FINAL REPORT TO THE UNITED STATES FOREST SERVICE

(REGION 1) - SOIL COMPACTION STUDY

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ABSTRACT

Eighteen forest soil pedons (boralfs and ochrepts) in the Bitterroot, Flathead and Kootenai National Forests were characterized and 54 pedons evaluated for the existence of soil compaction. The soils were examined over a range of parent materials: Tertiary Volcanics, limestone dominated glacial till and quartzite dominated glacial till. Characterization data included the amorphous character of surface horizons, texture, Proctor test, Atterberg limits, clay mineralogy, particle size distribution, bulk density, porosity, water holding characteristics, organic matter content, organic carbon content, pH, electrical conductivity, exchangeable cations, cation exchange capacity and calcium carbonate content.

Soil compaction was evaluated in timber harvest units ranging from 3 to 17 years old. Three treatment classes of soil compaction (control, moderate and severe) were established based on evidence of surficial disturbance and the presence of vegetation. Infiltration, bulk density and soil moisture retention data were collected and analyzed by two-way analysis of variance to determine if compaction had occurred as a result of treatment. Additionally, subsites were grouped by age as "young" (0-4 years since harvest), "medium" (5-9 years since harvest) and "old" (10-17 years since harvest). The data were analyzed to determine possible amelioratory effects of time on compaction.

Amorphous character of the surface deposits was strongly expressed in the Flathead and Kootenai National Forests of northwest Montana, while the surface deposits of the Bitterroot National Forest soils in the southwest were not amorphous. Three independent measurements showed that significant changes in the physical properties of the study soils had taken place with treatment. Significant reductions in infiltration and significant increases in bulk density of the surface horizon occurred at all three study sites. Significant reductions in soil water retention at three water potentials occurred in the surface horizon of the limestone and quartzite glacial till sites. With three exceptions, no significant changes occurred in the physical properties of the study subsoils. No significant changes attributable to age grouping were detected in infiltration, soil water retention or bulk density.

Compaction occurred at all three study sites examined. Although the compaction was found only in the surface horizon, the author feels that the effects of the compaction process are expressed throughout the profile in the form of reduced water and gas movement.

INTRODUCTION

Soil compaction is defined as the process of increasing soil bulk density as the result of applied loads or pressure (Baver et al., 1972). In the timberlands of western Montana, field soil scientists have observed that soil compaction may be inhibiting forest regeneration, productivity and the maintenance of a sustained yield management program.

In western Montana, harvesting, slash disposal and site preparation operations are accomplished in part by either rubber-tired or crawler tractor vehicles. The objective of this study is to measure possible soil compaction in areas which have undergone ground-harvest operations and to characterize the physical and chemical properties of the soils involved in compaction.

REVIEW OF LITERATURE

Successful establishment and maintenance of forest vegetation requires a root penetrable soil substrate capable of supplying aeration, water and nutrients. These capabilities are influenced by changes in soil physical properties which may be associated with compaction.

Effect on Root Growth and Proliferation

Most research on soil bulk density and plant root growth relationships concerns agricultural soils. Trouse and Humbert (1961) used soil core measurements of bulk density to establish bulk density values restricting to sugar cane root penetration. They comment that "the deformations that occur in roots growing in compacted soils that are approaching the critical levels are believed to lower their efficiency in moving air, water, and nutrients into the plant." Veihmeyer and Hendrickson (1948) drew similar conclusions with sunflowers. Roots did not penetrate soil with a bulk density of 1.9 g/cm^3 or greater. The threshold densities for root penetration seemed to be about 1.75 g/cm^3 for sandy soils. They also made the important observation that these critical levels were not the same for all soil materials. The critical level was lower (1.6-1.7 g/cm^3) in clayey soils. In addition to visual root counts, Veihmeyer and Hendrickson used the inability to extract moisture from a soil as an indication of the absence of roots in dense soils. In general, they state, "thus far, pine trees, grape vines, fig trees, and chapparal have shown little or no extraction of moisture from subsoils of about the same high densities reported in this paper."

They also present evidence refuting the idea that root penetration ceases due to lack of oxygen. They state that "roots penetrated the saturated noncompacted soils from which most of the air had been expelled by heating." Hopkins and Patrick (1969) believe that aeration is not the most limiting factor in root penetration, but that it is important to optimum root growth and proliferation. In soils with high bulk densities, compaction may worsen already poor soil aeration and thus restrict plant root growth.

Taylor and Gardner (1963) found, in laboratory studies with cotton, that the most critical limiting factor to root penetration was soil strength. They state, "to penetrate a soil mass, a plant root must exert a root growth pressure greater than the resistance of the soil through which it is growing." Taylor and Gardner (1963) demonstrated that soil strength increases with increasing bulk density. Thus, for a given soil material, an increase in bulk density will increase the amount of pressure required by a plant root to penetrate the soil. These results are supported in later work by Taylor et al. (1966). Minore et al. (1969) studied the effect of high soil density on the rooting habit of seven northwestern tree species in the greenhouse. Seedlings were allowed to grow for two years in soil columns compacted to bulk densities of 1.32, 1.45 and 1.59 g/cm^3. Roots of western red cedar and western hemlock could not penetrate soil of density 1.45 g/cm^3, but roots of red alder, lodgepole pine and Douglas-fir could penetrate. No roots penetrated soil densities greater than 1.59 g/cm^3. Forristall and Gessel (1955) report that a density of 1.5 g/cm^3 restricts red alder root growth in loam soils while Douglas-fir and western hemlock root growth was restricted at a bulk density of 1.25 g/cm^3 in the same soil.

Effect on Infiltration

When considered over a large area with no boundary effects, infiltration refers to the downward movement of water into the soil profile (Baver, 1972). Infiltration is one of the most important phases of water movement in the hydrologic cycle of a forest environment. Hills (1971) states that infiltration data relate closely to overland flow development. It is well known that erosion potential increases with increasing overland flow (Baver et al., 1972). Trimble and Weitzman (1953) found soil losses on heavily used, poorly permeable skid roads twice as great as losses on more permeable, lightly used skid roads.

Field infiltration measurements are subject to a high amount of natural variability. Thus, detectable differences in soil infiltration must be large to overshadow this natural variation.

Previous research indicates that infiltration is the factor most clearly affected by compaction. Soil compaction reduces macropore space inducing slow water entry and poor aeration. Trimble and Weitzman (1953) reported that it took 619 times longer for a given quantity of water to enter a forest soil skid road than a similar undisturbed soil.

Steinbrenner (1955) reported that after four passes with a tractor, moist soil was only very slowly permeable to water. The mean infiltration rate on primary skid trails was one-tenth that on undisturbed soil on nine loblolly pine soil sites of various textures on the Atlantic coastal plain (Hatchell et al., 1970). Five years after tractor logging a Douglas-fir timber stand on a silty clay loam in Utah (Tackle 1962), the tractor skid road infiltration rate was five percent of the rate on an undisturbed site. Mace et al. (1971) indicate that sites harvested on early spring snow underwent reductions in infiltration rates similar to those harvested in the summer (approximately 50%). However, the area disturbed was reduced by 30%. In areas with a pyroclastic influence in the soil surface horizon, Steinbrenner and Gessel (1955) observed an average reduction in permeability on skid roads of 92.3%.

Effect on Soil Aeration and Porosity

Adequate aeration is essential for the emerging seedling, as well as the growing plant, to carry on normal respiration activities. In poorly aerated soils, root growth is inhibited. This limits the amount of root surface area available for nutrient and water uptake and can lead to a reduction in total plant growth (Taylor and Ashcroft, 1972).

Important microbiological processes depend on adequate aeration. The microbial population is drastically affected by changes in soil aeration (Brady, 1974). Organic matter oxidation is reduced when sufficient oxygen is not present. Many microbial transformations are reduced, and some processes are eliminated (Alexander, 1977). Alexander also points out that when aeration is lacking, "new microbiological processes come into play, some of which may be deleterious to plant development; for example, N_2 or CH_4 is evolved, organic inhibitors appear, and sulfide, ferrous, and manganous ions accumulate . . ." Russell (1973) states that plants may be weakened sufficiently by the accumulation of toxic substances to become more susceptible to pests and insects. Mitchell and Mitchell (1973) state that many plant root diseases increase under conditions of poor soil aeration. Baker and Cook (1974) hold that under conditions of poor soil aeration, oxygen content decreases and carbon dioxide content increases near plant roots. They state that ". . . high carbon dioxide levels may favor the pathogen over less tolerant microorganisms."

Additionally, high concentrations of carbon dioxide inhibit root growth and may reduce water adsorption, causing a water stress condition (Baker and Cook, 1974). Mattson and Addy (1975) report conclusions that link outbreaks of phytophagus insects to soil-plant systems in which soil moisture regimes are less than optimal.

The same physical qualities that permit rapid infiltration also favor adequate aeration. The transfer of both water and gas in the soil are dependent largely on the porosity and pore size distribution.

Porosity is defined as the total soil volume not occupied by solids. Soil porosity is inversely related to soil bulk density by the following relationship:

$$e = 1 - \frac{B.D.}{P.D.} \times 100,$$

where e = total soil porosity, B.D. = bulk soil density and P.D. = particle density (Baver et al., 1972). 2.65 g/cm^3 is the accepted normal value of particle density in most soils. Thus, if the bulk density is known the porosity can be readily calculated.

There are essentially two types of pores in a soil with structural development: pores between aggregates and pores within aggregates (Baver, 1972). At high soil water potentials, the interaggregate pores are filled with water. This water is not held very tenaciously; it exists only during the wettest part of the year in well drained soils of western Montana. At these times hydraulic conductivities are highest and water movement in the soil is greatest. As the soil water potential decreases during drier parts of the year, interaggregate pores drain and the hydraulic conductivity decreases exponentially. A concommitant decrease in the flux of water occurs. Thus, interaggregate pores are very important in moving large quantities of water during seasonal and acute periods of high rainfall. Steinbrenner (1955) states that "the process of soil compaction brings the solid particles closer by breaking down the macroscopic pores, thus reducing the capacity of soil for air. Soil air is an important factor in tree growth; therefore, any reduction in the macroscopic pore space of the soil could result in a less favorable growing site."

Effect on Available Water Holding Capacity

Available water holding capacity is related to other soil physical properties such as structure, texture, porosity and clay mineralogy. The available water holding capacity of a soil is defined as the amount of water held in the soil between field capacity and the permanent wilting point (Taylor and Ashcroft, 1972). Hyder and Sneva (1956) found that compacting a sandy loam soil with a heavy roller improved available water holding capacity. Rashid and Khalid (1977) concluded that compaction up to 1.51 g/cm^3 bulk density can benefit wheat growth in areas with coarse-textured soils and where water is not available in sufficient quantities.

Factors Which Influence Susceptibility to Compaction

All soils are susceptible to compaction to a greater or lesser degree. Li (1956) describes the compaction process as follows:

> If applied stresses exceed the shearing strength of the soil local failure begins and the load starts to sink into the soil. As the load sinks, the soil under the load is pushed downward and outward. This motion will mobilize more and more resistance, consisting not only of the increased resistance due to lateral confinement from depth, but also that due to the increase in soil density that results from the settlement motion itself, provided the soil is not completely saturated. The settlement stops when equilibrium between stresses and resistance is reached.
>
> If the resistance of the soil is relatively high compared with the stresses, the load will cause very little settlement. . . . If the resistance is extremely low in comparison with the stresses, the load will cause a complete shear failure of the underlying soil by sinking deep and fast and

> replacing the volume of soil by pushing it in an outward direction. This completely disturbed state may result in compaction of the soil under the load and loosen the soil on the sides. The total net reduction in voids is questionable--energy is spent in compacting one portion of the soil and, at the same time, loosening another portion. Both compacting and loosening involve movement of particles and require energy to overcome the frictional resistance.

