SOIL TEXTURE OF PINUS PONDEROSA PLANT COMMUNITIES IN BRITISH COLUMBIA

by

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ABSTRACT

The field work for this investigation was carried out in the summer of 1952, during this time soil samples and field notes were made. Further soil samples were secured in the summer of 1953. The area in which the yellow pine communities were studied was in the Okanagan, Similkameen, Nicola and South Thompson Valleys as well as the southern Cariboo in the vicinity of Clinton.

The soil samples were air-dried, weighed and the gravel fraction (particles greater than 2 mm. in diameter) separated by sieve. The gravel fraction was weighed and the percentage determined for each sample. The mechanical analysis was done by means of the Bouyoucos Hydrometer Method, following the removal of organic matter by hydrogen peroxide, and carbonates by treatment with hydrochloric acid. The results of the mechanical analysis were expressed in terms of percentages, by weight, of sand, silt and clay on the basis of the soil sample with the gravel removed.

Using the textural classification of the United States Department of Agriculture the results were expressed in terms of sandy loam, loam, etc. for each plant community. The ranges in soil texture for each plant community are:

Agropyron association - sandy loam to clay loam with extremes of sand and clay.

Stipa subassociation - sandy loam.

Artemisia subassociation - clay loam.

Purshia association - generally sand, occasionally sandy loam.

Aristida subassociation- sand to sandy loam.

Rhus association - loamy sand with high percentage of gravel.

Arctostaphylos association - sandy loam or loamy sand to sand.

Arctostaphylos - *Calamagrostis* association - sand to sandy loam.

Calamagrostis association - sandy clay loam to sandy loam.

Symphoricarpos association - sandy loam and sandy clay loam.

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CONTENTS

INTRODUCTION

This study of soil texture is part of a project to investigate the plant communities and environmental conditions of the <u>Pinus ponderosa</u>[1] forest in British Columbia. The analysis of the vegetational and climatic factors of these communities is being carried out by Mr. T. C. Brayshaw. This project is also part of a larger programme, initiated and directed by Dr. V. Krajina, the aim of which is an ecological classification of the forests of British Columbia. Apart from the intrinsic value, knowledge of these forest communities has considerable value for its practical applications. This knowledge can serve as a sound basis for forest management and silvicultural practices. It is of importance also for the formation of policies for watershed control. In addition, knowledge of forest communities can be applied to the management of forest ranges.

This forest classification is based on environmental and vegetational characters, and uses as its fundamental unit the plant association. Through the examination of forest stands there becomes apparent certain plant communities which possess uniform floristic composition and which occur under similar environmental conditions. Starting with these observable communities, definite ecological units, which are called plant associations, can be established by means of a detailed analysis of their floristic, climatic, edaphic and topographic features.

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1 A list of species with their authors appears in the Appendix.

Stands of Pinus ponderosa were studied in the Okanagan, Similkameen, Nicola, and Thompson Valleys and in the southern Cariboo in the vicinity of Clinton. This area represents the general distribution of Pinus ponderosa in British Columbia. Certain other smaller and rather isolated stands also occur in other valleys adjacent to those mentioned above. These outlying stands occur in the Skagit, Fraser, North Thompson, Shushwap, Kettle and Kootenay River Valleys. These stands generally show considerable variation from the main body of the Pinus ponderosa forest as is displayed by the presence of different associate tree species. The stands to the east of Okanagan Valley, in the Kettle and Kootenay River Valleys, have Larix occidentalis as an associate species. The northern stands, along the North Thompson River, have a large proportion of Pinus contorta, while the western outlying stands contain several coastal tree species.

The field study was initiated in the spring of 1952, and during the summer soil samples were collected from a number of stands representing ten plant communities. During the following winter the soil samples were measured for pH. Additional soil samples were collected in the summer of 1953 from certain of the plant communities which were not as well represented by the collecting done in the previous year. During the following winter the mechanical analysis of the soil samples was begun.

GENERAL DESCRIPTION OF REGION

Physiography and Geology

The area under study consists of the southern part of the Interior Plateau of the Cordilleran System. The Interior Plateau has, in a very general way, a downward slope from south to north and is greatly dissected by rivers which in the restricted southern part flow in the opposite direction to this slope (i.e. from north to south). The altitude of the plateau in the north ranges from 3000 to 3500 feet above sea level, whereas the southern part ranges from 5000 feet to 5500 feet above sea level. Shushwap Lake, north of the Okanagan Valley, has a water level of 1130 feet above sea level, the water level of Osoyoos Lake in the southern Okanagan is 903 feet above sea level.

The present edaphic and physiographic features of this region are in part the result of the Pleistocene glaciation. However, in the Eocene period this region was one of low relief, during which were formed swamp deposits such as the coal formations at Princeton. Volcanic activity occurred during the Tertiary period, with deposition of lava fields during the Miocene which were continuous with the extensive Columbia lavas of Washington and the adjacent states. During the Pliocene considerable uplift and erosion occurred. In the Pleistocene the land was glaciated by the Cordilleran ice sheet. The glaciation resulted in the formation of U-shaped valley bottoms, the rounding off of topographical prominences and a general movement and mixture of all loose material which was deposited as glacial till. Three main types of deposits were formed. Terraces margining glacial lakes were formed with sandy or gravelly surfaces and underlain by sandy loam and with a substratum of boulder clay. Terraces of silt were formed in the South Thompson and Okanagan Valleys. In the latter case the deposition occurred while the Okanagan trough was occupied by glacial ice. In the more narrowly restricted part of the trough, south of the present Vaseaux Lake, the ice had a damming effect, and lakes were formed northward bordering the glacier. Tributary streams flowing into these lakes deposited the extensive terraces of white silts. Lacustrine deposits of clay were also formed, mainly in the northern part of the Okanagan Valley, some of these clay deposits reaching a depth of forty feet. Post-glacial erosion consisted mainly of streams carving valleys through the glacial lake terraces and lacustrine deposits. In the former case fan cones were formed which have the material sorted according to particle size.

Soil

There are two main types of weathering processes operating in this region now: kaolinization and skeletization. Skeletization of parent material involves only mechanical breakdown, without any chemical alteration. This process is occurring to a lesser extent now but certainly during the early post-glacial period it played a very significant role. Kaolinization is the chemical formation of clays by the removal of some of the silica from the parent material and the synthesizing of new alumino-silicate clays. It is the chief weathering process operating now. Of the soil forming processes there are three main ones taking place: melanization, podsolization and gleization. Melanization involves the infiltration of organic matter into the mineral horizons of the soil profile. This is the most prevalent process of soil formation in the Interior drybelt. It results in the formation of profiles having an A_1 or melanized horizon beneath the surface litter, which is a mixture of black organic material and mineral soil and merges gradually into the B horizon. In many of these soils, especially those with sandy texture and poor structure, there is no definite boundary between the melanized layer and the B horizon.

The process of podsolization is considerably more complex. Infiltrating water carries the bases and soluble materials from the surface layers down into the mineral horizons. The leached surface layer then has an abundance of hydrogen ions and is acid. Bacterial decomposition of organic matter is inhibited and a thick humus layer accumulates on the surface. Infiltrating water which passes through the humus layer is reinforced with organic acids and carbonic acid from dissolved carbon dioxide and brings about the reduction of iron and aluminum sesquioxides and their transport to the lower horizons. In the lower horizons the sesquioxides are precipitated and an illuvial or B horizon is formed. In addition to the downward movement of the iron and aluminum sesquioxides, colloidal material is also translocated. Under acid conditions the organic and inorganic colloids of the upper horizon are dispersed and in this condition can be easily moved down into the profile where flocculation occurs and the colloids are deposited. In the Interior drybelt the process of podsolization has given rise to the Intermountain Podsol Soils. In the Dark Brown and Black Soils, because of lower precipitation, only the first phase of the podsolization process takes place. Infiltrating water removes some of the soluble ions to produce a degraded or leached condition.

Certain soils are influenced by the lateral movement of groundwater, this process is called gleization and the resultant soils are classified as Groundwater Azonal soils. Lateral moving groundwater counteracts the process of podsolization by depositing in the profile soluble salts and colloids which it carries. When large amounts of colloidal material are deposited a sticky gley horizon results. In addition the gley layer has a mottled colour of red and bluish grey, from fluctuations in the groundwater level and alternating conditions of oxidation and reduction.

