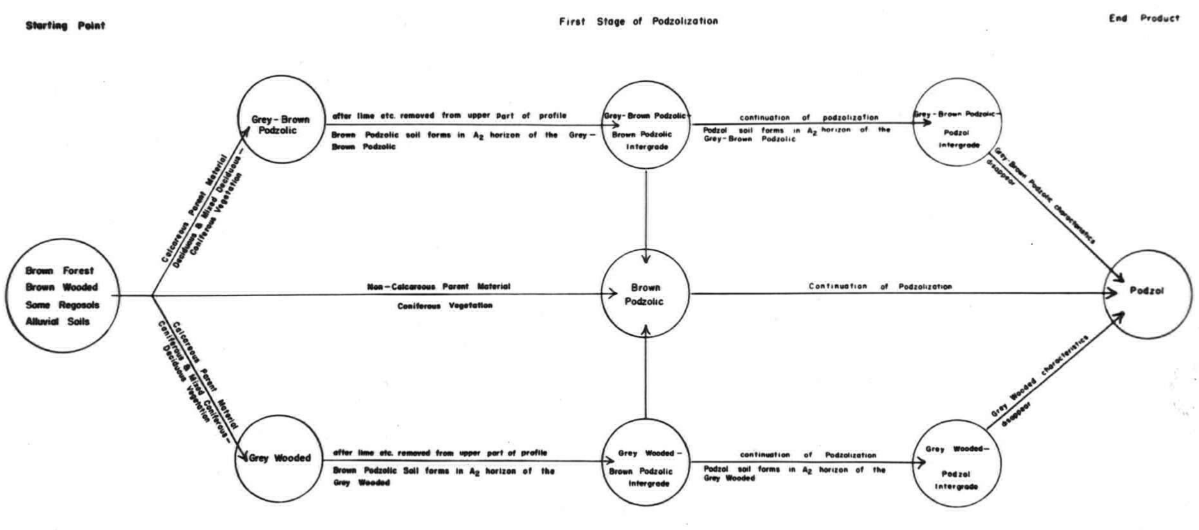
Although no Podzol soils have been found in the East Kootenay District, it would appear that such a profile will develop eventually from the Grey Wooded - Podzol intergrade. One profile examined, at an elevation of 5,330 feet above sea level, appears to show some of the characteristics of a Podzol soil. In this case the textural B_{22} horizon has dispersed to the point of now merely being a thin irregular horizon which no longer has its heavier texture. It may be, however, that the Podzols will only develop on coarse textured parent materials where the lime is most easily removed by leaching.

The writer agrees with Cline (4) and other workers (26),(46),(10) in suggesting that both Podzol and Brown Podzolic soils develop within the A_2 horizon of Grey Wooded soils as a result of an acidic condition being developed in the upper part of the Grey Wooded soil. Since an acidic parent material is required for the development of both Brown Podzolic and Podzol soils, this condition is satisfied after prolonged leaching of a Grey Wooded profile.

Soil Sequences in Canada

Figure (3)

A PROPOSED EXPLANATION of the VARIOUS KINDS of PODZOLIC SOILS WHICH OCCUR in CANADA



A proposed explanation of the stages through which some Canadian podzolic soils pass as they develop is shown in Figure (3) above. The diagram embraces the work of Stobbe (46) on Grey - Brown Podzolic, Brown Podzolic, and Podzol soils in Eastern Canada, as well as the observations noted in regard to the Alluvial, Brown Wooded, Grey Wooded, Grey Wooded - Brown Podzolic and Grey Wooded - Podzol soils studied in the East Kootenay District of British Columbia.

(2) Laboratory Study.

The laboratory studies included physical and chemical analysis of the horizons sampled. The tests selected were those thought most likely to assist in showing relationships between the soils, and also in their classification.

The physical determinations made were mechanical analysis and apparent specific gravity, and the chemical determinations included fusion analysis, cation exchange capacity and exchangeable calcium and magnesium, organic carbon, and soil reaction.

Three of the soils examined in the field were selected for laboratory analysis. These were the Brown Wooded, Grey Wooded and Grey Wooded Podzol soils. The Brown Wooded soil was chosen because it was felt that this soil varied sufficiently from the Grey Wooded and Alluvial soils to warrant separation in the classification. Analysis of the Grey Wooded soil was required to establish its relationship with the Brown Wooded and Grey Wooded - Podzol soils.