The soil properties having the greatest affect on the rate and degree of soil compaction are texture, coarse fragment content, structure, moisture content at time of compaction, and organic matter content (Lull, 1959). Although each factor has been studied separately, complete understanding of soil susceptibility to compaction is complicated by the interaction of these factors. In addition to soil properties, land use factors such as type of equipment being used (crawler tractor or rubber-tired vehicle), type of operation (log skidding, slash piling, etc.), number of vehicular passes, and the harvesting technique of the logger also influence the amount of compaction which occurs at any given site.

Texture

Krynine (1951) demonstrated that maximum densities, achieved by several methods of laboratory and field compaction, decrease with decreasing particle size. This occurred in order from gravel to clay size. In the same study, maximum densities for the coarse textured samples were obtained using heavy smooth-wheel rollers, whereas maximum densities were attained in the fine textured soils using tamping (sheepsfoot) rollers. As pointed out by Means and Parcher (1963), the coarse textured soils are cohesionless and require the vibration of the smooth-wheel rollers to achieve compaction. Cohesionless soils are very low in clay content and their strength and resistance to deformation and compaction depend on grain size, shape, mineralogy, and clay content (Schroeder, 1975). Clays cannot be compacted by vibration (Means and Parcher, 1963). The tamping action of the sheepsfoot roller provides the required pressure to compact the clays.

Huberty (1944) observed the highest densities and greatest reduction in water penetration on soils with a wide range of particle sizes. Raney et al. (1955) found that plowpans and compaction-induced hardpans exist most commonly in soils of medium texture such as loam, sandy loam and silt loam soils. Soils with a wide range of particle sizes can be reoriented so that small particles pack into the voids between the larger particles (Means and Parcher, 1963).

Clay influences the susceptiblity of soils to compaction by affecting shear strength. Depending on the clay mineralogy of a soil and, in some cases, the water content, it may either fracture or exhibit plastic flow upon application of a force. The shear strength of soils can be partly attributed to the cohesive forces between soil particles (Brown, 1977). Because of this, the amount and type of clay present is important when evaluating soil strength. In a clay soil containing 55% clay, shear strength more than doubled between soil water tensions of -1 and -10 bars while loam with 27% clay was nearly insensitive to the same changes in water potential (Brown, 1977). Trask and Close (1958) and Langston et al. (1958) showed that at water contents somewhat less than saturation there was decreasing shear strength from montmorillonite to illite to kaolinite. When the clays were very wet, the order of decreasing shear strength was reversed (Trask, 1959). Allophanic materials are variable with regard to their shear strength, depending on their exchangeable cation composition (Grim, 1962).

Coarse Fragments

Li (1956) concluded that "the influence of gravel content upon compaction is important because it hinders the compaction of fine grained soil fractions." Li presented data showing that at 35% gravel content by weight, soil could be compacted to a density 97% as dense as a similar soil without gravels. A soil with 60% gravels by weight could only be compacted 92% as dense as a soil with no coarse fragments. In explanation, Li notes that gravels, when grouped together, tend to form voids in the soil which may be empty or only partially filled with soil fines. As the gravel content increases, the chance of forming such voids also increases. In this study, Li did not specify the type of soil or gravels that he worked with. It is interesting to note that one of the standard Proctor Tests, which determine the optimum moisture content and maximum density for a given compactive effort, is based on using soil materials which pass a 3/4" sieve. Inclusion of coarse fragments excluded by this sieve in the laboratory test may make the results more representative of field conditions.

Structure

Soil structure also effects the degree to which a soil can be compacted and the subsequent effect on plant growth and water relations. Well aggregated soils generally have low bulk densities and good permeability. As a result of compaction, aggregates are crushed, interaggregate porosity reduced and permeability diminished (Lull, 1959; Baver et al., 1972). Intense rain storms can break down the structural units in a soil and form a dense, impervious crust in the soil surface. Crusting is a form of compaction in which the energy of raindrops acts on bared mineral soil. Baver (1972) states, "this type of structure degradation is least common with those aggregates that are stabilized with humus or iron compounds." It is an important point that crusting or puddling is associated with soils of low organic matter content and weak structure. Baver (1972) asserts that though the direct effect of crusting is confined to the immediate surface layer, "the structure of this layer may be broken down to limit the air and moisture relations of the entire profile." Taylor and Ashcroft (1972) give evidence that mechanical manipulation of soil reduces aggregate stability and suggest work on soil with machinery only at soil moisture contents where soil strength is optimized.

Moisture Content

Much research has been done on the effect of moisture content on compaction. Engineering studies show that the most compaction for the least expense occurs when the soil is slightly below its plastic limit (Lull, 1959). Because the plastic limit varies with the soil texture and type of clay present (Grim, 1962), it follows that the optimum moisture content at which soils compact will vary accordingly. Optimum water content tends to increase as the texture becomes finer (Felt, 1965). The less dense the initial soil sample, the greater moisture content required to reach maximum density (Lull, 1959) for a given compactive effort. For materials containing very little or no fines, moisture content has almost no effect on density (Li, 1956).

Moisture affects the size of the double layer between colloidal particles (Taylor and Ashcroft, 1972), the surface tension on non-colloidal particles, and subsequently the shear strength and ease of movement of soil particles with respect to each other (Li, 1956). Water lubricates the particles and allows their reorientation with respect to each other. This effect is operative up to the optimum moisture content for compaction. Thereafter, the incompressibility of water prevents reorientation and packing and the density is reduced because the density of water has a greater weight in the overall density of the soil-water mixture.

Li (1956) points out that the optimum moisture content for a given compactive effort is valid only for that effort. Each compaction pressure has its own optimum moisture content. It is difficult to relate the standard laboratory Proctor test to field conditions where the compactive effort may differ substantially. However, the Proctor test can serve as an index to the relative compactibility of soils. In working with 14 forest soils in California, Howard et al. (1979) state, "the Proctor maximum dry bulk density is a sensitive empirical way of ranking the soils based on their susceptibility to compaction."

Organic Matter

Alderfer and Merkle (1941) demonstrated that total organic matter content is closely related to aggregate size and stability. Thus, any reduction in organic matter content will result in loss of aggregate stability and a subsequent increase in a soils's potential for compaction. Howard et al. (1979) concluded that organic carbon was clearly the most important soil characteristic of California forest soils for predicting maximum soil densities and inferred that the same could be concluded regarding compaction. Organic carbon content and soil organic matter are directly correlated (Allison, 1965). Thus, soil organic matter content can be used to predict a soils compactibility. Working with four soils in New York, Free et al. (1947) concluded that soil samples containing the most organic matter would be compacted the least at given moisture contents and compactive efforts. Also, the soils with high organic matter content were compacted to their maximum densities at higher moisture contents. In addition to improving soil structure and water relations, forest humus and litter may offer a cushioning effect to provide underlying soil some protection from compaction (Lull, 1959).

RESEARCH METHODS

Site Selection

Study sites with a range of parent materials, soil properties and environmental conditions were selected in the Bitterroot, Flathead and Kootenai National Forests. These soils are widespread and produce significant amounts of timber in the Northern Region; they are of critical importance to forest management and planning. Bitterroot National Forest sites are located in the West Fork of the Bitterroot River drainage. These soils are formed in clay-rich Tertiary Volcanic parent materials which are often overlain by a thin layer of silty material. Flathead and Kootenai National Forest sites are located in glacial till and are overlain by a layer of volcanic ash. One group of pedons are in limestone dominated glacial till. The second group of pedons is in quartzite dominated glacial till. Study site locations are depicted in figure 1.

Soils in this study were located only on the above three parent materials. Each parent material defines a site. Within each site, three subsites were located. Each subsite was located in and adjacent to a timber harvest unit. In choosing subsites, an attempt was made to minimize the effect of the variability of the natural soil landscape. Comparative soil profiles within each study site were chosen based on soil morphology and geomorphic setting. Every attempt was made to keep soil and geomorphic properties within a given study subsite

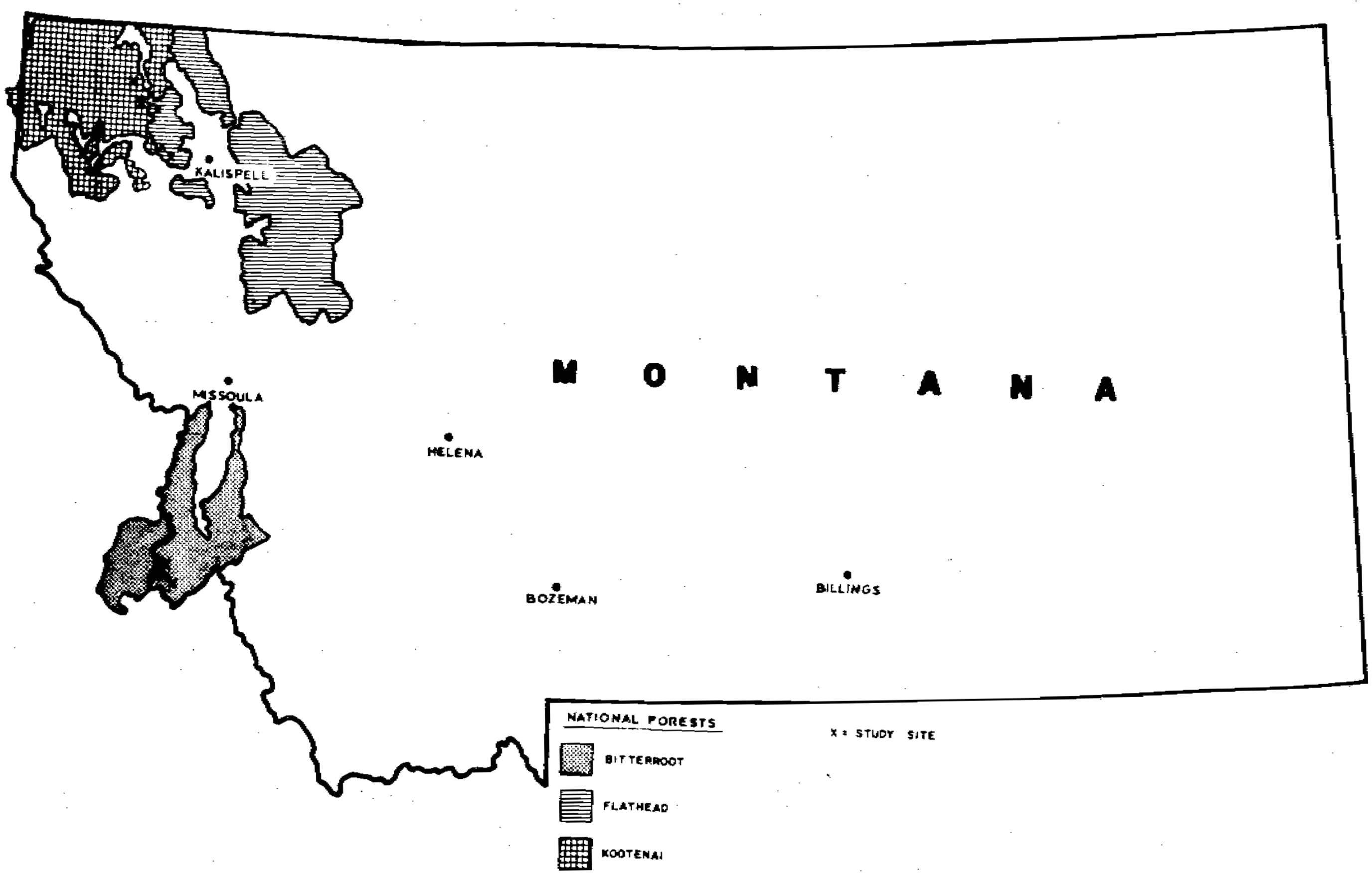


Figure 1. Site location map

constant. Study subsites were located within a particular geomorphic setting and profiles selected with similar texture, horizon depth and sequence, drainage, reaction, color, slope and aspect.