Climate

The climate of the yellow pine region consists of cool winters, hot summers and low precipitation. The average annual precipitation ranges from 9 - 24 inches and the seasonal distribution has two peaks, one in winter and the other in summer. The summer peak is of considerable significance as it occurs at an important time during the growing season, in the middle of a dry period. The precipitation pattern is governed by two influences, the Maritime influence and the Continental influence. In higher or more exposed locations (e.g. Merritt and Salmon Arm) the Maritime influence is more pronounced, resulting in a winter (December and January) maximum. The Continental influence is present in the lower and more northerly stations (e.g. Kamloops and Penticton) with a summer (June) maximum resulting. The average frost-free period ranges from 170-198 days, although certain localities have a shorter period. Merritt, for example, has a frost-free period which is less than 125 days.

Chapman (1952) has classified the climates of British Columbia using the Köppen system. The valley bottoms of the Okanagan and South Thompson Rivers are grouped as Middle Latitude Steppe (BSk), with cold-semi-arid conditions and with evaporation exceeding precipitation. The higher elevations above the valley bottoms are grouped into the Microthermal Climate, Humid Continental - cool summers (Dfb). Other areas in this region, mainly in the valley bottoms, are classified as Humid Continental - hot, dry summers (Dsa) and Humid Continental - cool, dry summers (Dsb).

Vegetation

As a result of the present topography and climate, the vegetation is zonally stratified. The altitudinal ranges are not rigid for the different vegetational groups, but vary from valley to valley and according to direction of exposure and other factors. Nevertheless approximate figures can be indicated for these altitudinal ranges. In the valley bottoms grasslands are present, up to approximately 2500 feet above sea level. Above this is the *Pinus ponderosa* forest, between 2000 and 3500 feet. The *Pseudotsuga menziesii* forest occurs at 3000 to 4500 feet. On the heights, between 4500 and 7000 feet, is the *Picea Engelmannii* - *Abies lasiocarpa* forest, which thins out to alpine meadows at heights above 7000 feet.

DISCUSSION OF SOIL TEXTURE

An investigation of soil texture is a limited aspect of the overall study of yellow pine forest communities. Nevertheless the single factor of soil texture has considerable significance. The publications of Wilde (1935), Daubenmire (1947), Lutz and Chandler (1946) have dealt thoroughly with the ecological importance of soil texture. Soil texture influences nutrient content, structure, aeration, water holding capacity, infiltration of water, rate of water movement, root penetration and soil temperature. The following are features of coarse sandy soils:

low nutrient content (cation capacity low)

poorly aggregated

good porosity for exchange of metabolic gases

low water holding capacity

rapid infiltration of water, hence subject to leaching and poor in nutrients

rapid capillary movement of water, but total distance of movement shorter

easy root penetration

more favourable temperatures for plant growth.

Heavy clay soils have the following properties:

high nutrient content

good aggregation unless deflocculated

poor aeration

high water holding capacity

impervious to water, or slow infiltration of water

slow capillary movement of water, but can move for longer distances

resistant to root penetration

more stable temperatures.

In general the optimum textural conditions for forest growth is a loam rather than a coarse sand or fine clay. The influence of soil texture on moisture availability results in a complex relationship in arid regions. In such regions grasses are favoured on fine soils and forests on coarse textured soils. In dry areas light rains can be totally held as hygroscopic water in heavy soils. Lutz and Chandler state that regeneration of P. ponderosa in the southwestern United States is poor on deep volcanic cinder soils, but when underlain with clay or loam good growth occurs.

Wilde has made several applications of texture to forestry and silviculture. He has developed a rapid field method for determining the proportion of fine material in a soil. He has classified Wisconsin soils for planting into six classes on the basis of texture. In forest nurseries he recommends a soil of 15 - 25 percent fine material to assure balanced nutrients and water conditions. In addition he has devised a scale based on the interaction of organic matter and fine material, the requirements of organic matter being lower when a higher percentage of fine material is present. This scale has been applied in the selection of suitable soils for the planting of four tree species. In forest management Wilde recommends light cutting and thinning on heavy soils to aid in the control of weedy species.

Soil texture has a direct effect upon the moisture equivalent, and several equations have been formulated for deriving the moisture equivalent from textural values. These equations can be applied if the soils are not too variable and more accuracy can be obtained when correction factors are applied and if different equations are used for soils having different percentages of fine material.

SURVEY OF LITERATURE

Thorough ecological investigations in the Pinus ponderosa region have been rather few and most of the literature concerning such work has been published in relatively recent times.

Whitford and Craig (1918) described five forest types of the interior drybelt of British Columbia. The following is a short summary of these five types:

Sage-Brush Type

Present in low valleys at elevations from 1000 feet - 3000 feet above sea level.

Grass and Semi-Open Forest Types

In the lower elevations from 1000 - 3000 feet. The grasslands are characteristically composed of *Agropyron spicatum* and are bordered on their upper limit by semi-open forests composed of *P. ponderosa*, *Pseudotsuga*, *Pinus contorta*.

Yellow Pine Type

Present on dry, well-drained soils at elevations of 1500 feet - 2500 feet and up to 3500 feet on south slopes. This type was described as occurring on upper bench lands and slopes and in the south on lower benches and on the valley floor. The stands were pure or mixed with *Pseudotsuga*, *Pinus contorta*, *Larix occidentalis*.

Interior Douglas-Fir Type

Immediately above the yellow pine type at elevations of 2000 - 2500 feet up to 4000 - 4500 feet, and occurring at lower altitudes in the southern part of the area. Stands were mixed with Yellow Pine when bordering on the yellow pine type.

Douglas-Fir - Western Larch Type

Occurring under temperature conditions intermediate between the yellow pine type and Douglas-fir type, and converging with the yellow pine type in dry sites. The altitudinal range is 1800 feet up to 3500 - 4000 feet.

In 1927 the Finnish forest ecologist Ilvessalo (1929) made some observations of some of the forest communities of North America. His main interest was in the stands of lodgepole pine, *Pinus contorta*. However some of the stands which he investigated in the Sicamous, Kamloops and Ashcroft districts contained *Pinus ponderosa*. He describes the vegetational zonation with *Artemisia tridentata* near the river (Thompson R.), *Pinus ponderosa* stands above it from 2000 to 3000 feet, stands of *Pseudotsuga menziesii* and

Larix occidentalis above 3000 feet, and Picea Engelmannii - Abies lasiocarpa stands at the highest elevations. He distinguishes five types in the Dry Forest Group (Xerophile Forests), three of which are pertinent here.

Arctostaphylos type

On very dry southern and southwestern slopes and on poor gravel-sandy soil on level ground. Arctostaphylos uva-ursi is the characteristic species with abundant lichens (Peltigera spp. and Cladonia spp.) and Carex spp. Mention is made of a type drier than this one which consists mainly of Artemisia tridentata, with Achillea sp. and Antennaria parvifolia.

Calamagrostis - Arctostaphylos type

A type rich in Calamagrostis rubescens and Arctostaphylos uva-ursi, and with an abundance of Agropyron spp., Poa spp. and other grasses, Rosa acicularis, Peltigera spp. and mosses.

Calamagrostis type

Rich in Calamagrostis rubescens and other grass species, and a well developed forb layer.

A few years following this work Kujala made a more detailed investigation of forest types in Canada. (Kujala, 1945) His work in the interior drybelt of British Columbia consisted mainly of further amplification and more detailed analysis of the work initiated by Ilvessalo. In addition to the forest types established by Ilvessalo, Kujala also describes a Tellima tenella - Danthonia spicata community. This is the only community established by him which contains an abundance of Pinus ponderosa.

Weaver and Clements' book "Plant Ecology", published in 1929, contains an ecological classification of the vegetation of North America. According to these authors the Yellow Pine forests of British Columbia come under the Petran montane forest : Pinus - Pseudotsuga association, which is one of two associations composing the Montane forest : *Pinus* - *Pseudotsuga* Formation.

Halliday, in his classification of Canadian forests, used Weaver and Clements' system of classification, with minor modifications, (Halliday, 1937). He added two more formations (forest regions) and introduced a new ecological unit termed forest section. The forest section is a category intermediate in rank between the formation and association of Weaver and Clements. It is an area within a formation which is marked by the presence of certain associations which differ from the other parts of the formation. A forest section is the result of variation in local climate, geological structure, character of surface deposits, topography and drainage. Halliday's classification of the *Pinus ponderosa* forest is: Montane Forest Region, Yellow Pine and Douglas Fir Section.