The reason for examining the Grey Wooded - Podzol soil was to confirm field observations which indicated that a Podzol profile had developed within the A_2 horizon of a Grey Wooded soil.

Laboratory Methods

Physical Methods:

(1)Mechanical Analysis:

The pipette method of mechanical analysis as described by Puri (35) and Kilmer and Alexander (20) was employed in this study. An automatic pipette was assembled which insured a constant filling time of 15 seconds for a 25 ml. pipette.

In preparing the samples for analysis the coarse skeletal fraction was removed with a 2 mm. sieve. Two 10 gram samples of this material were used for each analysis.

The dispersion technique involved oxidation of the organic matter with ten percent hydrogen peroxide, followed by removal of free calcium carbonate by digestion with dilute hydrochloric acid. Finally .05N sodium hydroxide was added until the pH of the soil suspension had reached 10.8. This method is suggested by Puri (35). Each sample was then shaken for two hours on a rotary shaker.

The sand fraction was separated by passing the dispersed sample through a 325 mesh sieve. This retained particles larger than .05 mm. diameter.

Three clay fractions were determined by pipetting, the settling time for a fixed depth of sampling being calculated from Stoke's Law. The fractions withdrawn were .005 mm. and smaller, .002 mm. and smaller, and .001 mm. and smaller. The percent of silt was calculated by summing the percent of sand and clay ($<$ .002 mm.) and subtracting from 100.

All calculations were based on moisture - free, organic matter - free, and carbonate - free samples. A correction was also made for the amount of sodium hydroxide dispersing agent added to each sample.

(2) Apparent Specific Gravity:

The apparent specific gravity of some horizons was determined from core samples taken with a Bradfield soil sampling tool (1).

It was not possible to obtain samples from all horizons since many were too thin for the type of sampler employed, and in certain cases sampling was not feasible due to excessive stoniness.

The samples obtained were carefully packed and shipped to the laboratory for examination.

The method used to determine the apparent specific gravity was to oven-dry each core sample, the oven-dry weight of soil in each core could then be determined. This figure was divided by the inside volume of the core used, giving the apparent specific gravity of the sample.

Chemical Methods:

(1) Fusion Analysis:

A fusion analysis of each horizon, for the profiles examined in the laboratory was carried out to determine the amounts of silica, alumina, iron, calcium and magnesium present. All determinations were carried out in duplicate.

For this work, the fusion analysis method described in Chemical Methods of Soil Analysis (3) was employed. Two notable modifications were made to the above mentioned procedure.

In place of the suggested Stannous Chloride method for iron determinations, a Jones' Reductor was used for reducing the iron solution. This method is described by Kolthoff and Sandell (21). A 150 mls. of ferric sulphate solution was reduced by passing it through a column of amalgamated zinc, the iron solution in the reduced state was then titrated with .1 N potassium permanganate.

The second change in procedure was made in the analysis for total magnesium. In place of the gravimetric method, described in Chemical Methods of Soil Analysis (3), the ammonium magnesium phosphate precipitate was dissolved in .1 N sulfuric acid and the excess acid back titrated with .1 N sodium hydroxide. A description of this method is given in Scott (4).

(2) Cation Exchange Capacity:

The neutral ammonium-acetate method of Schollenberger and Simon (39) was used for the determination of cation exchange capacity. Following leaching, the adsorbed ammonia was distilled into .1 N sulfuric acid and titrated with .1 N sodium hydroxide.

Exchangeable calcium and magnesium were determined from the leachate following the methods described by these workers. All determinations were made in duplicate.

(3) Organic Carbon:

Organic matter determinations were made using the Dry Combustion method described in Chemical Methods of Soil Analysis (3) and Kolthoff and Sandell (21). The carbon dioxide formed by combustion of the soil sample at 900°C was absorbed in ascarite (asbestos impregnated with sodium hydroxide), the gain in weight representing the amount of carbon present in the sample. The percent of carbon obtained multiplied by the factor 1.724 gave the percent of organic matter.

Blank determinations to check the operation of the apparatus were run using calcium carbonate as a standard. All samples were analyzed in duplicate.

(4) Soil Reaction:

The pH of each horizon examined was obtained by the paste method using a glass electrode. All determinations were carried out in duplicate.