Within each study subsite, three treatment locations were selected. The treatments consisted of severely disturbed areas, moderately disturbed areas and the controls or undisturbed areas. Undisturbed areas are obviously non-trafficked as evidenced by their location completely out of any harvesting unit or within a group of trees not scarred by logging equipment and close enough together to prevent the passage of heavy logging equipment. Vegetation in these areas was completely undisturbed. Severely disturbed areas have undergone a maximum amount of traffic and surficial disturbance. Absence of vegetation, drouthiness and apparent previous use were used to indicate this condition. Severely disturbed areas consist of primary and secondary logging skid trails, decks and landings. Moderately disturbed areas are within the zone of logging activities, but not in an obviously heavily trafficked area. There is an inherent amount of variability and uncertainty in the identification of the moderately disturbed treatment zone and this was expected to be reflected in the final results.

Sampling Design and Procedure

The sampling design is a nested or split-plot design. Within the three national forests, three study sites, based upon the soil parent material (Tertiary Volcanics, limestone glacial till, quartzite glacial till) were chosen. The primary criterion used for location of the study sites was parent material. The limestone till and quartzite till sites are located in areas of both the Kootenai and Flathead National Forests. Within each study site, there were three subsites located in separate harvesting units. Geomorphic and soil conditions were not necessarily identical between subsites but were held as constant as possible within subsites so that effects of harvesting could be evaluated over a range of typical field situations. Soil pedons representing the three degrees of treatment or trafficking were located within or adjacent to the harvest boundary. For each treatment at each subsite, duplicate soil pedons were sampled in an attempt to account for the spatial variability which normally exists within a given soil landscape.

All soil profiles were characterized for site geomorphology, bedrock geology, taxonomic classification (Soil Survey Staff, 1975) and habitat type (Pfister, 1977). In addition, a complete profile description was made at each soil pedon.

Undisturbed clod samples were collected from each soil pedon for laboratory determination of bulk density, soil moisture release characteristics and hydraulic conductivity. In addition, infiltration measurements were made within 2 meters of each pedon. For each subsite, samples were taken from the control pedons for the following characterizations: cation exchange capacity, exchangeable cations, pH, clay mineralogy, organic matter, organic carbon, sieve analysis, Atterberg limits, Proctor curves and particle density.

Infiltration rates were determined with a double ring infiltrometer (inner ring diameter = 15.2 centimeters; outer ring diameter = 35.6 centimeters) (Johnson, 1963) at each pedon. Three infiltrometers were used at each pedon to measure infiltration for 60 minutes.

Because pedons were chosen with morphological similarities, a compromise between sampling strictly by depth versus sampling strictly by horizon was possible. Samples were always taken at the 15, 30, and 45 cm depths. In the Tertiary Volcanic soils, the 15 cm depth nearly always corresponded with the surface horizon and the 30 cm and 45 cm depth samples were nearly always in argillic horizons. Likewise in the glacial till soils, the 15 cm depth nearly always corresponded with the volcanic ash layer and the 30 cm and 45 cm depth samples were nearly always in the IIA2 horizon. Thus, a basis for comparison exists by horizon material and by depth. A subroutine within the statistical computer program was set up to sort so that only samples which met both specific depth and horizon criteria would be compared. Additionally, samples were taken at the 5 cm (volcanic ash) depth and by horizon for each horizon below the IIA2 in the glacial till soils. These samples were extracted at the middle of the horizon.

In each horizon, saran peds (approximately 75-200 cm^3 in volume) were taken for analysis of bulk density and soil water retention. Larger paraffin coated peds (approximately 350-1500 cm^3 in volume) were taken for hydraulic conductivity investigations. In the control pedons, approximately 14 kg of disturbed soil sample was taken from each horizon for laboratory analysis and development of characterization data.

Laboratory Analysis

Soil bulk density was determined with undisturbed soil samples using the saran-coated clod method (Soil Conservation Service, 1967). Acetone was used as the solvent for the saran resin. A correction factor for the saran weight was generated using hand-sieved and separated samples. Saran weight was plotted as a function of ped volume and, using a least squares fit, a regression equation was developed to predict saran weight. Regression equations were developed for each horizon material type (till vs. ash). Because very large peds could be extracted from the argillic horizons of the Tertiary Volcanic profiles, saran weights amounted to less than 5% of the total ped weight and no correction factor was used. A correction for the coarse fragment (>2 mm) weight and volume was made by hand sieving and weighing each sample. Volume was calculated assuming a particle density of 2.65 g/cc (Soil Conservation Service, 1967).

Hydraulic conductivity calculations were made using the Darcy equation (Klute, 1972). Undisturbed samples were used for hydraulic conductivity determinations. Core samples were not feasible because of high coarse fragment content and the likelihood of compacting samples during extraction. Undisturbed paraffin coated clods were extracted from the field sites. Irregular clod shape presented problems in determining cross sectional area, so an average value was estimated for each clod. The undisturbed clod samples were set in 3-inch diameter aluminum cylinders. Paraffin wax was used to hermetically seal the margins of the clods to the inside of the aluminum cylinders. Top and bottom were left exposed to permit the flow of liquid through the clods. A constant head of .005N calcium chloride was maintained throughout the experiment. Length of flow, hydraulic gradient, time, and quantity of liquid were measured parameters.

Moisture release data was obtained using a pressure chamber apparatus similar to that described by Richards (1972). The suction control "membrane" was a porous ceramic plate. Moisture contents, by weight, were determined on undisturbed soil at .02, .1 and 1/3 bar absolute soil water potential. Moisture contents at 15 bars absolute soil water potential were determined in a similar, stronger pressure chamber apparatus on ground samples that passed a 2 mm sieve. A porous ceramic plate with sufficiently small pores to maintain impermeability to air was used.

The disturbed bulk samples from the control pedons were air dried and crushed in a flail-type soil grinder. Sieve analysis (ASTM, 1979b) was performed on the entire bulk sample and subsamples were taken for lab characterization (<2 mm), Atterberg limits (<No. 40 sieve) and Proctor analysis (<3/4 in). Care was taken during subsampling to obtain a representative sample using a quartering technique (ASTM, 1979d).

Lab characterization included analysis for pH and electrical conductivity with a 1:1 dilution, NH_4Ac extractable Ca, Mg, Na and K (Chapman, 1965a), organic matter (Sims and Haby, 1971), cation exchange capacity (Chapman, 1965b), particle size analysis (Day, 1965), Proctor analysis (ASTM, 1979a), liquid limit (ASTM, 1979e), plastic limit and plasticity index (ASTM, 1979c), particle density (Blake, 1965), and calcium carbonate equivalent (Allison and Moodie, 1965). In order to verify the results of the extractable cations and cation exchange analyses, random samples were split and duplicates sent to the Reclamation Trace Element Lab at Montana State University. Results for extractable Na, Ca and Mg were comparable to within 5%. Cation exchange capacity results were within 8%.

Clay mineralogy determinations were performed on 28 selected representative samples. Sample preparation followed a technique employed by Theisen and Harward (1962). Samples were analyzed and results interpreted according to methods outlined by Whittig (1965).

A semi-quantitative method (Klages, 1980) was used to determine the relative abundance of alumino-silicate minerals present in the clay fraction (<2 μ). The method consists of determining the area under the peaks produced in the x-ray diffraction patterns. Weighting factors are established for the various clay mineral types. The areas, when multiplied by their respective weighting factors, yield results which are classified into ranges categorized as "high", "medium", "low", or "trace".

Calculations

Calculations used in this report are as follows:

Porosity:

$e = (1 - \frac{B.D.}{P.D.}) \times 100$, where

e = percent pore space,

B.D. = bulk density,

P.D. = particle density (Soil Conservation Service, 1967).

Organic carbon:

% organic carbon = % organic matter ÷ 1.724, (Allison, 1965).

Exchange acidity:

H^{+} (exch.) = CEC − [Ca^{++} + Mg^{++} + Na^{+} + K^{+}](exch.), where

CEC = cation exchange capacity,

H^{+} = exchange hydrogen,

Ca^{++} = exchange calcium,

Mg^{++} = exchange magnesium,

K^+ = exchange potassium (Peech, 1965).

Percent Base Saturation:

$\%BS = [Ca^{++} + Mg^{++} + Na^+ + K^+] \div CEC$, where

% BS = percent base saturation.

Hydraulic Conductivity:

$K = -\frac{Q}{At} \cdot \frac{\Delta x}{\Delta \Psi}$ where

K = hydraulic conductivity (cm/sec),

Q = quantity of water (cm^3),

A = estimated average cross sectional area (cm^2),

t = time (sec),

$\Delta\Psi$ = change in hydraulic head (cm),

Δx = length of flow (cm).

Statistics

Data related to the effects of vehicle traffic and parent material on the physical properties of the soils were analyzed statistically. The statistical analysis included an analysis of variance for a split plot design (Snedecor and Cochran, 1973). The F test was used to indicate significance after main effect (treatment) and interactions at the P = .10, P = .05, and P = .01 levels. A schematic representation of the design is given in Table 1. Data were analyzed using the statistical package Analysis of Variance and Covariance Including Repeated Measures (Jennrich and Sampson, 1979) on the Xerox Sigma 7 computer at Montana State University.

Table 1. Schematic presentation of plot design.

Site	Sub-Site	Treatment*	Replication	
		Sev.	A	B
	1	Mod.	A	B
		Cont.	A	B
Tertiary Volcanics		Sev.	A	B
	2	Mod.	A	B
		Cont.	A	B
		Sev.	A	B
	3	Mod.	A	B
		Cont.	A	B
		Sev.	A	B
	1	Mod.	A	B
		Cont.	A	B
Limestone Till		Sev.	A	B
	2	Mod.	A	B
		Cont.	A	B
		Sev.	A	B
	3	Mod.	A	B
		Cont.	A	B
		Sev.	A	B
	1	Mod.	A	B
		Cont.	A	B
Quartzite Till		Sev.	A	B
	2	Mod.	A	B
		Cont.	A	B
		Sev.	A	B
	3	Mod.	A	B
		Cont.	A	B

* Sev. - Severe
Mod. - Moderate
Cont. - Control

Samples from the severely trafficked areas were grouped by time since harvest into three categories: young (0-4 years), medium (5-9 years), and old (10-17 years). Analysis of variance was used to determine if the effects of compaction are ameliorated over time. Harvest units from which the samples were extracted ranged in age from 3 to 17 years.

RESULTS AND DISCUSSION OF CHARACTERIZATION STUDY

Profile descriptions for 54 soil pedons and characterization data for the 18 control pedons are shown in Appendices 2 to 4 and Appendices 5 to 7, respectively. These data are representative of soils of the three parent materials of this study. A key to the coding scheme used to identify and locate the pedons is given in Appendix 1.

Amorphous Character of Surface Horizons

Ottersberg (1977) found that amorphous character was associated with high silt content (usually 60% or more, but as low as 40%), weak consistence (usually soft, friable, nonsticky, nonplastic), and weak aggregation as indicated by weak structural grade. The Soil Survey Staff (1975) conclude that soils with an exchange complex dominated by amorphous materials have a fine-earth fraction bulk density of less than 0.85 g/cc. They also have a ratio of 15-bar water content to measured clay of more than 1.0.

A summary of the properties of the surface horizons of the Bitterroot, Flathead and Kootenai National Forest study sites and the criteria indicative of amorphous character are shown in Table 2. The loess deposits on the Flathead and Kootenai National Forest Study sites are dominated by amorphous soil materials. They are high in silt content and have weak consistence and structural grade. They also have low bulk density and a high ratio of 15-bar water content to

Table 2. Summary[§] of properties of the surface horizons of the Bitterroot, Flathead, and Kootenai study sites and criteria used to define amorphous character.