Daubenmire in 1942 has published a preliminary survey of the vegetation of the Columbia plateau east of the Columbia River in Washington and Idaho. He distinguished a number of grassland and forest zones which he subdivided into a number of plant associations. The three grassland zones are *Artemisia tridentata* - *Agropyron spicatum* zone, *Agropyron spicatum* - *Poa secunda* zone, *Festuca idahoensis* zone. Four forest zones were listed: *Pinus ponderosa* zone, *Pseudotsuga taxifolia* zone, *Thuja plicata* - *Tsuga heterophylla* zone, *Picea engelmannii* - *Abies lasiocarpa* zone. This study dealt mainly with the shrub and grassland vegetation but mention was made of a *Pinus ponderosa* association present in the northern part of the *Artemisia tridentata* - *Agropyron spicatum* zone on the "scablands" (basaltic outcrops) around the Okanagan Highlands. Recently (Daubenmire, 1952) has described in detail the forest communities, defining four associations in the *Pinus ponderosa* zone and two associations in the *Pseudotsuga taxifolia* zone. The following is a brief outline of this classification:

Pinus ponderosa zone

1. *P. ponderosa* - *Agropyron spicatum* - an edaphic climax, on coarse soils with sparse humus, low cation capacity and slightly acid. Mention is made of variations within this association where *Stipa columbiana* or *Artemisia tridentata* dominate.
2. *P. ponderosa* - *Purshia tridentata* association - an edaphic climax, on alluvial soils which are slightly acid and have somewhat lower cation capacities and water holding capacities.
3. *P. ponderosa* - *Symphoricarpos rivularis* association - a climatic climax, on loams with lower pH, and undulating topography.
4. *P. ponderosa* - *Physocarpus malvaceus* association - a topographic climas in that it is topographically protected from insolation and therefore more moist, leaching is greater but the pH is higher and there is a lower degree of hydrogen ions than in the *Pinus-symporicarpos* association.

Pseudotsuga taxifolia zone

1. *Pseudotsuga taxifolia* - *Physocarpus malvaceus* association - a restricted climatic climax, but a topographic climax when occurring along dry ravines and north slopes in drier areas and on south exposures in higher altitudes. Surface organic matter is greater and soils are more acid than in the *Pinus* - *Physocarpus* stands.
2. *Pseudotsuga taxifolia* - *Calamagrostis rubescens* association - at altitudes lower than the preceding association and restricted to the northern parts of that region.

Spilsbury and Tisdale (1944) have made a study of zonation of vegetation and soil in the Kamloops district. This study was carried out on the

Tranquille range which possesses uniform soil texture, parent material and exposure. They determined six zones each confined within certain altitudinal ranges and each having distinctive soil and plants. Pinus ponderosa is present in a seventh, sporadically occurring zone at 2100 to 3000 feet above sea level, above the Lower Grassland Zone and replacing the Middle and Upper Grassland Zones. The soils associated with it resemble dark brown earth and "on the average soil texture was a little coarser, stones more plentiful and pH a little lower than for comparable grassland soils".

Results of further study of these grasslands was published in 1947 by Tisdale. This is mainly an amplification of the first work and also an investigation of the communities conditioned by grazing and edaphic factors. The region was also studied by Tisdale from the standpoint of grazing of forest ranges. Of the three forest range types (Pinus ponderosa, Pseudotsuga taxifolia, Picea Engelmannii - Abies lasiocarpa) the Pseudotsuga taxifolia ranges are the most important. The P. ponderosa ranges are more restricted in extent but afford good grazing and are open and readily accessible to livestock.

The soil survey report for the Okanagan and Similkameen Valleys was published in 1949 (Kelley & Spilsbury, 1949). Four zonal soils were distinguished: the Brown Soil Zone, Dark Brown Soil Zone, Black Soil Zone, and Intermountain Podsol Zone. Of these four zonal soils, all except the Black Soil Zone support Pinus ponderosa stands although these are most abundant on the Dark Brown and Intermountain Podzol zones. Other soil groups on which Pinus ponderosa occurs are the Groundwater Azonal soils and unclassified soils consisting of "colluvial fan rubble" and "rough mountainous land".

METHODS OF STUDY

Field Methods

Soil samples were collected in a number of stands of the ten Yellow Pine plant associations. The samples were taken from each horizon of the profile and were air dried as soon as possible. Field notes were made of the location, altitude, slope of ground, direction of exposure, and the plants growing adjacent to the soil pit. A description was made of the soil profile in regard to the depth of the various horizons, structure, apparent texture, colour, moisture, apparent gleization and podzolization, depth of roots and presence of carbonates as shown by effervescence with hydrochloric acid.

Laboratory Methods

Each sample was pulverized in a mortar to break up all lumps, and the soil was then passed through a 2 mm. sieve (No. 10 A.S.T.M.). The two parts of the sample were placed in separate containers and weighed. By this means the percentage of gravel (particles greater than two millimeters) was determined. The soil samples were pre-treated with hydrogen peroxide to remove the organic matter, and with hydrochloric acid to remove the carbonates. Since this mechanical analysis is based on a definite weight of soil, the amount of organic matter and carbonates which will be lost by pre-treatment must be taken into account and the weight of the sample increased to allow for this loss. To determine the amount of organic matter and carbonates which would be lost, a 10 gram sample was treated first and weighed, and the loss in weight was applied as a correction factor when weighing the sample to be analyzed for texture. The 10 gram sample was placed in a 100 ml. glass beaker and small amounts of 6 percent hydrogen peroxide added until effervescence no longer occurred. The beaker was then placed in a warm water bath and small quantities of hydrogen peroxide again added until effervescence stopped completely. Five millilitres of .2 N hydrochloric acid was added to the sample and after allowing it to sit for a short time the sample was washed and filtered. The sample was oven-dried for twelve hours at 105° C., cooled, and the weight determined. For mechanical analysis a 100 gram sample was used for sands, and a 50 gram sample for all other soils. The samples were based on oven-dry weight and corrected for loss of carbonates and organic matter. These samples were pre-treated with hydrogen peroxide and hydrochloric acid, washed and filtered in the same manner as described for the 10 gram sample. The soil samples were air-dried and 5 ml. of sodium hexa-metaphosphate added and allowed to slake in distilled water over night. After slaking, the sample was stirred by the dispersing machine, six minutes for the sands, ten minutes for light sandy loams, 15 minutes for all other soils except those which were recognized as being difficult to disperse, in which case they were stirred for twenty to twenty-five minutes. The sample was washed into a graduated soil cylinder, the hydrometer placed in the cylinder and distilled water added to increase the total volume to 1205 ml. for 100 gram samples and 1130 ml. for 50 gram samples. The contents of the cylinder were mixed by turning it upside down and back several times, the cylinder then placed on a level table and the time noted. Hydrometer readings were made at the end of four minutes and two hours and the temperature of the suspension recorded after both readings. To correct for variation in the temperature of the suspension, for every degree above 67° F. 0.2 grams was added to the hydrometer reading, and 0.2 grams was subtracted for every degree below 67° F. The percentages of sand, silt and clay were calculated in the following manner:

$$\% \text{ Sand} = 100 - \frac{(\text{Corrected reading at 4 mins.})}{(\text{Weight of sample})} \cdot 100$$

$$\% \text{ Clay} = \frac{(\text{Corrected reading at 2 hours})}{(\text{Weight of sample})} \cdot 100$$

$$\% \text{ Silt} = 100 - (\% \text{ Sand} + \% \text{ Clay})$$

A mechanical analysis, for percentages of gravel, sand, silt and clay, of a number of profiles each represented by several samples, yields a large quantity of data. This data can be presented by using a textural classification, such as that published by Davis and Bennett (1927), and the United States Department of Agriculture, (1951). Average values of sand, silt and clay are calculated by horizon for each profile. A triangular graph is used, each side of which is marked off in units of percentage. One side of the triangle represents the percent of sand, another side the percent of silt and the third the percent of clay. The area within the triangle is divided into a number of textural classes, in this work eleven classes were used. By plotting the average values for the three fractions the textural class can be determined for each horizon.