Laboratory Results

Physical Analyses:

(1) Mechanical Analysis:

The results of mechanical analyses for the fractions separated are shown in Table (2).

TABLE II

PARTICLE SIZE DISTRIBUTION DATA FOR HORIZONS OF BROWN WOODED, GREY WOODED, AND GREY WOODED - PODZOL SOILS IN PERCENT.

(Expressed on moisture and lime-free basis)

Horizon	Sand >.05 mm.	Silt .05-.002 mm.	Clay <.005 mm.	Clay <.002 mm.	Colloidal Clay <.001 mm.
			BROWN WOODED		
A_2	33.04	33.24	46.56	33.72	23.09
B	22.61	36.34	51.38	41.05	32.52
C	22.75	41.32	55.49	35.93	24.98
			GREY WOODED		
A_{21}	48.11	36.34	26.78	15.55	10.79
A_{22}	42.38	38.71	31.07	18.91	13.74
B_{22}	41.18	27.82	40.90	31.00	24.53
C	46.78	32.55	39.13	27.62	20.67
			GREY WOODED - PODZOL		
A_{2p}	44.76	39.84	32.06	15.40	9.54
B_p	46.84	36.70	30.85	16.46	11.40
C_p	45.68	31.82	34.38	22.50	15.58
B_{22gw}	41.97	17.19	47.74	40.84	35.16
C_{gw}	61.03	15.92	28.57	23.05	17.28

It is evident from the data presented that clay is disappearing from the A horizon and is being concentrated in the B horizon of all profiles.

However, the amount translocated varies with the different profiles; the Brown Wooded profile shows the least and the Grey Wooded - Podzol the greatest clay accumulation. Since clay movement or accumulation is an important characteristic of Grey Wooded soil development, this can be taken as a fair indication of the degree of maturity of each profile. On this basis it can be safely stated that the Brown Wooded is the most immature of the three soils and the Grey Wooded - Podzol the most mature, with the Grey Wooded being intermediate between the two. This data confirms the observations made in the field and reported elsewhere (48),(50),(25).

The results of the analyses show also that the clay movement or accumulation does not differentiate between coarse clay and fine clay, that is, there is no indication to show that fine clay is carried down or formed before coarse clay.

According to the work of others (48),(30), Grey Wooded soils accumulate clay in the B horizon but Podzols do not (12). The results of this analysis are therefore in agreement since the Grey Wooded soil has a clay content of 15.55 percent in the A_2 horizon and 31 percent in the B_2. The Podzol soil, developed in the A_2 of the Grey Wooded, shows an increase of only one percent between the A_{2p} and B_p horizons.

In regard to the Brown Wooded soil there is an apparent increase of 7 percent between the A_2 and B horizons. It is difficult to conceive that this increase is due to the normal movement of clay from the A_2 to the B horizon since the A_2 is very thin, having a maximum thickness of one inch. At the same time the A_2 is only 2 percent lower in clay content than the C horizon.

There are four possible explanations for the higher clay content of the B as compared to the C horizon. These are in increasing order of probability:

(1) Formation of clay in situ.

(2) Incomplete removal of calcium carbonate has affected the dispersion of the C horizon.

(3) Removal of calcium carbonate has led to an apparent increase in clay content of the B horizon.

(4) Differences in clay content of the parent material.

The fourth explanation seems the most likely since the parent material is water deposited and as such would not necessarily be homogeneous throughout.

(2) Apparent Specific Gravity:

The results of the apparent specific gravity determinations are shown in Table (3).

The results also indicate that the three profiles are at different stages of development. A wider spread in apparent specific gravity values, between the A and B horizons, occurs in the Grey Wooded - Podzol intergrade than in the modal Grey Wooded soil. This indicates that there has been a greater removal of organic matter from the A horizon, and a greater accumulation of clay in the B horizon of the Grey Wooded - Podzol profile than in the Grey Wooded soil.

TABLE III

APPARENT SPECIFIC GRAVITY DATA FOR HORIZONS OF BROWN WOODED, GREY WOODED, AND GREY WOODED-PODZOL SOILS
(expressed on moisture-free basis)

Brown Wooded		Grey Wooded		Grey Wooded-Podzol	
Horizon	App.Spec.Gravity	Horizon	App.Spec.Gravity	Horizon	App.Spec. Gravity
A_2	-	A_{21}	.98	A_{2p}	.85
B	1.09	A_{22}	1.26	B_p	.87
C	1.22	B_{22}	1.27	C_p	.95
		C	1.44	B_{22gw}	1.28
				C_{gw}	-

Similar results were obtained by Leahey (25) for Brown Wooded and Grey Wooded soils in the Hay River District of Alberta. The Brown Wooded soil examined by him had a bulk density or apparent specific gravity of .97 in the A_2 horizon and 1.16 in the B, while in the Grey Wooded the values were 1.14 in the A_2 and 1.47 in the B horizon.