	Ratio of 15 bar water content to % clay	Bulk Density	% Silt	Structural grade	Consistence
Bitterroot National Forest Surface horizon	.87 [.52]	1.44 [.16]	39.5 [5.5]	moderate	soft-slightly hard, friable slightly sticky slightly plastic
Flathead and Kootenai National Forests Surface horizon	3.05 [1.73]	.72 [.27]	64.7 [4.25]	weak-moderate	soft, very friable, non-sticky, non-plastic
Definition of amorphous character	1.0[†]	.85g/cc[†]	60%[‡]	weak[‡]	soft, friable non-sticky non-plastic[‡]

[§]Data are means with standard deviations in brackets.

[†]From Soil Taxonomy (1975).

[‡]From Ottersberg (1977).

measured clay. Conversely, the soils located in the Bitterroot National soils located in the Bitterroot National Forest of southwest Montana do not meet the criteria for amorphous soil materials. They are lower in silt content, have stronger consistence and structure, have bulk densities greater than 1.00 g/cm^3 and a ratio of 15-bar water content to measured clay of less than 1.0.

Texture

Soils on the Tertiary Volcanic study site are characteristically high in clay. Clay content varies from 22% to 67% clay in the argillic horizon. The overlying surface horizon is much coarser. Textures range from silt loam to sandy loam (33-57% sand). One anomaly was observed in Bitterroot subsite 2. The subsurface horizon of a control test pit (profile B2AC) was high in sand and low in clay (7%), reflecting possible differences in geologic parent material and the spatial variability of soils.

The limestone and quartzite dominated glacial till soils are alike in texture. Both are dominantly silt loam throughout. Both tills are overlain by a silt loam loess deposit (3-15% clay) of apparent volcanic origin.

Proctor Test

The Proctor test is an analysis originally devised by engineers to determine: 1) the optimum moisture content at which fill material for roadbeds and embankments is compacted, and 2) the maximum density to which the material could be compacted. As stated before, the results of a Proctor test are not directly applicable to field conditions under which forest soils are exposed to vehicular traffic. However, the Proctor test can provide a general index as to the relative compactibility of various soil materials (Howard et al., 1979).

Table 3 summarizes the optimum moisture content for compaction and the maximum soil density achieved by the Proctor test for major horizons of the study soils.

In the glacial till soils, highest optimum water contents and lowest maximum densities were observed in the loess cap samples. The Bitterroot surface horizon samples, with lower silt and higher sand and clay contents, compacted to a higher maximum density at a lower water content.

The data in Table 3 indicate that, when contrasting comparable horizons in the glacial till soils, quartzite till compacts to a higher density at a lower moisture content than the limestone till. This may be due to the slightly higher clay contents observed in the limestome till profiles. Subsoils at the Tertiary Volcanic study sites compacted to lower bulk densities than those of the glacial till subsoils. Again, this probably relates to their high clay content.

Table 3. Summary of optimum moisture content and maximum soil density§ achieved using standard Proctor Test (Method C)† on major horizons in three parent materials.

	Horizon	Optimum Moisture content	Maximum Density
		(% wt.)	(g/cm^3)
Limestone Till			
	B2ir	25.6 [4.4]	1.36 [.10]
	IIA2	12.7 [1.7]	1.89 [.05]
	IIA+B/IIB+A	13.7 [1.9]	1.91 [.05]
	IIB2t	14.7 [1.9]	1.89 [.04]
	IICca	11.1 [2.2]	2.02 [.07]
Quartzite Till			
	B2ir	22.8 [4.3]	1.50 [.12]
	IIA2	11.7 [2.0]	1.97 [.07]
	IIA+B	12.0 [2.6]	2.00 [.14]
	IIC	10.6 [1.4]	2.04 [.06]
Tertiary Volcanics			
	A2	15.5 [1.9]	1.83 [.10]
	B21t	21.6 [6.4]	1.70 [.22]
	B22t	23.5 [5.0]	1.60 [.17]

§Data are means with standard deviations given in brackets.

†Does not include correction for coarse fragments.

Atterberg Limits

An important measure of a soil's consistence is its plastic limit. Plastic limit is the moisture content at which soils behave plastically. That is, under loading they shear rather than break. As the moisture content is increased further, a soil eventually reaches a point at which it behaves as a liquid. This is known as the liquid limit and the difference between the liquid limit and the plastic limit is known as the plastic index. Collectively, the plastic limit, liquid limit and plastic index are called the Atterberg limits. A summary of plastic limits and plastic indices is given in Table 4.

The large amount of variability inherent in determination of the Atterberg limits is reflected in the standard deviations for the plastic index. In addition to means and standard deviations, the percent of the total samples recorded as non-plastic are included in the data.

The loess caps on till in the Flathead and Kootenai National Forests are non-plastic, whereas all the Bitterroot Tertiary Volcanic surface horizon samples are plastic. This suggests that the Flathead and Kootenai loess caps may be more susceptible to vibrational compaction, whereas the Bitterroot surface horizon may undergo compaction primarily by compression. Because of the high silt (non-cohesive) content in the Bitterroot, the effect of vibration is probably also operative.

Table 4. Summary of Plastic Limit and Plastic Index Data[§] for major horizons of the three parent materials.

	Plastic Limit	Plastic Index
Limestone Till		
B2ir	NP[†]	NP; (100)
IIA2	21.4; [.1]	2.8; [1.2]; (80)
IIA+B/IIB+A	20.7; [1.5]	3.6; [2.3]; (11)
IIB2t	20.8; [1.3]	6.8; [1.4]; (0)
IICca	19.4; [1.7]	3.2; [2.8]; (14)
Quartzite Till		
B2ir	NP	NP; (100)
IIA2	20.3; [3.6]	2.1; [1.4]; (64)
IIA+B	19.9; [.9]	7.5; [3.0]; (60)
IIC	19.4; [1.6]	3.5; [1.5]; (25)
Tertiary Volcanics		
A2	23.6; [5.3]	3.0; [1.1]; (0)
B21t	29.7; [12.5]	31.6; [22.5]; (0)
B22t	25.8; [3.5]	43.7; [38.1]; (0)

§ Data are means followed by standard deviations in brackets with the percent of samples non-plastic in parentheses.

† NP = non-plastic.

Clays are dominantly responsible for the cohesive forces in soils, and the plastic index generally increases with increasing clay content. Plastic indices for the limestone and quartzite glacial till subsoils were about equal, whereas those of the Tertiary Volcanic sites being much greater, reflecting their higher clay contents.

Clay Mineralogy

X-ray diffraction patterns for the surface horizons of the three study sites support the conclusion that amorphous character is more strongly expressed in the surface horizon of the limestone and quartzite till sites. Crystalline clays, in the form of illite and kaolinite, were found in only trace amounts in the loess cap samples of the limestone and quartzite till sites. The surface horizon samples from the Tertiary Volcanic sites contained appreciable amounts of crystalline clays. Illite was present in medium to high amounts with relatively low amounts of smectite and kaolinite.

The argillic subsoils of the Tertiary Volcanic parent materials are of variable mineralogy. Subsites 1 and 2 have clay minerals dominated by the smectite group. Lesser amounts of illite and kaolinite are present. Four soil pedons (B3AC, B3AM, B3BM, B3AS) at subsite 3 have mineralogies dominated by kaolinitic clays with only trace amounts of smectite present. Clay mineralogies in these pedons were correlated by color and by the absence of cracking when dry to the dominantly kaolinite mineralogy of the sample extracted from the IIB23t horizon in profile B3AC. Clay mineralogies are included in the family names of all soil pedons and are listed in Appendices 2 to 4.

The limestone and quartzite dominated glacial till subsoils have similar mineralogies. Illite is the dominate crystalline clay. Only trace to low amounts of kaolinite and smectite are present. In addition, some samples have trace to low amounts of vermiculite and chlorite.

These results suggest that a general ranking of the subsoils on the three parent materials can be made based on their clay strength under dry and wet conditions. During the time when these subsoils are dry, the data suggest that the shear strengths of the two glacial till soils are about equal and less than that of the Tertiary Volcanic subsoils. Under wet conditions, this ranking would be reversed.

Because of the presence of crystalline clays, the surface horizon on the Tertiary Volcanic sites is ranked higher in dry shear strength and lower in wet shear strength than the loess cap on the limestone and quartzite dominated glacial till sites.

Chemical Characteristics

Chemical characteristics of the study soils are typical of soils forming under a coniferous forest with relatively high rainfall. They are acid, non-saline and non-sodic. Summaries of the chemical data for the major horizons of these soils are shown in Tables 5 to 7.

Organic matter and organic carbon percentages are greatest in the surface horizons with much lower amounts found in the subsurface horizons. This fact probably accounts, in large part, for the higher cation exchange capacity (CEC) found in the surface horizons than in the subsurface horizons. The Tertiary Volcanic surface horizons have much lower organic matter contents and CEC than the loess caps in the limestone and quartzite dominated glacial till sites. Susceptibility to soil compaction is inversely related to organic matter content (Free et al., 1947). Thus, on this basis, the Bitterroot surface horizon may be more easily impacted by vehicular traffic than its northwestern analog.

Soils forming in limestone dominated glacial till have the highest amounts of calcium carbonate. Calcium carbonate in the quartzite till IIC horizon is due to one subsite located on the Prichard Formation where the till has some limestone mixed with it.

Particle Size Distribution

Fig. 2 illustrates the particle size distribution of the major horizons of the soils involved in the study. The surface horizon of the soils forming on all three parent materials have a uniform distribution of particle sizes. In engineering jargon this is termed "well

Table 5. Summary of chemical data† for major horizons of soils at limestone glacial till sites.

			1:1 Extract		Exchangeable Cations					Base		
Horizon	O.M.	O.C.	pH	EC	Ca	Mg	Na	K	H‡	Saturation	CEC	$CaCO_3$
	%	%		(mmhos/cm	meq/100g					%	meq/100g	%
B2ir	4.0 [.58]	2.3 [.33]	5.8 [.49]	.09 [.05]	2.10 [.79]	.48 [.24]	.09 [.03]	.28 [.18]	17.37 [4.51]	15.00 [6.01]	20.31 [4.75]	--
IIA2	.7 [.25]	.4 [.21]	6.3 [.43]	.05 [.02]	4.00 [1.07]	.95 [.82]	.07 [.06]	.15 [.05]	1.07 [.87]	80.37 [13.99]	6.39 [1.05]	--
IIA+B/ IIB+A	.5 [.19]	.4 [.17]	6.3 [.42]	.05 [.03]	6.04 [1.54]	1.11 [.35]	.10 [.06]	.18 [.04]	2.96 [1.19]	72.51 [7.88]	10.56 [2.26]	--
IIB2t	.6 [.33]	.4 [.18]	6.7 [.31]	.12 [.06]	8.65 [2.76]	1.18 [.26]	.07 [.04]	.19 [.04]	1.42 [1.37]	86.34 [9.73]	11.34 [2.70]	--
IICca	.4 [.16]	.2 [.09]	6.8 [.20]	.13 [.03]	26.82 [3.92]	1.26 [.61]	.09 [.06]	.15 [.05]	0	100.00 [0]	6.40 [1.78]	10.99 [2.22]

† Data are means with standard deviations in brackets.

‡ Exchangeable H calculated as follows: H[exch.] = CEC - (Ca + Mg + Na + K) [exch.].

Table 6. Summary of chemical data[†] for major horizons of soils at quartzite dominated till sites.