DISCUSSION OF METHODS

Stokes' Law (1851) is the basis for all mechanical analyses which separate the soil fractions by means of their settling velocities. This law states that the settling velocity of a solid particle in a liquid varies with the radius of the particle. The formula derived from this law is:

$$V = 2/9 \cdot \frac{(D - d)\, g\, r^2}{n}$$

where V = velocity of sedimentation
g = acceleration due to gravity
r = radius of spherical particles
n = coefficient of viscosity of the liquid
D = density of the spherical particles
d = density of the liquid

In applying Stokes' law to soil particles certain assumptions must be made. It must be assumed that the particles are spherical and smooth. As this is not the case the equivalent radius is used, i.e., the radius of a sphere of the same material which would fall with the same velocity as the particle in question. The particles must be larger than the molecules of the liquid. It is assumed that the settling velocity of the larger sand particles follow Stokes' law. Since the density and viscosity of the liquid will vary with temperature, this factor must be kept constant. The temperature used for making mechanical analysis is 67° F. (20° C.). With small variations from this temperature, measurements can be corrected by applying a correction factor. However wide variations in the temperature of the suspension during measurement will give inaccurate results due to the convection currents interfering with the settling.

Many methods of mechanical analysis have been developed using the sedimentation principle. The following is a summary of the methods most commonly used:

Elutriation Methods

These methods separate the soil fractions by allowing them to settle out in moving water. In slow moving water only the finest particles are kept in suspension, in fast moving water some of the larger particles will remain suspended as well. The Schöne apparatus (1867) consists of a cone-shaped vessel with an outlet and inlet tube. The soil suspension is placed in the cone and water is run through from the bottom tube at such a rate that only the finest particles will be washed out through the upper outlet, the stream of water is continued until no more of the finer particles come out. The speed of the water is then increased so the next sized particles will be washed out. In this manner each soil fraction is washed out, caught and weighed. The Kopecky apparatus (1930) consists of three vessels of different diameter connected to one another. Water is run through the apparatus at an exact velocity, entering the small tube first. Since this tube has a smaller diameter, the speed of the water will be most rapid and all particles except the coarsest will be washed through into the second tube. A gradual decrease in upward velocity of the water continues through each of the three tubes of different diameters and the various fractions will settle out in each of the three tubes. When the water leaving the last vessel is completely clear, the settling out has been completed.

Beaker Method (Osborne, 1886)

The coarse sands are removed by washing through a sieve, and after drying this portion is weighed and its percentage determined. The fine material is placed in a beaker, dispersed and allowed to sediment for a given time at a certain temperature. After sedimenting for the specified time, the suspension (containing the clay) is decanted. This process of dispersing, sedimenting and decanting is repeated until all the clay has been collected. The clay is then evaporated, weighed and the percentage determined. The portion remaining in the beaker contains the silt and fine sand, this is dispersed and allowed to settle for a given time at a certain temperature. The suspension containing the silt is decanted and the process repeated until all the silt has been collected. The two fractions, containing the silt and fine sand, are evaporated, weighed and their respective percentages determined.

Atterberg Sedimentation Method (1912)

This method makes use of a graduated cylinder having a side outlet near the base. A dispersed soil is placed in the cylinder and when the sand and silt have settled to the bottom the suspension of clay is drawn off through the side outlet. The percentage of clay is determined by weight. The material in the cylinder is dispersed again and when the sand has settled out the suspension containing the silt is removed and the weight and percentage of silt determined. The material remaining in the cylinder corresponds to the sand fraction.

Wiegner Sedimentation Method (1918)

The apparatus used consists of a glass cylinder to which is attached a parallel tube of equal length but smaller diameter, the two tubes are separated from one another by a stopcock at the juncture. Water is placed in the small tube and the soil suspension in the large cylinder, the suspension is shaken and the stopcock opened. The difference between the levels of the minisci in the two tubes corresponds to the amount of soil in suspension at that time. This method is based on the fact that when two liquids of different densities are placed in the two arms of an U-tube the liquids will assume different levels according to their densities. The less dense liquid will rise to a higher level than the denser liquid.

Pipette Method (1922-23)

The sample is washed through a sieve to separate the coarse sand fraction. This portion is weighed and the percentage determined. The percentage of fine sand is determined by the decantation method. The remainder of thè sample, containing the silt and clay, is completely dispersed, placed in a graduate cylinder and water added to a certain volume. By means of a pipette, samples of certain volume are withdrawn from definite depths at certain times. The depths and times of sampling used should correspond to the limiting velocities of the silt and clay particles. By evaporating and weighing the samples one can determine the percentage of material in suspension at a given time.

Hydrometer Method (Bouyoucos, (1927 & 1951)

This makes use of a hydrometer calibrated in grams per litre. The soil samples are dispersed and placed in a graduated soil cylinder and distilled water is added to bring the total volume up to 1130 or 1205 ml. At the end of four minutes all particles greater than .02 mm. (the sands) have settled out and when the hydrometer is placed in the suspension the reading will indicate the number of grams per litre of silt and clay in suspension. At the end of two hours all particles greater than .002 mm. (silt and sands) have settled out and a hydrometer reading will indicate the number of grams per litre of clay in suspension.

In addition to these laboratory methods of mechanical analysis there are a number of less accurate field methods in use. One of these is a modification of Bouyoucos' method by Wilde (1935). The soil is passed through a 20-mesh sieve and a sample of approximately 40 grams of the finer material is placed in a 125 cc. flask with 1 gram of dispersing agent. Water is added to the 100 cc. mark, the flask covered and the contents shaken well. After one minute 60 cc. of the suspension is placed in a cylinder, a small, specially calibrated Cenco-Wilde hydrometer is floated in the suspension and the reading made immediately. This reading gives the approximate percentage of fine material (silt and clay) in the soil. For those soils containing more than 35 percent fine material, 30 cc. of the suspension are used and it is diluted with water to 60 cc. The hydrometer reading is multiplied by two to give the approximate percentage of fine material. One of the most common field methods is the textural classification by hand. A handful of soil is moistened and worked in the palm of the hand until it has a paste-like consistency. By feeling the particles of the soil the percentages of sand, silt and clay are estimated and the soil is classified into one of the textural groups. With experience a high degree of accuracy can be attained. However, this method has the disadvantage of being qualitative rather than quantitative.

The laboratory methods outlined above give quite uniform results. Although the Bouyoucos method shows the most variation from the others, it has the advantage of being the most rapid method and for a mechanical analysis of a large number of samples it is the most practical. In all methods of mechanical analysis the main source of error rests in the method of dispersion. The sample must have all aggregates broken up and the soil reduced to a state where all particles are broken down to their ultimate size and are acting independently of one another. To obtain this condition the organic matter should be removed. This can best be done by treatment with hydrogen peroxide. All soils containing lime should be treated to remove the carbonates, treatment with hydrochloric acid is most effective for this. For mechanical dispersion a milk-shake machine is very efficient. Before the soil is stirred a dispersing agent should be added. Sodium hexametaphosphate is recommended for this.

RESULTS

Of the ten plant communities defined,[1] six of them have only *Pinus ponderosa* as the dominant tree: *Pinus ponderosa* - *Purshia tridentata* association and its *Pinus ponderosa* - *Aristida longiseta* subassociation; *Pinus ponderosa* - *Agropyron spicatum* association and its *Pinus ponderosa* - *Stipa comata* subassociation and *Pinus ponderosa* - *Artemisia tridentata* subassociation; *Pinus ponderosa* - *Rhus glabra* association.

The other four communities have *Pseudotsuga Menziesii* as a co-dominant or dominant species. These are: *Pseudotsuga Menziesii* - *Pinus ponderosa* - *Arctostaphylos uva-ursi* association, *Pseudotsuga Menziesii* - (*Pinus ponderosa*) - *Arctostaphylos uva-ursi* - *Calamagrostis rubescens* association, *Pseudotsuga Menziesii* - *Calamagrostis rubescens* association, *Pseudotsuga Menziesii* - (*Pinus ponderosa*) - *Symphoricarpos albus* association.