It is difficult to estimate the change that has occurred in the Brown Wooded profile since sampling of the A_2 horizon was not possible. However, the value for the B horizon appears to indicate that clay accumulation has not reached the extent to which it has in either the modal Grey Wooded or Grey - Wooded Podzol soils.

Chemical Analyses:

(1) Fusion Analysis:

Mean values of total chemical analysis, soil reaction and organic matter content of the profiles are given in Table (4).

TABLE IV

MEAN CHEMICAL COMPOSITION, REACTION AND ORGANIC MATTER CONTENT OF THE BROWN WOODED, GREY WOODED AND GREY - WOODED - PODZOL SOILS. (EXPRESSED ON MOISTURE FREE-BASIS)

Soil	Horizon	Depth	pH	SiO_2 %	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Organic Matter %
Brown	A_2	0 - 1"	5.81	69.37	21.05	4.80	16.25	.99	2.04	2.88
Wooded	B	1 - 6"	6.67	69.02	21.79	5.31	16.48	.97	2.69	1.76
	C	6" +	8.24	44.16	12.59	3.12	9.48	18.85	3.50	-
Grey	A_{21}	0 - 2"	7.09	75.27	19.49	4.00	15.48	1.13	1.19	1.20
Wooded	A_{22}	2 - 9"	7.19	75.14	20.96	4.57	16.38	.68	1.30	.72
	B_{22}	9 -14"	7.08	71.90	21.87	6.99	14.88	.73	1.65	1.32
	C	14" +	8.13	57.92	17.31	5.26	12.05	10.96	3.16	-
Grey	A_{2p}	0 - 2"	4.45	82.91	13.16	1.60	11.56	.93	.51	.97
Wooded-	B_p	2 -6½"	5.56	68.02	22.40	4.62	17.78	1.19	1.29	1.72
Podzol	C_p	6½-14"	6.04	77.70	17.16	3.70	13.46	.60	1.90	.54
	B_{22gw}	14-17"	7.05	66.79	20.13	4.88	15.25	2.92	3.47	3.12
	C_{gw}	17" +	7.86	59.65	14.15	3.27	10.88	9.48	4.15	-

Generally, the same type of development appears to be taking place in each profile, the normal trends with depth, however, are least evident in the Brown Wooded profile and most evident in the Grey Wooded-Podzol intergrade.

Silica is highest in the A_2 horizon of all profiles and decreases with depth, being at a minimum in the C horizon. In comparing the horizon of eluviation (A_2) with the horizon of illuviation (B_2), the widest spread in silica content occurs in the Grey Wooded - Podzol, while the narrowest is in the Brown Wooded. It should be noted that in the Grey Wooded - Podzol the silica content decreases sharply in two horizons, the B of the Podzol and the B_2 of the Grey Wooded. This can be attributed to the accumulation of sesquioxide in these horizons. The most striking change in silica content, in all the profiles, occurs between the B and C horizon where a sharp decrease occurs due to the diluting effect of carbonates in the parent material.