Horizon	O.M.	O.C.	1:1 Extract pH	1:1 Extract EC	Exchangeable Cations Ca	Exchangeable Cations Mg	Exchangeable Cations Na	Exchangeable Cations K	Exchangeable Cations H[‡]	Base Saturation	CEC	$CaCO_3$
	%	%		(mmhos/cm	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	%
B2ir	3.4 [.92]	1.2 [.51]	6.0 [.71]	.09 [.03]	2.22 [.78]	.70 [.39]	.09 [.01]	.34 [.10]	13.72 [2.87]	20.18 [7.53]	17.07 [2.08]	--
IIA2	.6 [.30]	.4 [.18]	6.3 [.43]	.04 [.02]	1.78 [1.23]	.68 [.51]	.07 [.04]	.13 [.02]	2.30 [1.17]	51.97 [16.67]	4.97 [1.93]	--
IIA+B	.6 [.42]	.4 [.23]	6.7 [.21]	.05 [.03]	4.35 [2.61]	1.26 [.48]	.07 [.03]	.15 [.05]	2.97 [.72]	63.92 [6.98]	8.79 [3.74]	--
IIC	.4 [.18]	.2 [.11]	6.9 [.15]	.08 [.05]	14.33[§] [13.29]	.95 [.44]	.07 [.02]	.13 [.03]	1.56[§] [1.91]	74.04 [28.30]	6.07 [1.71]	4.12[§] [4.79]

[†]Data are means with standard deviations in brackets.

[‡]Exchangeable H calculated as follows: H[exch.] = CEC - (Ca + Mg + Na + K) [exch.].

[§]High standard deviation caused by two control pits located on Prichard Formation where some limestone is mixed with quartzite till.

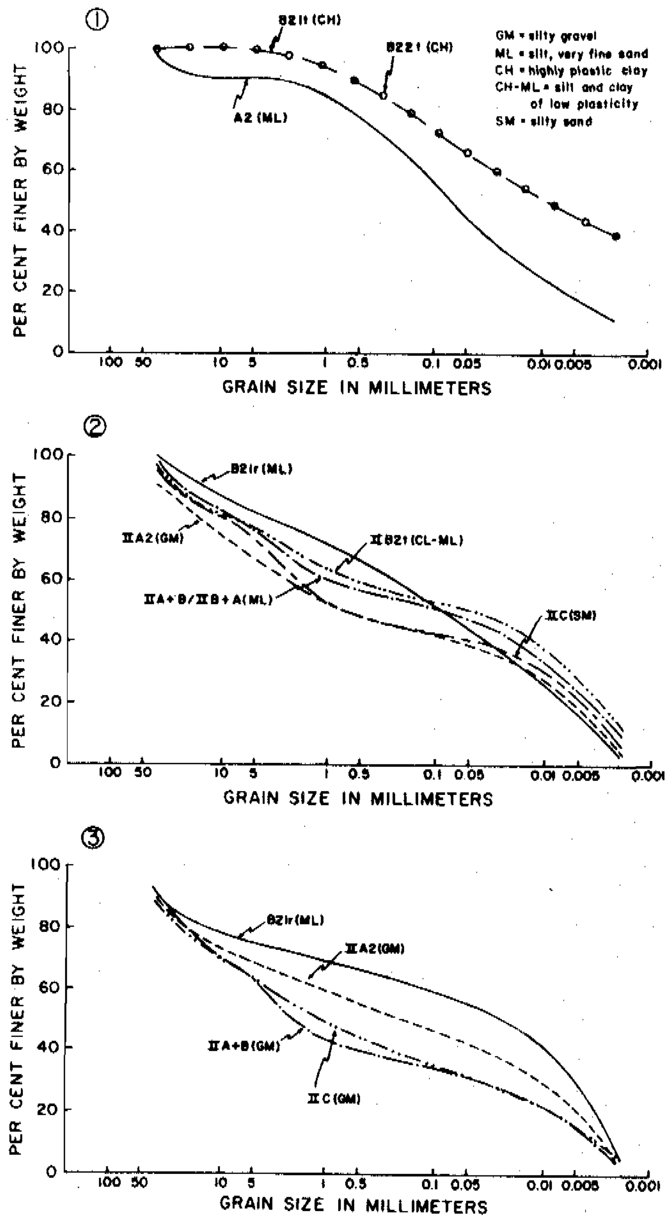
Table 7. Summary of chemical data† for major horizons of soils on Tertiary Volcanic sites.

Horizon	O.M.	O.C.	1:1 Extract		Exchangeable Cations					Base Saturation	CEC	$CaCO_3$
			pH	EC	Ca	Mg	Na	K	H‡			
	%	%		(mmhos/cm	meq/100g					%	meq/100g	%
A2	1.7 [.55]	1.1 [.26]	6.1 [.52]	.11 [.07]	4.94 [1.36]	1.63 [.56]	.09 [.03]	.40 [.20]	3.56 [.77]	65.03 [8.80]	10.66 [1.96]	--
B21t	.8 [.43]	.5 [.25]	6.2 [.51]	.14 [.08]	12.93 [8.15]	6.99 [4.33]	.16 [.10]	.56 [.29]	8.45 [3.54]	67.74 [13.08]	28.77 [15.27]	--
B22t	.9 [.47]	.4 [.38]	6.4 [.31]	.13 [.05]	14.48 [8.07]	8.26 [5.08]	.18 [.09]	.66 [.33]	8.93 [9.07]	69.52 [21.71]	32.49 [15.05]	--

† Data are means with standard deviations in brackets.

‡ Exchangeable H calculated as follows: H[exch.] = CEC - (Ca + Mg + Na + K)[exch.].

Figure 2. Particle size distribution and unified soil classification for major horizons of soils forming in: 1) Tertiary Volcanics, 2) limestone dominated glacial till and 3) quartzite dominated glacial till.



graded." Well graded soil materials are generally considered well suited to compaction and use for road fill material. The soils forming in the glacial tills are characterized by generally higher coarse fragment contents throughout the profile (35-60% by weight) than in Tertiary Volcanic parent materials (less than 10% by weight). Coarse fragments reduce the impact of vehicular traffic. Thus, higher coarse fragment content in the tills may reduce susceptibility to compaction.

Bulk Density and Porosity

Bulk density and total porosity are inversely related. Any changes or relationships regarding bulk density exist inversely for porosity. Table 8 summarizes the bulk densities and porosities of the control profiles on sites of the three parent materials.

Decker (1972) found that the mean bulk density (air dry) of 201 Montana soil samples was 1.56 g/cm^3. The bulk density values of this study vary around Decker's figure. The surface horizons are high in organic matter and have relatively low undisturbed bulk densities. Subsurface soils in glacial till have low organic matter contents and higher undisturbed bulk densities. Subsurface soils from clay-rich Tertiary Volcanic sediments are also low in organic matter and have high undisturbed bulk densities. Figure 3 illustrates the changes in bulk density with horizon type for the three soil parent materials of the study.

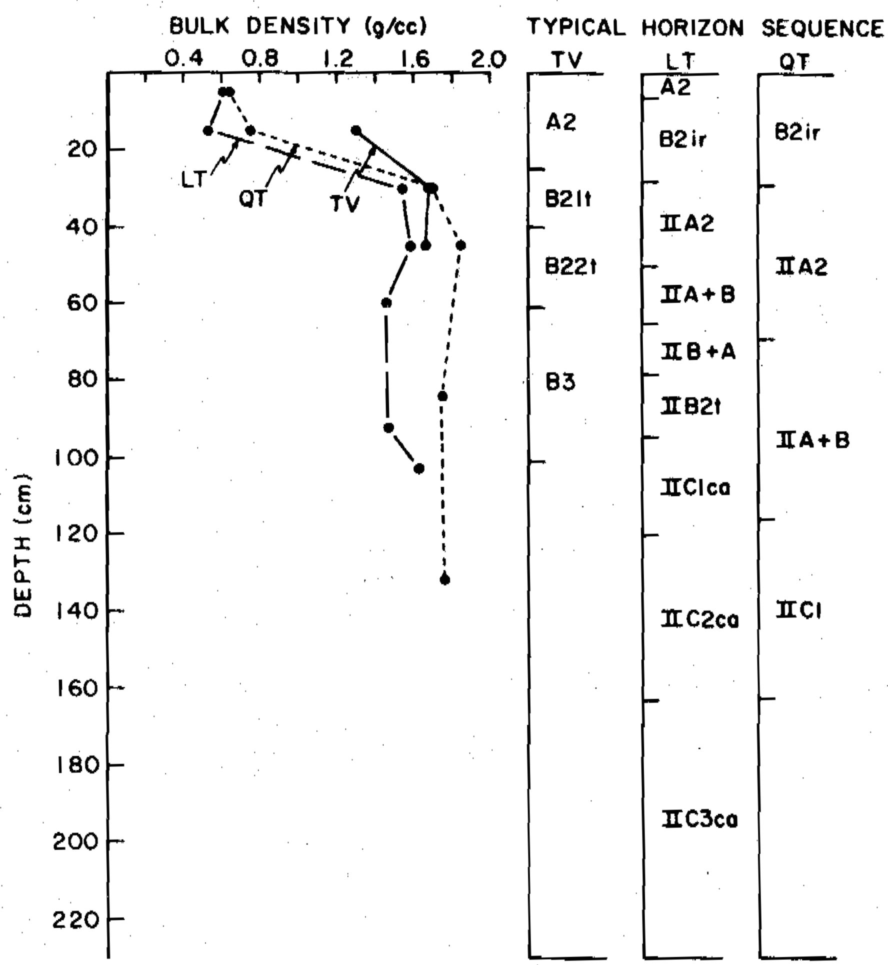
Table 8. Summary of saran-clod bulk density and porosity data† for major horizons of the control pedons on the three parent materials.

	Bulk density	Total porosity‡
	g/cm^3	% vol.
Limestone Till		
B2ir	.53 (.25)	80%
IIA2	1.56 (.20)	41%
IIA+B/IIB+A	1.46 (.17)	45%
IIB2t	1.46 (.13)	45%
IICca	1.63 (.07)	38%
Quartzite Till		
B2ir	.76 (.27)	71%
IIA2	1.77 (.13)	33%
IIA+B	1.75 (.16)	34%
IIC	1.76 (.11)	34%
Tertiary Volcanics		
A2	1.30 (.07)	51%
B21t	1.67 (.11)	37%
B22t	1.66 (.25)	37%

† Data are means with standard deviations in parentheses.

‡ Total porosities were derived by calculation from bulk density values.

Figure 3. Control bulk density changes (with depth) and typical horizon sequences for soils forming in the three parent materials of the study.



TV - Tertiary volcanic parent material
LT - Limestone dominated glacial till parent material
QT - Quartzite dominated glacial till parent material

Water Holding Characteristics

The water holding capacities of the major horizons of the soils involved in the study are summarized in Table 9.

Highest amounts of water held at 1/3 bar soil water tension were found in the loess cap on sites located in northwestern Montana. The surface horizon on Tertiary Volcanic sites holds much less water at 1/3 bar and 15 bar than the loess cap on the limestone and quartzite glacial till sites. In addition, Table 9 shows available water holding capacities calculated as the difference between the means of 1/3 bar water content and 15 bar water content. The data show that the surface horizons on the Tertiary Volcanic sites holds 1/4 to 1/2 less available water than the loess cap on the glacial till sites.

On both quartzite and limestone glacial till sites, considerably less available water is held in the subsoils than in the loess cap. One-third bar moisture contents show the same trend.

Examination of the summary data reveals higher standard deviations associated with the means of 1/3 bar water content values than those associated with 15 bar water contents. This greater variability is probably due to the use of undisturbed saran peds for 1/3 bar water content determinations. The amount and degree of aggregation varies from ped to ped. The variability seems acceptable in view of the fact that the peds more accurately reflect field moisture conditions than sieved and ground disturbed samples would.

Table 9. Summary of water holding† characteristics of the major horizons of the soils forming in the three parent materials of the study.

	1/3 Bar	15 Bar	A.W.H.C‡
	% by wt		
Limestone Till			
B2ir	73.7 [12.3]	14.8 [1.6]	58.9
IIA2	24.8 [3.7]	7.4 [3.1]	17.5
IIA+B/IIB+A	32.5 [13.7]	11.4 [3.4]	21.1
IIB2t	33.0 [1.6]	12.5 [2.1]	20.5
IICca	27.8 [3.5]	9.2 [2.9]	18.6
Quartzite Till			
B2ir	47.8 [17.4]	15.6 [2.6]	32.2
IIA2	24.9 [8.3]	7.3 [4.3]	17.6
IIA+B	29.0 [9.4]	7.6 [3.5]	21.4
IIC	25.7 [9.2]	7.7 [2.4]	18.0
Tertiary Volcanics			
A2	25.5 [9.2]	10.2 [3.0]	15.3
B21t	38.8 [8.5]	23.5 [9.2]	15.3
B22t	54.1 [11.7]	24.2 [7.5]	29.9

† Data are mean percent water by weight with standard deviations in brackets.