Pinus ponderosa - *Agropyron spicatum* association

The common associate species of this association are: *Festuca occidentalis* (incl. *F. idahoensis*), *F. scabrella*, *Poa Cusickii*, *P. secunda*, *Koeleria cristata*, *Stipa* spp., *Carex Rossii*, *Artemisia tridentata*, *Artemisia trifida*, *Eriogonum heracleoides*, *Erigeron pumilus*, *Balsamorhiza sagittata*, *Lupinus sericeus*, *Geranium viscosissimum*. This association occurs from low to middle elevations but is variable in its habitat features, tree growth and soil. The texture varies from sandy loam to clay loam with extremes of loamy sand and clay. The pH values of the B horizon range usually from 5.8 to 8.7. However, two profiles with the highest clay content in the B horizon were exceptionally acid, in one case pH 5.48 and in the other, pH 4.2. (Tables I and II)

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1 The floristic data of these associations has been supplied by Mr. T. C. Brayshaw.

Pinus ponderosa - Stipa comata subassociation

This community is similar to the preceding association but contains a higher abundance of *Stipa comata*, *S. columbiana*, and other *Stipa* species. It is considered that it results from overgrazing of stands of the *Agropyron* association which are present on the coarser textured soils. Consequently this community is placed as a subassociation of the *Agropyron* association. The soils are of medium to coarse texture, typically sandy loams, which are generally alkaline or neutral. The pH values of B horizon range from 6.4 to 8.7. (Table III)

Pinus ponderosa - Artemisia tridentata subassociation

This community is confined to heavy textured soils (clay loam) at low elevations. It is classed as a subassociation of the *Agropyron* association and is considered to result from overgrazing of those stands which occur on fine soils at low altitudes. Communities of *Artemisia tridentata* occur more frequently without the presence of *Pinus ponderosa*. The soil profiles are usually undifferentiated into horizons and are strongly alkaline. Two of the soils were extremely uniform throughout the profile, the total range of pH being only 7.95 - 8.2. One profile showed the effects of a small amount of humus infiltration, the surface having a pH of 6.4 and the lower horizon having a maximum of 8.69. (Table IV)

Pinus ponderosa - Purshia tridentata association

The common associate species of this association are: *Aristida longiseta*, *Poa secunda*, *P. Cusickii*, *Phlox longifolia*, *Opuntia fragilis*. This association is confined to the southern part of the Okanagan Valley, from Kelowna southward. It occurs at low elevations with low precipitation and high temperatures. The parent material from which the soils have developed is coarse river terrace deposits and the resultant soils are usually sands and occasionally sandy loams. The surface layer is semi-decomposed litter intermixed with sand and has a pH range from 4.9 to 5.8. Below this is a melanized A_1 which ranges from pH 6.2 - 7.4. In the heavier textured soils (sandy loams) the pH values of B horizon are higher, varying from 7.0 - 8.6. The pH values of this horizon in the sandy soils range from 6.8 - 7.6. (Table V)

Pinus ponderosa - Aristida longiseta subassociation

This community is considered to result from the burning of stands of the Purshia association, and is therefore placed as a subassociation of that association. The common associate species are: Stipa comata, Chaenactis Douglasii, Gilia pungens, Eriogonum niveum, Phacelia linearis. The soils are sands or sandy loams and are similar to those of the Purshia association. (Table VI.)

Pinus ponderosa - Rhus glabra association

The common associate species are: Rhus radicans, Philadelphus Lewisii, Sambucus glauca, Amelanchier alnifolia, Panicum Scribnaerianum, Stephanomeria tenuifolia. This association is found at the foot of talus slopes and consequently the soil is extremely rocky. The soil texture is coarse, typically loamy sands, with a high percentage of gravel. Lateral moving groundwater is sometimes present in the lower horizons. The pH is slightly acid or circumneutral, the values for the B horizon ranging from 6.3 - 7.3. (Table VII.)

Pseudotsuga Menziesii - Pinus ponderosa - Arctostaphylos uva-ursi association

Mixed stands of Pseudotsuga Menziesii and Pinus ponderosa occur, or these species may compose pure stands. The common associate species are

Cladonia gracilia, Fragaria virginiana, Allium cernuum, Anemone multifida, Juniperus communis, Juniperus scopulorum, Penstemon fruticosus, Sedum stenopetalum, Solidago missouriensis, Apocynum androsaemifolium, Antennaria Howellii, Carex concinnoides, Shepherdia canadensis, Ceanothus velutinus. This association occurs at medium elevations on level to sloping ground. The soils are coarse with a large amount of gravel, and are generally sandy loam or loamy sand, with extremes of sand. pH values vary from slightly acid to alkaline. The B horizon has a range of 6.4 - 8.8. (Table VIII.)

Pseudotsuga Menziesii - Calamagrostis rubescens association

The common associate species are: Polytrichum juniperinum, Antennaria anaphaloides, A. rosea, Lilium columbianum, Poa ampla, Arnica cordifolia, Fritillaria lanceolata, Lathyrus Nuttallii, Spiraea lucida. Stands of this association occur at higher elevations, usually on sloping ground. Soils are sandy clay loam to sandy loam which are slightly acid or neutral in reaction. The humus layer (Ao) is duff mull which is underlain by a well developed melanized A_1. There is no conspicuous A_2 horizon present, although leaching is obvious. (Tables IX and X.) This soil corresponds to the German Braunerde or Russian brunozem soils.

Pseudotsuga Menziesii - (Pinus ponderosa) - Symphoricarpos albus association

The common associate species are: Spiraea lucida, Salix Bebbiana, Acer glabrum, Prunus virginiana, Mahonia aquifolium, Crataegus Douglasii, Clematis columbianum. Pinus ponderosa is considered as a seral dominant species in this association since it is unable to regenerate under a well developed canopy. pH values range from slightly acid to alkaline, the B layer varying from pH 6.0 - 8.65. Lateral moving groundwater is frequently present in the lower horizons. The soil texture is sandy loam and occasionally sandy clay loam. (Table XII.)

Pseudotsuga Menziesii - (*Pinus ponderosa*) - *Arctostaphylos uva-ursi* - *Calamagrostis rubescens* association

This association has features which are similar to both the *Arctostaphylos* and *Calamagrostis* associations. The common associate species are: *Carex concinnoides* *Shepherdia canadensis*, *Fragaria virginiana*, *Allium cernuum*, *Sedum stenopetalum*, *Spiraea lucida*, *Cladonia gracilis*, *Polytrichum juniperinum*. The soils are coarse with a large amount of gravel, and range from sandy loams to sands. The pH values vary from slightly acid to neutral. (Table XI.)

TABLE I.

Texture and pH of Three *Agropyron spicatum* Profiles *

HORIZ.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
A	0-5	5.90	43.4	80.8	8.8	10.4	0.2	6.00	32.1	-	-	-	0.2	6.00	38.9	-	-	-
	6-12	6.55	48.6	85.8	6.6	7.6	2-7	6.75	30.7	72.9	13.5	13.6	2-9	6.46	29.4	53.6	41.0	5.4
							10-20	6.65	54.3	70.1	13.2	16.7	10-19	7.10	30.6	61.0	15.4	23.6
B	12-20	6.30	48.9	81.4	9.0	9.6	20-30	6.48	73.6	72.0	10.0	18.0	19-29	6.73	19.0	49.6	16.6	33.8
	25-30	6.30	43.1	79.4	12.0	8.6	30-35	6.54	59.4	71.0	8.0	21.0	32-40	6.48	21.6	-	-	-
	40-50	6.70	45.3	80.8	8.6	10.6	35-48	6.70	77.6	72.0	8.5	19.5	40-50	6.30	21.2	40.8	19.0	45.2
	50-60	6.83	49.0	82.0	8.0	10.0	52-55	6.65	77.5	75.5	7.0	17.5	50-60	6.15	23.7	40.2	18.6	41.2
	65-75	6.83	56.1	82.4	2.6	10.0	55-60	6.38	66.1	63.0	11.0	23.0	64-74	5.82	36.2	30.0	20.0	50.0
	80-90	6.9	50.9	-	-	-							90-100	5.48	33.9	34.8	20.6	44.6
C	100-110	7.13	45.4	91.4	2.8	5.8												

* The following abbreviations are used in the tables: Horiz. - Horizon, Gr. - Gravel, Sa. - Sand, Si. - Silt, Cl. - Clay, L - Litter, F - Fermentation layer, Mel.- Melanized layer.

TABLE II.