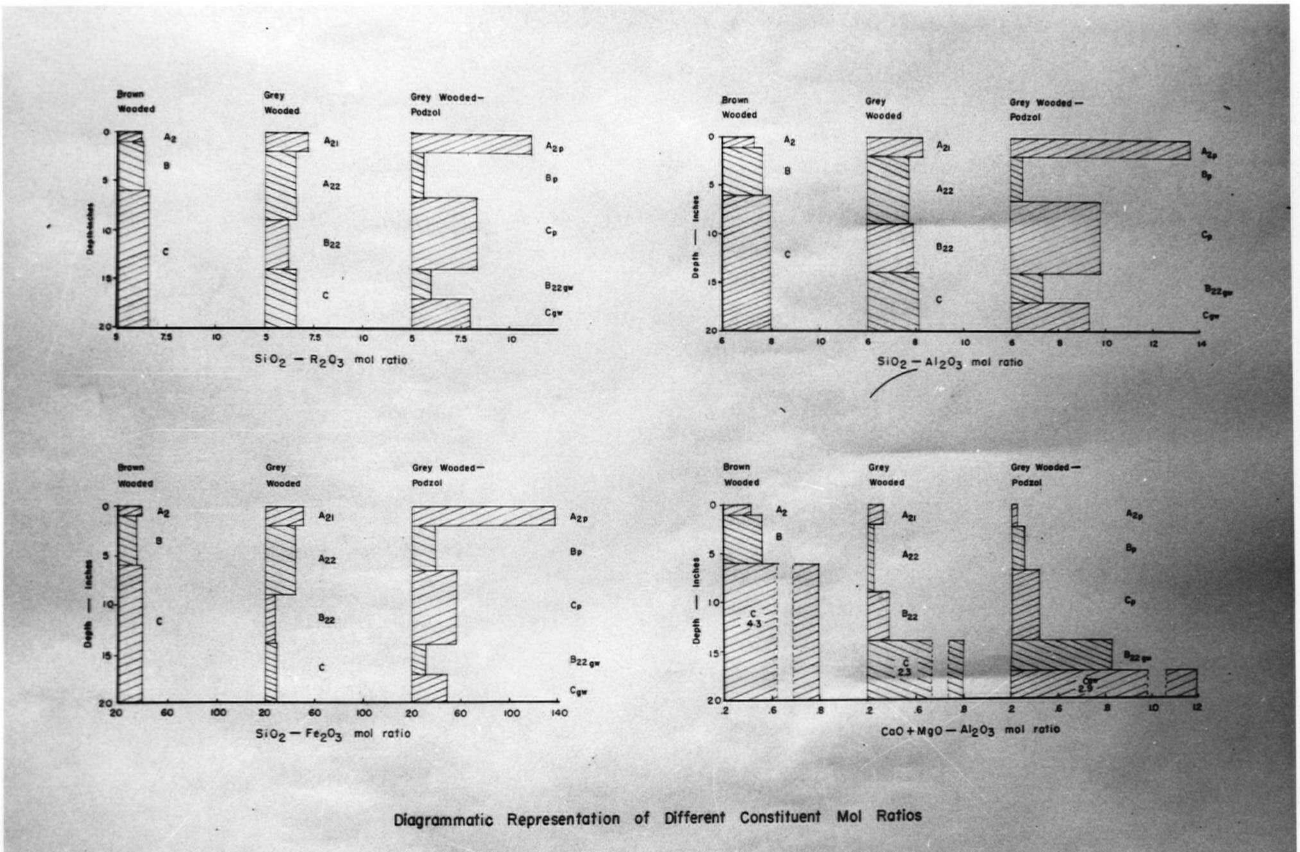
Sesquioxides, alumina and iron, vary inversely with the silica contents, that is, they are at a maximum in the B horizons and a minimum in the A horizons. Again the differences are most evident in the Grey Wooded - Podzol and least evident in the Brown Wooded, the Grey Wooded being intermediate between the two. If the Grey Wooded - Podzol is considered to be a "double - profile," it can be seen that a maximum iron accumulation occurs in the B_p of the Podzol and again in the B_2 of the Grey Wooded. This effect provides fairly strong evidence to show that a Podzol profile has developed or is still in the process of developing in the A_2 of the Grey Wooded. Podzols as a group are characterized by an accumulation of sesquioxides but not clay in the B horizon, while Grey Wooded profiles show an accumulation of sesquioxides and silicate clays in the B_2 horizon. These facts have been borne out in this analysis. As already stated, the Podzol B_p shows no appreciable accumulation of clay while the B_{2gw} of this same profile shows a distinct clay accumulation. These results agree with the work of Stobbe (46) who found increases in sesquioxide content in the B_p and B_{22gp} horizons of Tioga loamy fine sand, a Grey Brown Podzolic - Podzol intergrade found in Ontario.

Leaching has removed large amounts of bases from the solums of all three profiles. This would appear to be the point to which the Brown Wooded has developed, since the bases have been removed but little sesquioxide has been translocated. Some return of calcium to the surface by root action is evident in the Brown Wooded and Grey Wooded profiles but not in the Grey Wooded - Podzol intergrade.