‡ A.W.H.C. = available water holding capacity.

An interesting comparison can be made from the water holding characteristics data in Table 9 and the data for optimum moisture content for compaction in Table 3. In every case except one, the mean optimum moisture content lies within the range of the mean available water. The one exception is probably best explained by spatial variability in sampling and the normal variability associated with laboratory soil analysis. In general, the optimum moisture content is considerably less than that at 1/3 bar but still within the range of available water. These optimum moisture contents are only for the compactive effort under which the standard Proctor analysis is conducted. Each compactive force has its own optimum moisture content. As the compactive effort is increased, the optimum water content decreases. For the normally lower compactive efforts found in the field, the optimum moisture contents would be somewhat higher.

RESULTS OF SOIL COMPACTION STUDY

Possible changes in the physical properties of the soils involved in the study were investigated to determine if and in what manner soil compaction had occurred. Infiltration, bulk density and porosity, moisture retention and hydraulic conductivity measurements were made and statistically analyzed for soils of the three parent materials.

Infiltration

A summary of cumulative infiltration rates over a 60-minute period for the soils of the three parent materials is given in Table 10.

Variability of the infiltration data was high. For this reason the median reading was used as the average for the three determinations made at each pedon. The median readings were then used for further statistical analysis. Significant reductions in the infiltration rates occurred in the severe treatment areas on all three parent materials. Infiltration rates were also significantly reduced in the moderate treatment areas of the limestone and quartzite dominated glacial till sites. Infiltration rates on moderate treatment areas of Tertiary Volcanic sites were lower than the control, but the difference was not statistically significant.

No statistically significant differences in infiltration rates could be attributed to differences in soil parent material or age grouping.

Table 10. Summary of infiltration data† at the three parent material sites.

	Control	Moderate	Severe
		cm^3	
Limestone Till	7019.8 (38.5)	1516.2** (8.3)	1334.0** (7.3)
Quartzite Till	6578.7 (36.1)	1626.7** (8.9)	1358.3** (7.4)
Tertiary Volcanics	5281.8 (29.0)	3068.8 (16.8)	671.9* (3.7)

† Data are the means of the median cumulative volume of water (cm^3) that infiltrated into soil through a 15.29 cm diameter cylinder over a one hour period. Data in parentheses are infiltration rates (cm/hr) for first one hour period.

= difference from control significant at P = .10 level.
* = difference from control significant at P = .05 level.
** = difference from control significant at P = .01 level.

Bulk Density

Mean bulk densities from the major horizons of the soils on the three parent materials were measured and statistically analyzed. The resultant data are presented in Tables 11 through 13.

Bulk density was measured at the 15 cm depth on the Tertiary Volcanic site and at the 5 cm and 15 cm depth in the loess cap on the glacial till sites.

The surface horizons at the three study sites showed significant increases in bulk density in the severe treatment areas. Significant increases occurred at the 5 cm and 15 cm depth in the limestone and quartzite dominated glacial till sites. Surface horizon bulk density increases were statistically significant in the moderate treatment areas of all study sites except the one on the quartzite till, which had non-statistically significant increases.

Analysis of subsoil bulk densities revealed no statistically significant increases due to treatment in any of the parent materials. Significant decreases were noted in the IIA2 horizon of the severely treated quartzite till study areas and in the moderate treatment of the IIA2 horizon on the limestone till sites. These differences were significant only at the lowest ($P = .10$) level of statistical confidence employed.

No statistically significant differences in bulk density could be attributed to differences in age of the harvested areas.

Table 11. Saran-clod bulk densities[†] of major horizons for three treatments on soils forming in Tertiary Volcanic parent material.

Horizon	Depth	Control	Moderate	Severe
	cm		g/cm^3	
A2	15	1.30 (.07)	1.53* (.21)	1.58** (.18)
B21t	30	1.67 (.11)	1.63 (.11)	1.81 (.21)
B22t	45	1.66 (.25)	1.58 (.18)	1.72 (.18)

† Data are mean bulk densities in g/cm^3. Numbers in parentheses below means are standard deviations.

= difference from control significant at P = .10 level.
* = difference from control significant at P = .05 level.
** = difference from control significant at P = .01 level.

Table 12. Saran-clod bulk densities† of major horizons for three treatments on soils forming in limestone dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm		g/cm^3	
01/B2ir -5 cm	5	.61 (.24)	.84** (.24)	.97** (.28)
B2ir -15cm	15	.53 (.15)	.97** (.32)	.93** (.09)
IIA2 -30 cm	30	1.55 (.20)	1.53 (.12)	1.39# (.25)
IIA2 -45 cm	45	1.59 (.10)	1.54 (.07)	1.43 (.09)
IIA+B	~	1.46 (.17)	1.52 (.11)	1.42 (.07)
IIB2t	~	1.46 (.13)	1.50 (.10)	1.49 (.07)
IIC	~	1.63 (.07)	1.81* (.14)	1.72 (.04)

† Data are mean bulk densities in g/cm^3. Numbers in parentheses below means over standard deviations.

= difference from control significant at P = .10 level.
* = difference from control significant at P = .05 level.
** = difference from control significant at P = .01 level.
~ = from center of horizon; depth variable.

Table 13. Saran-clod bulk densities† of major horizons for three treatments on soil forming in quartzite dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm		g/cm^3	
O1/B2ir	5	.64 (.27)	.66 (.25)	1.01** (.38)
B2ir	15	.76 (.25)	.88 (.32)	.92# (.22)
IIA2	30	1.71 (.13)	1.52# (.51)	1.75 (.18)
IIA2	45	1.83 (.07)	1.74 (.17)	1.88 (.22)
IIA+B	~	1.75 (.16)	1.66 (.15)	1.78 (.17)
IIC	~	1.76 (.11)	1.81 (.14)	1.72 (.21)

† Data are mean bulk densities in g/cm^3. Numbers in parentheses below means are standard deviations.

= difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

** = difference from control significant at P = .01 level.

~ = from center of horizon; depth variable.

Soil Water Retention

Mean water content (percent by weight) at .02, .10 and .33 bar soil water potentials were determined and statistically analyzed by horizon and treatment for the soils of the three parent materials of the study. The data are presented in Tables 14 through 22.

Soils of the limestone till sites showed significant changes in water content with treatment at .02, .10, and .33 bars in the surface, or loess cap, horizons only. Significant reductions in the amount of water held at the three soil water potentials occurred in both the moderate and severe treatment areas. No statistically significant changes of water content occurred in the limestone glacial till subsoil, although a general trend of water content reduction with treatment throughout the profile can be observed in the data. In one case (IIA2-45 cm, severe treatment), the mean water content at the three soil water potentials increased slightly over the control. This change was not statistically significant.

Treatments on quartzite till areas also showed significant decreases in the water held at .02, .10, and .33 bars for both moderate and severe treatment areas only in the surface horizon. Again, a general trend showed reductions throughout the profile with the exception of the moderately treated IIA2 at 30 cm, moderately treated IIA+B, and moderately treated IIC horizons. Small increases in mean

Table 14. Water content† at .02 bars soil water potential of major horizons in soils forming in Tertiary Volcanic parent material.

Horizon	Depth	Control	Moderate	Severe
	cm	----------------	% by wt	------------
A2	15	33.1 (5.9)	28.2 (4.6)	27.8 (4.3)
B21t	30	41.8 (9.7)	33.5 (17.0)	39.0 (13.2)
B22t	45	59.0 (15.7)	42.0* (10.4)	44.1* (25.8)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

= difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

Table 15. Water content† at .1 bars soil water potential of major horizons in soils forming in Tertiary Volcanic parent material.

Horizon	Depth	Control	Moderate	Severe
	cm	----------------	% by wt	-------------
A2	15	30.8 (5.8)	26.3 (4.4)	25.6 (4.6)
B21t	30	40.7 (9.4)	31.8 (16.2)	37.5 (12.7)
B22t	45	57.7 (15.7)	40.5** (10.4)	42.7* (24.8)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

\# = difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

** = difference from control significant at P = .01 level.

Table 16. Water content† at .33 bars soil water potential of major horizons in soils forming in Tertiary Volcanic parent material.

Horizon	Depth	Control	Moderate	Severe
	cm		% by wt	
A2	15	25.5 (9.2)	20.7 (6.6)	20.7 (5.9)
B21t	30	38.8 (8.5)	28.8# (18.2)	34.1 (13.6)
B22t	45	54.1 (11.7)	38.1** (11.7)	26.5** (8.7)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

= difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

** = difference from control significant at P = .01 level.

Table 17. Water content† at .02 bars absolute soil water potential of major horizons in soils forming in limestone dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm		% by wt	
B2ir	15	82.9 (29.5)	65.3* (18.7)	59.7** (15.2)
IIA2	30	29.7 (3.0)	27.1 (6.4)	26.6 (4.9)
IIA2	45	28.2 (3.6)	26.1 (0)	30.7 (0)
IIA+B	~	37.7 (14.2)	34.9 (6.7)	36.3 (4.7)
IIB2t	~	38.0 (1.7)	32.7 (7.6)	33.4 (3.7)
IIC	~	33.4 (6.0)	31.2 (3.1)	28.9 (3.9)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

= difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

** = difference from control significant at P = .01 level.

~ = from center of horizon; depth variable.

Table 18. Water content† at .1 bar soil water potential of major horizons in soils forming in limestone dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm	% by wt		
B2ir	15	78.3 (26.8)	62.03* (16.8)	55.28** (18.2)
IIA2	30	27.2 (3.3)	25.4 (6.5)	24.6 (4.5)
IIA2	45	26.2 (4.2)	24.1 (0)	29.4 (0)
IIA+B	~	34.4 (14.4)	33.1 (7.0)	33.6 (4.3)
IIB2t	~	35.2 (1.5)	30.9 (6.7)	31.0 (3.1)
IIC	~	29.8 (4.4)	28.6 (2.0)	27.0 (3.2)

† Data are percent water by weight. Numbers in parentheses are standare deviations.

= difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

** = difference from control significant at P = .01 level.

~ = from center of horizon; depth variable.

Table 19. Water content[†] at .33 bars soil water potential of major horizons in soils forming in limestone dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm	----------------	% by wt	----------------
B2ir	15	73.9 (26.7)	58.6* (18.4)	53.9** (17.5)
IIA2	30	25.4 (3.3)	24.4 (6.3)	23.2 (4.4)
IIA2	45	23.8 (3.9)	22.9 (0)	28.2 (0)
IIA+B	~	32.5 (13.7)	31.7 (7.2)	32.4 (4.0)
IIB2t	~	33.0 (1.6)	29.3 (5.8)	28.7 (2.8)
IIC	~	27.8 (3.5)	27.2 (2.4)	25.3 (2.9)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

= difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

** = difference from control significant at P = .01 level.

~ = from center of horizon; depth variable.

Table 20. Water content† at .02 bar soil water potential of major horizons in soils forming in quartzite dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm	-------------	% by wt	-------------
B2ir	15	57.6 (17.6)	43.1# (23.8)	43.0# (21.9)
IIA2	30	24.9 (4.0)	31.4 (5.8)	23.6 (2.9)
IIA2	45	30.6 (15.4)	29.6 (8.4)	30.0 (9.8)
IIA+B	~	30.4 (10.2)	33.6 (7.5)	25.8 (4.0)
IIC	~	34.8 (16.3)	33.2 (13.7)	33.4 (15.0)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

= difference from control significant at P = .10 level.