Texture and pH of Three *Agropyron spicatum* Profiles

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
	0-1.3	5.40	8.5	-	-	-	0-2	6.21	37.4	-	-	-	0-2	5.96	28.7	-	-	-
	1.3-3.8	6.35	9.5	-	-	-	2-10	6.00	14.2	-	-	-	2-10	6.48	31.9	65.2	24.2	10.6
A	3.8-7.6	6.52	7.9	35.4	28.2	36.4												
	7.6-10.2	6.50	10.5	32.0	25.0	43.0												
	12.7-15.2	6.50	30.7	33.4	24.4	42.2												
	15.2-17.8	6.30	20.0	43.0	19.1	37.9	10-20	6.78	24.5	73.2	16.2	10.6	10-25	6.10	30.9	70.8	18.4	10.8
	19.1-22.9	5.90	22.5	41.7	16.9	41.4	20-30	6.83	53.5	77.2	13.4	9.4						
	25.4-28	5.80	37.6	25.6	22.6	51.8	30-40	6.80	49.3	77.6	11.0	11.4	25-35	6.10	53.7	80.8	10.8	8.4
B	36.8-40.6	5.40	3.2	60.0	15.5	24.5	40-55	7.10	62.2	84.4	7.6	8.0	40-60	6.80	80.4	-	-	-
	48.3-50.8	4.60	-	-	-	-	55-70	7.20	65.5	84.8	6.8	8.4						
	82.6-85	4.20	-	-	-	-							65-75	5.95	78.8	66.4	16.0	17.6
C	114-121	4.25	-	-	-	-												

TABLE III.

Texture and pH of a Profile of <u>Stipa</u> subassociation

Horizon	Depth (cm.)	pH	% Gravel	% Sand	% Silt	% Clay
A	0-5	7.29	0.85	67.6	19.2	13.2
	5-10	7.90	0.48	70.0	18.8	11.2
B	15-25	7.71	24.80	72.8	16.9	10.3
	25-35	8.22	16.70	72.8	18.4	8.8
	35-45	8.62	24.50	72.3	16.7	11.0
	65-75	8.59	6.95	8.40	9.4	6.6

TABLE IV.

Texture and pH of a Profile of <u>Artemisia</u> subassociation

Remarks Horizon	Depth (cm.)	pH	% Gravel	% Sand	% Silt	% Clay
sparse litter	0-2	6.40	23.6	47.6	28.4	24.0
platy	3.8-7.6	6.60	8.1	36.4	30.0	33.6
crumby	7.6-12.7	6.80	30.4	34.6	44.6	20.8
crumby	14-24	7.00	15.8	40.6	24.0	35.4
compact	36.8-44.5	8.10	34.0	60.8	22.6	16.6
carbonates	53.3-63.5	8.50	12.4	33.0	34.0	33.0
carbonates	68.6-78.8	8.69	10.2	14.8	32.0	53.2
carbonates	91.4-101.6	7.91	14.3	34.2	38.6	27.2

TABLE V.

Texture and pH of Three Profiles of *Purshia* association

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
	0-0.5	-	-	-	-	-												
	0.5-1.5	5.80	2.5	82.3	8.7	9.0	0-2.0	5.03	13.50	-	-	-						
	1.5-3.5	6.65	.7	80.2	11.7	8.1	2-7	6.08	1.96	90.8	5.2	4.0	0-5	6.02	0.90	89.0	4.6	6.4
A	3.5-7.0	-	-	-	-	-												
	7-12	7.10	1.8	78.2	11.8	10.0							5-12	7.00	.09	88.6	6.4	5.4
	13-20	7.40	7.5	79.0	9.3	11.7	12-20	7.22	3.40	93.2	3.6	3.2	12-22	7.09	.01	90.8	4.2	5.0
	30-40	7.00	4.3	81.7	8.3	10.0	25-35	7.14	3.00	92.2	3.6	4.2						
	50-60	7.50	13.5	85.2	7.2	7.6	40-50	7.08	2.70	91.5	2.6	5.9	40-50	7.29	.02	94.0	2.7	3.3
B	70-80	8.15	9.75	77.6	11.6	10.8	50-60	7.40	3.80	95.4	1.4	3.2						
	85-95	8.45	4.7	75.3	12.7	12.0	70-75	7.40	4.10	96.9	1.0	2.1						
	100-108	8.60	11.5	79.8	9.0	11.2	90-100	7.35	4.40	96.4	1.9	1.7	95-105	7.60	.07	92.6	4.4	3.0
							110-120	7.10	6.60	96.8	1.4	1.8						

TABLE VI

Texture and pH of two Profiles of *Aristida* subassociation

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
	0-2	4.57	8.40	91.0	4.4	4.6	0-5	7.35	45.3	64.4	19.2	16.4
A	2-10	6.53	0.20	91.6	4.8	3.6	5-10	7.70	43.9	68.0	17.2	14.8
	10-15	6.78	0.09	92.8	3.8	3.4	10-20	7.85	76.7	62.4	20.0	17.6
	15-25	6.88	0.03	94.2	3.0	2.8						
B	35-45	7.18	0.01	96.7	0.5	2.8	25-35	8.11	65.9	72.8	16.4	10.8
	55-65	7.30	0.00	96.6	1.1	2.2	45-55	8.08	31.0	60.0	23.6	16.4
	70-80	7.49	0.00	97.6	0.4	2.0	60-70	8.05	52.6	65.0	18.2	16.8
	90-100	7.48	0.00	98.4	0.0	2.0						

TABLE VII

Texture and pH of two Profiles of *Rhus* association

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
	0-1.0	5.59	29.8	-	-	-	0-4	5.20	12.4	-	-	-
A	1-5	5.80	14.0	80.0	10.4	9.6	4-8	5.75	10.6	87.2	6.7	6.1
	5-13	6.51	17.2	80.5	12.7	6.8	10-20	6.38	24.6	83.0	9.0	8.0
	20-35	6.49	42.8	85.2	8.4	6.4	20-25	6.30	52.8	86.4	8.4	5.2
B							25-30	6.40	57.2	87.4	6.4	6.2
	45-55	6.48	36.6	83.2	9.2	7.6	35-50	6.30	49.5	84.4	8.8	6.8

TABLE VIII

Texture & pH of Four Profiles of **Arctostaphylos** Association

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
A	0-6	6.90	19.0	85.8	6.6	7.6	0-2	6.40	14.6	70.5	13.1	16.4
	6-17	6.90	47.5	84.4	3.7	11.9	8-9	7.11	3.1	62.8	21.2	17.0
B	17-24	6.69	43.6	87.6	6.8	5.6	10-20	7.01	40.3	73.2	7.8	19.0
	24-39	6.88	52.6	-	-	-	25-35	7.62	27.5	75.2	9.8	15.0
	39-50	6.89	41.6	96.0	1.9	2.1	50-60	8.81	22.9	63.0	24.9	12.1

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
A	0-5	6.60	3.6	69.6	18.0	12.4	0-3	6.47	31.1	93.7	2.7	3.6
	5-13	6.75	15.4	70.8	16.0	13.2	3-10	6.60	45.9	64.0	18.8	17.2
B	13-26	6.78	36.4	79.0	11.7	9.3	10-24	6.42	43.7	62.2	15.6	22.2
	30-40	7.62	53.1	66.8	23.6	9.6	24-35	6.61	45.4	64.2	15.6	20.2
	55-65	8.33	35.4	87.7	9.6	2.7	50-60	7.02	57.0	75.8	12.0	12.2

TABLE IX

Texture and pH of Three Profiles of *Calamagrostis* Association

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH.	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
A	0-5	5.82	3.9															
	5-8	6.40	26.1	63.6	19.4	17.0	2-10	6.00	18.3	54.8	23.0	21.2	1.10	5.91	40.5	71.7	15.7	12.6
	16-25	6.75	25.7	76.4	17.6	16.0	10-20	6.35	22.8	56.4	24.4	19.2						
B	25-37	6.40	39.3	67.2	15.8	17.0	20-30	6.09	26.3	59.6	26.0	14.4	10-30	6.20	36.45	70.2	15.7	14.1
	38-48	6.32	34.7	65.6	14.8	19.6	30-45	5.88	27.8	62.4	16.4	21.2	30-50	6.17	47.6	76.6	11.2	12.2
	50-60	6.16	40.3	75.4	4.2	20.4	45-60	5.69	56.4	46.2	18.8	35.0	50-60	6.10	38.6	75.6	11.1	13.3
	62-75	6.20	45.3	67.2	12.8	20.0												
	80-85	6.40	32.5	63.6	15.4	21.0							73-81	6.03	25.75	72.1	16.2	11.7