A general lowering of soil reaction, as a result of removal of bases, has occurred in all three profiles. It is to be noted that the solum of the Brown Wooded is generally more acidic than the Grey Wooded. This is not typical of most Brown Wooded profiles, and may in this example be a result of organic acids being produced from a heavier coniferous needle litter. In the case of the Grey Wooded - Podzol intergrade the reaction in the A_{2p}, B_p, and C_p horizons is typical of Podzol profiles, while the lower horizons, the B_{22gw} and C_{gw}, are typical of Grey Wooded soils. This condition lends support to the idea that a Podzol profile has developed within the A_2 horizon of a Grey Wooded soil.

The molecular ratios suggested by Jenny (12) for illustrating the relative concentration of constituents are shown in Figure (4). Considering the $SiO_2 - R_2O_3$ ratio, it is seen that there has been little movement of sesquioxides in the Brown Wooded profile, a slightly greater movement in the Grey Wooded and the greatest movement has taken place in the Grey Wooded - Podzol soil.

Figure (4)



Diagrammatic Representation of Different Constituent Mol Ratios

It is interesting to note that the SiO_2 - Al_2O_3 ratio in the Grey Wooded soil remains relatively constant whereas the SiO_2 - Fe_2O_3 ratio, between the A_2 and B_2 horizons, shows a marked difference. It would appear, therefore, that the process of soil development in the Grey Wooded profile has resulted in downward movement of iron but not alumina. A similar conclusion was arrived at by Farstad (6) who, in working with Grey Wooded soils of the Central Interior district of British Columbia, found that the movement of sesquioxides was primarily a movement of iron and not alumina. This conclusion is further substantiated by the work of McCaleb and Cline (29) in New York State.

Movement of alumina occurs in the most acidic profile, the Grey Wooded - Podzol intergrade. Apparently, translocation of this constituent will only take place when podzolization is the soil forming process in operation, and does not take place in the Grey Wooded type of soil development. A condition similar to this was found by McCaleb and Cline (29) who only found evidence of alumina movement in the most acidic of the three profiles they studied.

The loss of divalent bases from the solum of each profile is shown in Figure (4) by means of $CaO + MgO$ - Al_2O_3 mol ratio. Jenny (12) suggests using alumina as a basis for this comparison since it is known to be one of the most stable constituents found in the soil profile. A striking difference can be seen between the C horizon and other horizons of all three profiles, indicating that leaching has removed large amounts of calcium and magnesium compared to alumina in all cases.

The B_p and C_p horizons of the Grey Wooded - Podzol soil appear to have slightly higher ratios than comparable horizons in the modal Grey Wooded profile. This may be due to removal or translocation of alumina from the upper horizons of this intergrade.

(2) Cation Exchange Capacity and Organic Matter Content:

The mean values from cation exchange determinations together with the percent organic matter, colloidal clay, reaction and base saturation in the various horizons of the Brown Wooded, Grey Wooded, and Grey Wooded - Podzol soils are shown in Table (5).

Generally the total exchange capacity of all three profiles increases with depth, and therefore, closely parallels the clay content, which also increases with depth. The highest total exchange capacities occur in the Brown Wooded profile and the lowest in the Grey Wooded - Podzol intergrade. It is to be noted that in the Brown Wooded soil the highest exchange capacity occurs in the A_2 horizon and decreases in the B and C. A greater content of organic matter in this horizon could account for this result. The organic matter content of the A_2 is 2.88 percent while the amount of this constituent in the B horizon is only 1.76 percent. Within the Grey Wooded and Grey Wooded ÷ Podzol profiles the most striking difference in exchange capacity occurs between the A and B horizons. The eluviated A horizons in both cases show a much lower value than the B_{22} horizon, the horizon of illuviation. The relatively high clay and organic matter content of this horizon would contribute greatly to increasing the exchange capacity.

TABLE V

MEAN CATION EXCHANGE CAPACITY, ORGANIC MATTER CONTENT, COLLOIDAL CLAY, REACTION AND BASE SATURATION VALUES FOR THE BROWN WOODED, GREY WOODED AND GREY WOODED - PODZOL SOILS.