~ = from center of horizon; depth variable.

Table 21. Water content† at .1 bar soil water potential of major horizons in soils forming in quartzite dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm	% by wt		
B2ir	15	50.9 (18.3)	38.6# (25.6)	38.6# (23.1)
IIA2	30	24.1 (3.8)	30.4 (5.6)	22.2 (2.7)
IIA2	45	29.1 (14.2)	28.7 (8.3)	28.2 (8.8)
IIA+B	~	29.4 (9.9)	32.2 (7.1)	24.7 (4.3)
IIC	~	27.6 (10.2)	28.8 (11.3)	26.2 (8.1)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

= difference from control significant at P = .10 level.

~ = from center of horizon; depth variable.

Table 22. Water content[†] at .33 bars soil water potential of major horizons in soils forming in quartzite dominated glacial till.

Horizon	Depth	Control	Moderate	Severe
	cm		% by wt	
B2ir	15	47.8 (17.4)	33.4[#] (23.6)	30.9[*] (23.6)
IIA2	30	22.9 (4.0)	28.8 (5.8)	20.2 (3.3)
IIA2	45	26.9 (12.7)	26.8 (8.0)	25.9 (7.3)
IIA+B	˜	28.0 (9.4)	29.0 (6.2)	23.5 (4.1)
IIC	˜	25.7 (9.2)	26.3 (10.0)	24.2 (7.1)

† Data are percent water by weight. Numbers in parentheses are standard deviations.

\# = difference from control significant at P = .10 level.

* = difference from control significant at P = .05 level.

˜ = from center of horizon; depth variable.

soil water retention were observed in these horizons. Overall, no significant changes in soil water retention were detected in the quartzite till subsoils.

Mean water content for the three soil water potentials was reduced with both moderate and severe treatment in every horizon of soils located on Tertiary Volcanic sites. However, significant reductions were observed only in the B22t horizon at 45 cm in the profile. These reductions were detected in both moderate and severe treatment areas at all three soil water potentials.

Hydraulic Conductivity

Statistical analysis of hydraulic conductivity determinations was not feasible due to a number of factors.

Coarse fragment content of the glacial till samples prevented the usual method of sample collection with a core sampler.

No flow occurred through clayey samples from Tertiary Volcanic sites at any time during the 2 week trial. Poor cohesion caused loess cap samples from the limestone and quartzite till sample sites to collapse or wash out resulting in highly variable data.

In some cases, no results were obtained. The paraffin wax used to seal the samples often penetrated the sample, making results unreliable. In the laboratory, coarse fragments often occupied critical points of flow. Coarse fragments located at the point of inflow or outflow effectively plugged flow through the sample. In all cases, an accurate determination of the cross sectional area was not possible because of the irregular shape of the sample peds. Determinations of the hydraulic gradient within the samples were confounded by convergent and divergent flow within the irregular shaped peds. The sum amount of variability encountered with these problems prevented analysis of the effect of treatment on hydraulic conductivity of soil samples collected at the study sites.

DISCUSSION OF COMPACTION STUDY

Within a given parent material, climatic region, and time period, an equilibrium is eventually established between the microclimate, vegetation and soil conditions. This concept is a premise upon which much work in soil science is based (Jenny, 1941). Recent work (Billings, 1977; Munn, 1978; Pfister et al., 1978) attempts to verify aspects of this plant-soil-microclimate interrelationship in the forest ecosystems of the northwest. Since these factors are at equilibrium with one another, any change which alters the equilibrium will result in a change of the factors that make up the equilibrium. For example, a significant change in soil conditions will precipitate a shift in the vegetation growing on the site. The new vegetation, in turn, will alter the microclimate of the site and eventually a new equilibrium will be established between the soil, vegetation and microclimate. In this study, the soil changes under investigation are those caused by the impact of timber harvesting equipment. This study does not attempt to ascertain whether or not these changes affect timber production. It is simply an attempt to detect the possible presence and magnitude of changes in soil physical properties. If changes have occurred, then evidence is present to support the premise that the vegetation has been altered to maintain the soil-plant-microclimate equilibrium.

Infiltration

Data analysis shows that infiltration was significantly reduced on all three parent material sites in the severe treatment areas. Infiltration rates were also significantly reduced in the moderate treatment areas of the limestone and quartzite till sites. No significant differences could be attributed to parent material.

Infiltration is an important link in the hydrologic cycle. The infiltration reductions observed imply that other soil physical and hydrologic properties have been altered.

Soil Water Retention

Soil water retention at .02, .10, and .33 bars was significantly reduced in the B2ir (loess cap) horizon on the moderate and severe treatment areas of the limestone and quartzite till sites. No significant changes occurred in the surface horizon on Tertiary Volcanic sites and, with one exception, no significant changes with treatment occurred in any of the subsoils involved in the study. Significant reductions were observed in the B22t (45 cm) horizon of the Tertiary Volcanic sites. However, a large amount of variability must be associated with a water related measurement in a soil of high clay content and differing mineralogy. This places the significance of these reductions in question.

Soil moisture retention at low absolute soil water potential (less than 2-3 bars) is closely related to pore size distribution. When a compactive effort is exerted on an undisturbed soil, the soil aggregates are forced together reducing the size of the macropores. The size of pore which will hold water at a given soil water potential can be calculated by the equation

$$h = \frac{2\sigma\cos\theta}{\rho g r} \qquad (1),$$

where h = soil water potential in cm of water, σ = surface tension of water, θ = wetting angle, ρ = density of water, g = acceleration due to gravity, and r = radius of pore (Baver, 1972). Thus, when water content at a given soil water potential is reduced, it is an indication that the volume of pores that hold water at that soil water potential has been reduced. In other words, macropores have been reduced in size.

Hsiao et al. (1976) list twelve plant physiological processes and parameters detrimentally affected by water stress. One of the most sensitive is growth by cell enlargement. When a plant is stressed by a water deficit, the following general sequence of events takes place. As soil water content declines, the absolute soil water potential increases. In order to extract water from the soil, the plant root must develop a greater absolute water potential. In order for water to move throughout the plant, each successive point along its path must have a greater absolute water potential. As the plant water potential is increased, the osmotic and matric potential must be increased in order to maintain cell turgor. This is accomplished by cell dehydration and migration of solutes to the affected cells. Both of these processes take place at the expense of other vital processes within the plant. Hsaio (1976) states that ". . . plants subjected to mild water stress may exhibit significant reduction in growth while turgor pressure is apparently maintained."

Rosenthal et al., (1977) demonstrated that significant reductions in corn yield were apparent when 40% of the available water was depleted.

Available Water Holding Capacity

Based on the soil water retention data, no changes in available water holding capacity could be calculated for the surface horizon on the Tertiary Volcanic sites. This is an apparent indication that the frequency of relatively large pores in the undisturbed soil is low. Reductions in the amount of water held at .33 bars occurred but were not statistically significant.

Table 23 shows the available water (percent by weight) in the three treatments on the B2ir (loess cap) horizon of the glacial till sites. A 45% reduction in the moderate treatment areas and a 53% reduction in the severe treatment areas occurred on the quartzite till. A 26% reduction in the moderate treatment areas and a 34%

Table 23. Available water[†] in the loess cap of three treatments on quartzite and limestone glacial till sites.

	Control	Moderate	Severe
B2ir-15cm Quartzite till sites	32.2	17.8 (45%)	15.3 (53%)
B2ir-15 cm Limestone till sites	59.2	43.8 (26%)	39.1 (34%)

[†] Data are percent water by weight. Percent reduction from control appear in parentheses.

reduction in the severe treatment areas occurred in the limestone till. The profile descriptions in Appendices 2 to 4 show that most roots were found in the B2ir horizon. Thus, a substantial loss of water available for plant uptake has occurred.

After a soil is saturated, water is gradually redistributed downward through the profile. The study data show that the infiltration capacity and water holding capacity have been significantly reduced in the glacial till sites. Since the water table at these sites is at great depth, only rainfall and snowmelt is available to replenish soil profile moisture. The evidence suggests that subsoil moisture replenishment is limited by compaction of the surface horizon.

Bulk Density

Significant increases in bulk density occurred with treatment in the surface horizons of soils on all three parent materials. Bulk density increases were detected at the 15 cm depth in the Tertiary Volcanic sites and at the 5 cm and 15 cm depth in the limestone and quartzite dominated glacial till sites. Increases were significant only on severe treatment areas in the surface horizon of the Tertiary Volcanic sites. Both moderate and severe treatment areas showed significant increases of bulk density in the B2ir (loess cap) horizon on the till sites.

As shown in the literature review, an increase in bulk density is normally associated with an increase in shear strength. Thus, a plant-soil-microclimatic system must adjust to new soil conditions encountered in the form of increased soil bulk density (and a consequent increase in the shear strength). Root systems are less easily able to penetrate the denser, stronger soil. Research has shown that the greater the bulk density, the less total root weight will be present (Zimmerman and Kardos, 1961; Hopkins and Patrick, 1969; Rickman et al., 1966).

Field profile descriptions (Appendices 2 to 4) show that most root growth is in the surface horizons of the three sites. The subsoil is dense before disturbance and apparently limiting to root growth below the surface horizon. The increases in surface horizon bulk density may be adding an additional restriction to an already limited root growth environment.

Much higher surface horizon bulk densities were observed in the treatment area of the Tertiary Volcanic sites than those of the limestone and quartzite glacial till sites. Surface horizon samples from the Tertiary Volcanic sites generally have lower silt content, higher clay content and a greater amount of crystalline clays. A higher shear strength would be expected in the Tertiary Volcanic surface horizons than in its northwestern Montana analog and bulk densities of the Tertiary Volcanic surface horizon may be more limiting to plant growth than those of the loess caps on the limestone and quartzite till sites.

In three cases, bulk densities in the IIA2 horizon at the glacial till sites decreased with treatment. These differences occurred at the lowest level of statistical confidence used in a highly variable till. The magnitude of bulk density change from the control was greatest in the moderate treatment areas and lowest in the severe treatment areas in the IIA2 (30 cm) horizon on the quartzite glacial till sites. The opposite was true on the limestone till sites. This may be indicative of the variability present in glacial till. Because of the low statistical confidence in these trends and high variability of the till, the authors question their validity.

In a similar study on the same types of glacial till soils, Kuennen et al. (1979) found only small increases (less than 5%) in subsoil bulk densities with a more sensitive statistical test (paired t) and a larger sample size. Their result indicates ". . . less possibility of subsoil drainage due to compaction." This is consistent with the results of this study.

Porosity

Porosity is inversely related to bulk density. Therefore, in the surface horizons of the three parent materials, significant reductions in porosity parallel the bulk density increases.

Baver (1972) states that Hannen and Buckingham showed that the sum of the cross-sectional areas of the effective pore volume is the most important factor affecting gas diffusion in soils. In addition, Buckingham showed that the rate of diffusion is reduced one-fourth when the free pore space is reduced one-half. In the study soils, this means that the ability of gases such as CO_2 and O_2 to move freely in and out of the soil has been substantially reduced. For example, the bulk density in the B2ir (15 cm) horizon of the limestone till sites increased 43% in the severe treatment areas. This is equivalent to a 19% reduction in pore space. If it is assumed that all of the pores are free pore space, a 34% reduction in diffusion rate may have occurred. The assumption is not completely valid, but the example is given to illustrate the effect that a porosity reduction has on the movement of gas through a soil. In actuality, the aeration situation is further complicated by a reduction in soil pore number and size, as demonstrated by the soil water retention data. As the soil dries out, water is held more tenaciously in the smaller pores by the relationship described in equation (1), and the air-filled pore space is reduced. A reduction in gaseous diffusion results.