TABLE X

Texture and pH of Two Profiles of *Calamagrostis* Association

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
	0-1.3	5.40	36.6	-	-	-	0-1	5.80	31.2	-	-	-
	1.3-3.8	6.00	40.2	64.6	20.6	14.8						
	3.8-6.35	6.05	36.8	-	-	-	1-11	6.14	12.4	49.0	24.2	26.8
A	6.35-8.9	6.05	38.5	61.	19.2	19.8						
	8.9-11.4	6.05	31.4	64.2	16.8	19.0						
	12.7-15.2	5.95	34.5	66.	16.2	17.8	11-20	5.58	13.6	53.2	22.4	24.4
	15.2-17.8	6.10	33.4	63.6	17.2	19.2						
	20.3-25.4	6.10	31.8	62.0	21.4	16.6	20-30	6.00	11.3	51.2	24.2	24.6
B	35.6-40.6	6.15	42.2	65.0	15.8	19.2	35-51	6.05	16.7	60.8	15.2	24.0
	50.8-55.9	6.20	51.97	66.6	12.2	21.2	51-62	5.98	27.9	59.2	15.2	25.6
	68.6-73.7	6.30	70.3	56.0	19.8	24.2						
	91.4-96.5	6.75	59.58	54.8	16.8	28.4						
C	111.8-122	6.95		-	-	-						
	135-147	7.20		-	-	-						

TABLE XI

Texture and pH of Three Profiles of *Arctostaphylos-Calamogrostis* Association

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
	0-2	5.50	30.8	-	-	-	0-1	5.00	35.7	-	-	-	0-1	5.20	24.2	-	-	-
A							1-2	5.62	8.1	86.0	7.6	6.4						
	3-7	6.05	28.2	66.6	20.2	13.2	2-5	6.58	15.9	89.6	7.4	3.0	1-10	5.95	18.1	73.2	19.6	7.2
	10-17	5.65	40.2	68.0	19.0	13.0	5-12	6.60	23.0	87.2	7.4	5.4						
	25-40	5.55	31.6	78.6	12.4	9.0	12-18	6.60	23.0	91.8	0.8	7.4	10-20	5.94	56.5	79.2	13.2	7.6
	44-60	5.79	39.9	79.6	11.2	9.2	19-29	6.80	24.5	90.0	3.6	6.4						
B	80-85	5.80	44.6	77.4	10.2	12.4	29-35	6.70	33.9	90.3	5.3	4.4	20-35	6.00	38.4	83.2	9.2	7.6
	90-100	5.90	57.0	77.0	9.4	13.6	35-40	6.95	24.8	96.2	2.4	1.4	40-55	6.13	60.8	91.2	4.2	4.6
	100-110	5.9	42.0	78.4	8.6	13.0	70-80	7.20	32.2	96.4	2.4	1.2	60-70	6.11	70.3	94.5	1.9	3.6
C	110-118	6.00	38.9	80.6	6.4	13.0	90-100	7.10	41.4	95.7	2.4	1.9	70-80	6.41	83.5	95.3	2.1	2.6
	135-140	5.85	42.1	76.6	10.4	13.0												

TABLE XII

Texture and pH of Three Profiles of <u>Symphoricarpos</u> Association

Horiz.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.	Depth (cm.)	pH	% Gr.	% Sa.	% Si.	% Cl.
A_L	0-1	-	-	-	-	-												
A_L+F	1-2	-	-	-	-	-												
A_F	2-3	5.90	-	-	-	-												
A Mull	3-4	5.90	9.80	-	-	-	0-4	6.85	19.6	-	-	-	0-6	6.42	38.1	64.0	20.2	15.8
	4-45	6.20	11.65	51.0	26.8	22.2												
Mel.	4.5-10	6.10	13.9	63.2	30.4	16.4	4-8	5.95	54.8	76.0	11.0	13.0	6-16	6.69	30.3	62.4	23.4	14.2
	10-20	6.05	19.9	63.2	21.6	15.2	10-20	6.55	34.7	70.5	25.0	4.5	16-25	6.82	28.2	64.0	23.2	12.8
	20-30	6.05	13.7	61.2	19.2	19.6	22-30	6.86	45.9	62.0	22.0	16.0						
B	32-42	6.50	14.5	70.9	16.3	12.5	30-40	7.60	40.9	65.0	13.5	21.5	30-40	6.99	45.4	64.8	24.4	10.8
	43-53	6.65	17.15	73.2	12.8	14.0	42-52	7.12	43.2	67.5	9.0	23.5	45-55	6.99	38.6	67.8	20.4	11.8
							52-62	7.21	65.4	66.0	10.0	24.0						
	74-84	7.10	35.9	75.8	13.4	10.8	70-80	7.18	39.7	59.0	14.5	26.5						
C	110-120	8.00	21.1	60.4	19.1	20.5	86-90	7.16	45.0	63.0	9.5	27.5	80-90	7.28	39.6	70.0	20.2	9.8

DISCUSSION

It cannot be said that soil texture is the determining factor in the yellow pine communities. Nevertheless, textural ranges, typifying each community can be shown. The Arctostaphylos association is found at the lowest altitudinal range of Pseudotsuga Menziesii on the driest sites. The soil texture is coarse with a high percentage of gravel and sand. The Calamagrostis association is found at higher altitudes on brunozem soils which are well melanized and are often slightly leached. The soil texture of these soils is finer. The Arctostaphylos - Calamagrostis association is a community intermediate to the Arctostaphylos and Calamagrostis associations and is a result of overlapping of the vegetation and habitat conditions of these two associations. Ilvessalo (1929) briefly described these associations in his ecological survey in the Sicamous, Kamloops and Ashcroft districts. Daubenmire discusses this in his vegetational study of northern Idaho and Washington. The latter has established a Pseudotsuga taxifolia/Calamagrostis rubescens association, containing Calamagrostis rubescens and usually accompanied by Arctostaphylos uva-ursi. This community of Daubenmire's is very restricted and present only in the northernmost parts of eastern Washington and northern Idaho, at middle elevations. The extensiveness of these three associations in British Columbia seems to justify defining them as three distinct associations.

The distinctive features of the Symphoricarpos association are the higher summer precipitation and lower evaporation, frequent seepage water, and soils of sandy loams and sandy clay loams. This association seems to correspond closely to Daubenmire's Pinus ponderosa/Symphoricarpos rivularis association, although there is considerable difference in the soil pH.

Daubenmire states that this association has the highest percent saturation with hydrogen ions and the lowest pH, the range in the values of three profiles being 5.5 - 6.12. The pH values of the British Columbia soils were: semi-decomposed litter 5.6 - 5.9, A_1 5.95 - 6.95, B 6.60 - 8.65. The majority of the pH values for the B horizon were alkaline or neutral, although one profile had pH 6.1 in the upper B, 7.1 in the lower B, and 8.0 in the C.

The features which are characteristic of the Rhus association are its occurrence on colluvial rubble and the stoniness of the soil, frequent groundwater seepage, and high gravel content with loamy sand texture.

Stands of the Purshia association are distinctive for their high temperatures and dry climate, and soils of sandy texture with low percentages of gravel. The fact that this community occurs only in the southern part of the Okanagan Valley and in the Kootenay Valley as far north as Kimberley is probably not related to ecological factors as the valleys to the north (e g., Thompson and Nicola) have similar habitat conditions which could conceivably support Purshia stands. Possibly a temporal barrier is the restricting factor in its distribution. This association is similar to the Pinus ponderosa/Purshia tridentata association of Daubenmire's, although his soil pH values are lower. Stands of the Aristida subassociation have been observed by Brayshaw which have a large number of dead Purshia shrubs, this seems to indicate that the Aristida subassociation is a result of fire damage to the Purshia association. Other than the floristic differences these two communities are very similar in their features.

The Agropyron association is very extensive in its occurrence and shows considerable variability. This association is similar to Daubenmire's Pinus ponderosa/Agropyron spicatum association in that it occurs on coarse soils and stony loams. However two of the profiles analyzed showed high clay content and are classed as clay loams and clays. These soils are also more alkaline than those described by Daubenmire. The two subassociations of this association, the *Artemisia* subassociation and the *Stipa* subassociation are restricted to fine soils and coarse soils respectively and observations of enclosed areas within the stands of the subassociations seem to indicate that they have resulted from overgrazing of *Agropyron* stands.