(Expressed on a moisture - free basis)

Horizon	Total Exchange m.e./100gms.	Exchange Ca m.e./100 gms.	Exchange Mg m.e./100 gms.	Base Sat.%	Organic Matter %	Colloidal Clay <.001 mm. %	pH
			Brown Wooded				
A_2	27.90	12.24	1.78	50.0	2.88	23.09	5.81
B	22.08	11.20	1.69	58.2	1.76	32.52	6.67
C	17.18	18.34	.69	100.0	-	24.98	8.24
			Grey Wooded				
A_{21}	18.74	7.43	1.59	48.4	1.20	10.79	7.09
A_{22}	16.97	6.82	1.53	49.2	.72	13.74	7.19
B_{22}	21.81	8.59	2.49	52.4	1.32	24.53	7.08
C	11.61	17.03	2.05	100.0	-	20.67	8.13
			Grey Wooded - Podzol				
A_{2p}	17.43	3.33	.35	21.2	.97	9.54	4.45
B_p	26.60	1.67	.43	7.8	1.72	11.40	5.56
C_p	16.61	5.17	1.66	41.1	.54	15.58	6.04
B_{22gw}	25.71	15.76	1.58	67.2	3.12	35.16	7.05
C_{gw}	18.25	19.42	.84	100.0	-	17.28	7.86

The results of this analysis also provides strong evidence to show that the Grey Wooded - Podzol is a polygenetic profile. It is seen that the cation exchange capacity of the B_p horizon is 26.60 m.e./100 grams as compared to 17.43 m.e. in the A_{2p} and 16.61 m.e. in the C_p horizon. Again this increase in the B_p can be correlated with organic matter, the content of this constituent is .97 percent in the A_{2p}, 1.72 percent in the B_p, and .54 percent in the C_p horizon. This result is in agreement with Joffe (15) who characterizes the B horizon of Podzols as being higher in cation exchange capacity and organic matter than the A_2.

In all three profiles the horizon with the lowest exchange capacity is the C. This is probably due to the diluting effect of carbonates on the sample taken for analysis. Results of total analysis show that all the parent materials are high in calcium carbonate, exceeding 40 percent in the case of the Brown Wooded profile. Although a 50 gram sample was taken for each determination, this 50 grams would not represent 50 grams of soil, but actually in the case of the Brown Wooded profile, it represented 29.55 grams of soil and 20.45 grams of calcium carbonate. By correcting for carbonates the exchange capacities of the C horizons become 29.07 m.e./100 grams in the Brown Wooded, 17.18 m.e. in the Grey Wooded and 24.55 m.e. in the Grey Wooded - Podzol. It is not necessary to make this correction for the horizons in the solum since leaching has removed free carbonates.

A comparison of the absolute amounts of adsorbed calcium and magnesium gives some indication as to the degree of weathering that has taken place in each profile. The Brown Wooded profile has the greatest quantity of these constituents adsorbed on the cation exchange complex while the more mature Grey Wooded - Podzol has the least. The Grey Wooded profile is again intermediate between the two.

Perhaps a better means of characterizing the extent of development is on the basis of percent base saturation of the exchange complex. For this study base saturation has been calculated as the percent of the total exchange capacity occupied by adsorbed calcium and magnesium. This is not strictly the base saturation status of the horizons since sodium and potassium are held in much lesser amounts on the exchange, but have not been included here. However, the base saturation as calculated herein, serves to indicate the overall status of the exchange complex.

It is seen that the percent base saturation is highest in the Brown Wooded profile and decreases through the Grey Wooded to the Grey Wooded - Podzol intergrade. Generally the degree of saturation increases with depth in each profile reaching a 100 percent in the parent materials where free lime occurs. Complete saturation of the C horizon is commonly found in soils developed on calcareous materials, as shown by the analyses of Williams and Bowser (49) and Ableiter, Leighty et al (8).

One noticeable exception to the downward increase of base saturation occurs in the Grey Wooded - Podzol profile. A sharp difference between the saturation percentages of the horizons in the Podzol profile occurs. The exchange complex of the A_{2p} is 21.2 percent saturated, while the B_p and C_p are 7.8 percent and 41.1 percent saturated respectively. As already mentioned, the B_p horizon has a relatively high exchange capacity which would account, in part at least, for the lower percent saturation. This lowering of the saturation percentage in the B_p horizon may be characteristic of the "double - profiles" in this region. In 1949 a group of American pedologists, Ableiter, Leighty et al (8) described a profile near the eastern edge of Kootenay National Park that appears to have many features in common with the Grey Wooded - Podzol profile described in this study. These men described a Podzol profile that shows the following horizons: A_0, A_2, B_{21}, B_{22}, B_{31}, B_{32}, C. This writer believes that their description is actually that of a Grey Wooded - Podzol intergrade. The reasons for this deduction are twofold: First, the B_{32} horizon shows a definite accumulation of clay which is characteristic of Grey Wooded soils but not Podzols, and second, the parent material is highly calcareous which again is not typical of Podzol soils. Podzols normally develop on acidic materials. Therefore, it would seem that with our present knowledge of this area that the horizon sequence should be A_{2p}, B_p, C_p, B_{2gw}, and C_{gw}, in which case their A_2 horizon would correspond to the A_{2p}, the B_{21} and B_{22} to the B_p, the B_{31} to the C_p, the B_{32} to the B_{22gw}, and the C to the C_{gw}. On this basis the two profiles are comparable in many respects. In the profile described by the American workers the base saturation of the B_{21} and B_{22} horizons is 5 percent and 9 percent respectively, whereas the B_p of the Grey Wooded - Podzol examined for this study has a base saturation of 7 percent.

SUMMARY AND CONCLUSIONS

Field observations and laboratory analyses were made on five soils of the East Kootenay District of British Columbia. From these investigations it is concluded that they form a sequence showing different degrees of horizon development.

The first soil in the sequence consists of recently deposited alluvium and shows a thin A_0 horizon over a high lime parent material. There is no evidence of any carbonate, sesquioxide, or other material being moved down the profile. It is suggested that this profile be classified as an Alluvial soil.

The second soil, termed Brown Wooded, has several morphological, chemical and physical properties which indicate it has reached a greater stage of development than the Alluvial soil. Whereas free lime occurs right to the surface in the Alluvial soil it has been leached to a depth of six inches in the Brown Wooded profile, with a consequent lowering of the soil reaction. There is also a suggestion of a B horizon in the Brown Wooded soil. The same degree of weathering over a longer period of time has resulted in a greater intensity of color and a slightly firmer consistence in the B horizon.

Although it shows greater development than the Alluvial soil, the Brown Wooded does not possess the characteristics necessary for classification with Grey Wooded soils. The B horizon does not conform to the definition of this horizon given in the U.S.D.A. Soil Survey Manual (45). It is merely a "color B" and as such cannot be recognized as a horizon of illuviation.

The results of the mechanical analysis, apparent specific gravity, cation exchange, and total constituent determinations indicate that silicate clays and sesquioxides are not accumulated in the B horizon.

This evidence indicates that the properties of Brown Wooded soils are such that a separation from both Alluvial and Grey Wooded soils is warranted in soil classification. It appears that the separation should be made at the family level of classification, in such a manner as to recognize the development of some zonal properties associated with Grey Wooded soils.

The Brown Wooded soils handled in this manner may be considered Alluvial - Grey Wooded intergrades.

The third profile examined is considered to be a modal Grey Wooded soil. The field and laboratory examinations have shown that it has the major horizons and chemical and physical properties necessary for inclusion in this great soil group. A well-defined grey A_2 horizon under an A_0 and a textural B_2 horizon overlaying a calcareous parent material are characteristic of Grey Wooded Soils.

The fourth soil in the sequence appears to be a polygenetic Grey Wooded - Brown Podzolic intergrade. This profile is characterized by a Brown Podzolic soil which is underlain by a heavy textured horizon typical of Grey Wooded soils. It would appear that a Brown Podzolic soil has developed in the A_2 horizon of a Grey Wooded soil as a result of acid leaching.

The fifth soil examined represents an intermediate stage between Grey Wooded and Podzol soils and as such can be termed a Grey Wooded - Podzol intergrade. The field examination suggested that a Podzol soil has developed in the A_2 horizon of a Grey Wooded soil. This observation has been confirmed by the laboratory analyses. An accumulation of sesquioxides and organic matter in the upper B_p horizon is typical of Podzol soils, while the accumulation of clay in the lower B_{2gw} horizon is characteristic of Grey Wooded soils.

It would appear that the polygenetic profiles, Grey Wooded - Brown Podzolic intergrade and Grey Wooded - Podzol intergrade, should be recognized in soil classification in the East Kootenay District. It is suggested that the separation should be made at the family level in the classification system so that the podzolic characteristics superimposed on Grey Wooded soils can be recognized.

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