SUMMARY

Soils from the stands of the ten *Pinus ponderosa* communities were collected and analyzed for texture. The mechanical analysis was done by Bouyoucos' hydrometer method after the soils had been treated to remove organic matter and carbonates. The ranges in soil texture were shown for each community. (Fig.I) The ranges are:

Agropyron association - sandy loam to clay loam with extremes of sand and clay.

Stipa subassociation - sandy loam.

Artemisia subassociation - clay loam.

Purshia association - generally sand, occasionally sandy loam.

Aristida subassociation - sand to sandy loam.

Arctostaphylos association - sandy loam or loamy sand to sand.

Arctostaphylos - *Calamagrostis* association - sand to sandy loam.

Calamagrostis association - sandy clay loam to sandy loam.

Symphoricarpos association - Sandy loam and sandy clay loam.

Other significant habitat features were pointed out for the different communities.

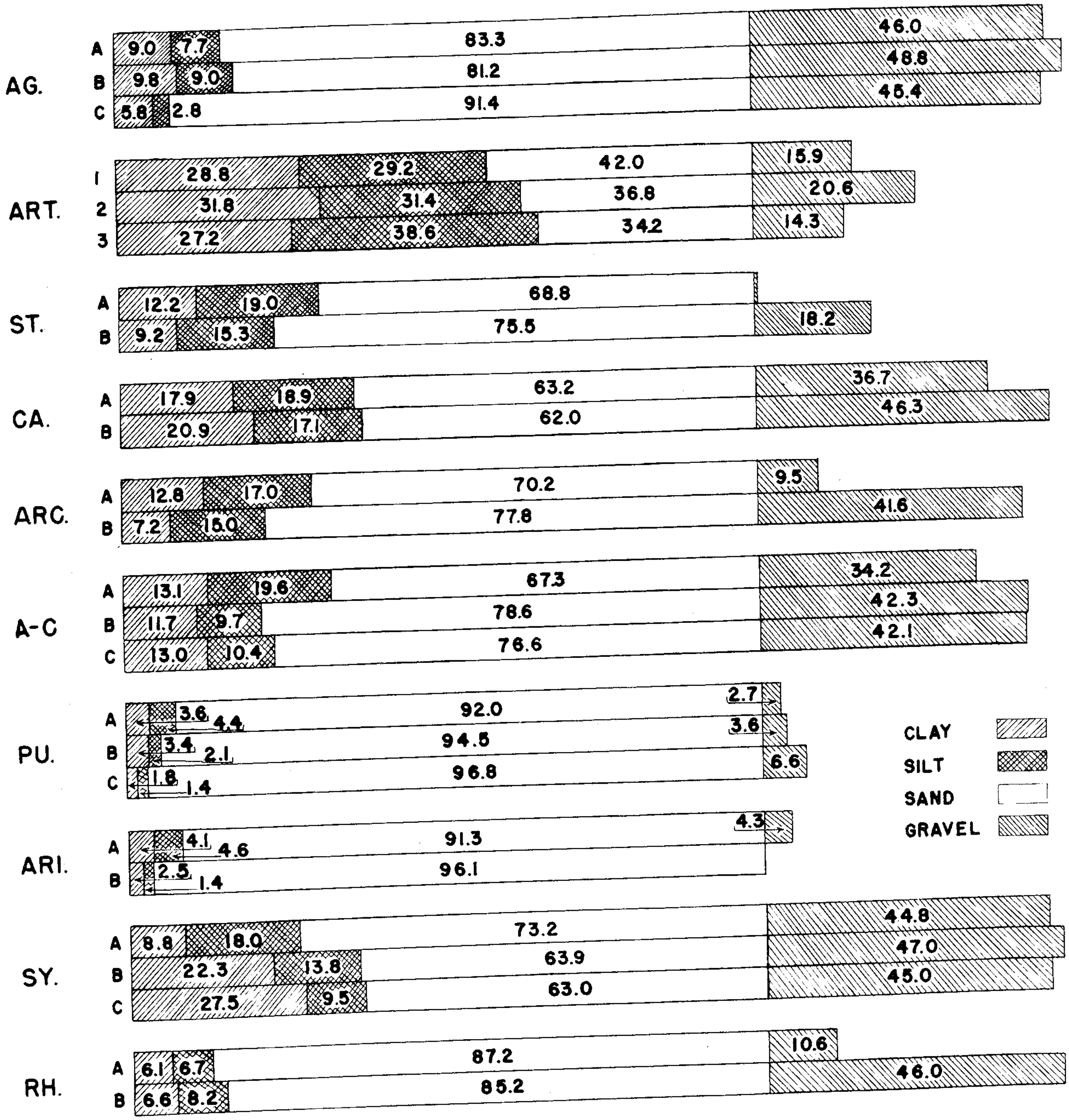

Fig. l. Percentages of clay, silt, sand and gravel of soil profiles representing the ten Pinus ponderosa communities.

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APPENDIX

List of Plant Species and their Authors

Abies lasiocarpa (Hook.) Nutt.

Acer glabrum Torr.

Agropyron spicatum (Pursh) Scribn. & Smith

Allium cernuum Roth.

Amelanchier alnifolia (Nutt.) Nutt.

Anemone multifida Poir. (=*A. globosa* Nutt.)

Antennaria anaphaloides Rydb.

Antennaria Howellii Greene

Antennaria rosea (D.C.Eaton) Greene

Apocynum androsaemifolium L.

Arctostaphylos uva-ursi (L.) Spreng.

Aristida longiseta Steud. var. *robusta* Mur.

Arnica cordifolia Hook.

Artemisia tridentata Nutt.

Artemisia trifida Nutt.

Balsamorhiza sagittata (Pursh) Nutt.

Calamagrostis rubescens Buckl.

Carex concinnoides Mack.

Carex Rossii Boot.

Ceanothus velutinus Dougl.

Chaenactis Douglasii Hook. & Arn.

Cladonia gracilis (L.) Willd.

Clematis columbiana (Nutt.) T.& G.

Crataegus Douglasii Lindl.

Erigeron pumilus Nutt.

Eriogonum heracleoides Nutt.

Eriogonum niveum Dougl.

Festuca idahoensis Elm.

Festuca occidentalis Hook.

Festuca scabrella Torr.

Fragaria virginiana Duchesna var. glauca Wats.

Fritillaria lanceolata Pursh.

Geranium viscosissimum F.& M.

Gilia pungens Benth.

Juniperus communis L.

Juniperus scopulorum Sarg.

Koeleria cristata (L.) Pers.

Larix occidentalis Nutt.

Lathyrus Nuttallii Wats.

Lilium columbianum Hans.

Lupinus sericeus Pursh.

Mahonia aquifolium (Pursh) Nutt. (= Berberis aquifolium Pursh)

Opuntia fragilis (Nutt.) Haw.

Panicum Scribnaerianum Nash.

Penstemon fruticosus (Pursh) Greene

Phacelia linearis (Pursh) Holz.

Philadelphis Lewisii Pursh

Phlox longifolia Nutt.

Picea Engelmannii (Parry) Engelm.

Pinus contorta Dougl. var. *latifolia* Engelm. (= P. *Murrayana* Grev. & Balf.)

Pinus monticola Dougl.

Pinus ponderosa Laws.

Poa ampla Merr.

Poa Cusickii Vas.

Poa secunda Presl.

Polytrichum juniperinum Hedw.

Prunus virginiana L.

Pseudotsuga Menziesii (Mirb.) Franco (= *P. taxifolia* (Lamb.) Britt.)

Purshia tridentata (Pursh) DC.

Rhus radicans (L.) Kuntze

Salix Bebbiana Sarg.

Sambucus glauca Nutt.

Sedum stenopetalum Pursh

Shepherdia canadensis (L.) Nutt.

Solidago missouriensis Nutt.

Spiraea lucida Dougl.

Stephanomeria tenuifolia (Torr.) H.M.Hall

Stipa comata Trin. & Rupr.

Stipa columbiana Macoun

Symphoricarpos albus (L.) Blake

Symphdricarpos rivularis Suksd. (= *S. albus* var. *laevigatus* (Fern.) Blake)