Time

No statistically significant differences attributable to age of harvest unit were found in infiltration, soil water retention or bulk density. In other words, the effects of soil compaction were not ameliorated over the range of time investigated. Present timber management policies dictate a rotation schedule of about 120 years (Bigler, 1980) for a commercial stand of timber. If future research shows that the soil physical changes documented in this study inhibit timber productivity, this inhibition will have existed for at least one-tenth of the rotation period.

The possibility for extracting a biased sample exists in this analysis. It is possible that areas that would, at one time, have been identified as severely disturbed are now being identified as moderately disturbed.

Reliability of Data

The study soils are highly variable systems difficult to sample and analyze for chemical and physical determinations. Differences due to treatment effect were especially difficult to detect in the subsoils. Variability encountered in the study is attributed to the following:

1) amorphous character of surface deposits at all three study sites.

2) variable clay content and mineralogy in the Tertiary Volcanic soils.

3) possible differential glacial compaction of till sites.

4) subtle changes in parent material which occur in glaciated areas (different till types, outwash, fluvial deposits, etc.).

5) lack of profile homogeneity due to tree windthrow history, wild animal activity, cattle grazing history, etc.

6) lack of knowledge of logging history such as type of machinery used, type of harvest (clear cut, shelterwood cut, commercial thinning, etc.), soil moisture conditions at time of harvest and number of vehicular passes at each sample site.

Three separate analyses showed definite trends in the results and the authors feel that these trends reflect field conditions accurately. Ongoing studies using more sensitive techniques may be able to detect more subtle changes in soil physical properties. However, it is likely that their conclusions concerning the relative magnitude and importance of changes throughout the profile will verify and support this study.

SUMMARY AND CONCLUSION

This research characterized forest soils forming in three parent materials: Tertiary Volcanics, limestone glacial till, quartzite dominated glacial till. In addition, field and laboratory data show that the physical properties of these soils have been significantly altered by the impacts of harvesting machinery. The literature review and discussion show that the physical changes observed are normally associated with soil conditions inhibiting to optimum plant growth and productivity.

Sites with a loess cap of strong amorphous character were found in Flathead and Kootenai National Forests of northwest Montana. Amorphous character was not expressed in the surface horizon on sites located in the Tertiary Volcanics of the Bitterroot National Forest.

Soils involved in the study can generally be arranged into two groupings. The first group is composed of soils in the Bitterroot National Forest which are forming in Tertiary Volcanic parent material. The typical soil profile has a 15 to 30 cm loamy surface horizon overlying clay rich sediments. Clay content in the subsoil typically ranged from 20 to 67 percent with clay content above 45 percent being most common. The more permeable surface horizon has a lower bulk density (1.3 g/cm^3) than the less permeable clay subsoil (1.66 g/cm^3). Along with clay content, exchangeable cations, base saturation and cation exchange capacity increase with depth in the Tertiary Volcanic profile. Soils in this group are Boralfs.

The second group of soils is composed of those forming in glacial till deposits in the Flathead and Kootenai National Forests of Northwestern Montana. These soils are overlain by a loess cap of strong amorphous character. A lithologic discontinuity exists between the highly permeable, low density (.53-.75 g/cm^3) loess cap and the underlying less permeable, denser (1.45-1.76 g/cm^3) glacial till subsoils. Textures throughout the profile are predominantly silt loam. Within the profile, highest organic matter content, lowest pH, and the highest CEC were found in the B2ir (loess cap) horizon. Although cation exchange capacities in the till subsoils are less than half of those found in the surface horizon, base saturation and exchangeable calcium and magnesium are higher in the till subsoils. Exchangeable sodium and potassium levels are lower in the till sequum than in the surface horizon. Soils in this group consist of Alfisols and Inceptisols.

Three independent measurements show that significant changes in the physical properties of the study soils have taken place. In the three parent materials, infiltration rates were changed as follows:

1) Tertiary Volcanics

   - 87% reduction in severe treatment areas,

2) Limestone dominated glacial till

   - 78% reduction in moderate treatment areas,

   - 81 % reduction in severe treatment areas,

3) Quartzite dominated glacial till

- 75% reduction in moderate treatment areas,

- 79% reduction in severe treatment areas,

4) No significant infiltration changes were found due to parent material differences.

Bulk densities in the surface horizons of the three parent materials were changed as follows:

1) Tertiary Volcanics

- 18% increase in moderate treatment areas,

- 21% increase in severe treatment areas,

2) Limestone dominated glacial till (5 cm)

- 38% increase in moderate treatment areas,

- 59% increase in severe treatment areas,

Limestone dominated glacial till (15 cm)

- 83% increase in moderate treatment areas,

- 76% increase in severe treatment areas,

3) Quartzite dominated glacial till (5 cm)

- 3% increase in moderate treatment areas,

- 58% increase in severe treatment areas,

Quartzite dominated glacial till (15 cm)

- 16% increase in moderate treatment areas,

- 21% increase in severe treatment areas.

4) Statistically significant decreases in the subsoil bulk densities of the IIA2 horizon in the moderately treated quartzite till

study areas and in the severe treatment on the limestone till sites were found. These occurred at the lowest (P = .10) level of statistical confidence employed. Because of the variable nature of the glacial till and because the changes fit no trend in the data, the authors question the validity of these decreases.

Significant reductions in soil water retention were found at three soil water potentials (.02, .10, .33 bars) in the loess cap horizon of the limestone and quartzite dominated glacial till sites. Significant reductions were also found in the B22t (45 cm) horizon at the Tertiary Volcanic sites. This change was not a part of any trend in the data and is interpreted by the authors to be a function of the high variability encountered when doing a water related analysis on high clay samples of differing clay mineralogy. Changes in available water holding capacity of the surface horizons are summarized as follows:

1) Tertiary Volcanics

- no significant changes detected,

2) Limestone dominated glacial till

- 25% reduction in moderate treatment areas,
- 24% reduction in severe treatment areas,

3) Quartzite dominated glacial till

- 45% reduction in moderate treatment areas,
- 52% reduction in severe treatment areas.

Although there have been no physical manifestations of compaction in the study site subsoils, authors feel that these already dense subsoils have had soil air and water supply appreciably reduced by the compaction of the surface layer. Thus, the effects of the compaction process are expressed throughout the soil profile.

The subsites (ranging from 3 to 17 years since harvest) were categorized as "young," "medium," and "old." No significant changes attributable to age grouping were detected in infiltration, soil water retention or bulk density. The effects of soil compaction were not ameliorated over the range of time investigated.

RECOMMENDATIONS

1) Further study is needed in the following areas:

- To determine if and how much sediment is being transported away from timber harvesting units due to reduced infiltration capacities and increased runoff.
- To determine the local species' growth pattern and response to increasing bulk densities.
- To determine the local species' growth pattern and response to water stress.
- To determine the local species' growth pattern and response to deficiencies in aeration.
- To determine areal extent and severity of disturbance in a typical harvest unit.
- To determine the feasibility of establishing alternative successional plant species (e.g., *Alnus sinuata*) which may be able to penetrate dense subsoils and subsequently aid in the amelioration of compaction.

2) Development of alternative plans for harvesting timber from compactible soils such as those involved in this study is needed. Such planning might include alternative logging systems, dedication of land to be set aside for use by timber harvest vehicles only, use of silvicultural practices after harvest to prepare the sites for new timber stands (ripping, etc.), lengthening of rotation schedules.

LITERATURE CITED

Alderfer, R. B., and F. G. Merkle. 1941. Structural stability and permeability of native forest soils compared with cultivated areas of the same soil type. Soil Sci. Soc. Am. Proc. 6:98-103.

______________, and R. R. Robinson. 1947. Runoff from pastures in relation to grazing intensity and soil compaction. J. Am. Soc. Agron. 39:948-958.

Alexander, M. 1977. Soil Microbiology, 2nd edition. John Wiley and Sons, Inc. 472 p.

Allison, L. E. 1965. Organic carbon. In C. A. Black et al., (eds) Methods of soil analysis. Part 2. Agronomy 9:1367-1369. Am. Soc. of Agron., Madison, Wis.

______________, and C. D. Moodie. 1965. Carbonate acid neutralization method. In C. A. Black et al., (eds) Methods of soil analysis. Part 2. Agronomy 9:1387-1388. Am. Soc. of Agron., Madison, Wis.

ASTM. 1979a. Moisture-density relations of soils using 5.5 lb (2.5 kg) rammer and 12 in (304.8 mm) drop, method C. In 1979 Annual book of the American Society of Testing and Materials Standards 19:D698.

____. 1979b. Standard method for particle size analysis of soils. In 1979 Annual book of the American Society of Testing and Materials Standards 19:D422.

____. 1979c. Standard method for plastic limit and plasticity index of soils. In 1979 Annual book of the American Society of Testing and Materials Standards 26:D424.

____. 1979d. Standard method of sampling coke for analysis. In 1979 Annual book of the American Society of Testing and Materials Standards 26:D346.

____. 1979e. Standard method of test for liquid limit of soils. In 1979 Annual book of the American Society of Testing and Materials Standards 19:D423.

Baker, K. F., and R. J. Cook. 1974. Biological control of plant pathogens. W. H. Freeman and Co.

Baver, L. D., W. H. Gardner, and W. R. Gardner. 1972. Soil physics. 4th ed. John Wiley and Sons, Inc., New York. 498 p.

Bertrand, A. R., and H. Kohnke. 1957. Subsoil conditions and their effects on oxygen supply and growth of corn roots. Soil Sci. Soc. of Am. Proc. 21:135-140.

Bigler, B. 1980. Silviculturist, Bitterroot National Forest. Personal communication.

Billings, R. F. 1977. Soils and associated ecosystems of southeast Alaska. In-service publication. Tongass National Forest. U.S. Forest Service. 250 p.

Blake, G. R. 1965. Particle density. In C. A. Black et al., (eds) Methods of soil analysis. Part 1. Agronomy 9:371-373. Am. Soc. of Agron., Madison, Wis.

Brady, N. C. 1974. The nature and properties of soils. 8th edition. MacMillan Publishing Company, Inc. 639 p.

Brown, K. W. 1977. Shrinking and swelling of clay, clay strength, and other properties of clay soils and clays. In Minerals in soil environments. Soil Sci. Soc. of Am. 948 p.

Chapman, H. D. 1965a. Cation-exchange capacity by sodium saturation. In C. A. Black et al., (eds) Methods of soil analysis. Part 2. Agronomy 9:899-901. Am. Soc. of Agron., Madison, Wis.

____________. 1965b. Total exchangeable bases. In C. A. Black et al., (eds) Methods of soil analysis. Part 2. Agronomy 9:902-904. Am. Soc. of Agron., Madison, Wis.

Day, P. R. 1965. Hydrometer method of particle-size analysis. In C. A. Black et al., (eds) Methods of soil analysis. Part 1. Agronomy 9:562-567. Am. Soc. of Agron., Madison, Wis.

Decker, G. L. 1972. Automatic retrieval and analysis of soil characterization data. Ph.D. thesis. Montana State Univ., Bozeman.

Felt, E. J. 1965. Compactibility. In C. A. Black et al., (eds) Methods of soil analysis. Part 1. Agronomy 9:400-412. Am. Soc. of Agron., Madison, Wis.

Forristall, F. F., and S. P. Gessel. 1955. Soil properties related to forest cover type and productivity on the Lee Forest, Snohomish County, Washington. Soil Sci. Soc. Am. Proc. 19:384-389.

Free, G. R., John, Jr., Lamb, and E. A. Carleton. 1947. Compactibility of certain soils as related to organic matter and erosion. J. Am. Soc. Agron. 39:1068-1076.

Gingrich, J. R., and M. B. Russell. 1956. Effect of soil moisture tension and oxygen concentration on the growth of corn roots. Agron. J. 48:517-520.

Grim, R. E. 1962. Applied clay mineralogy. McGraw-Hill Book Company. 422 p.

Hatchell, G. E., C. W. Ralston, R. R. Foil. 1970. Soil disturbances in logging. J. of For. 68:772-775.

Hills, R. C. 1971. The influence of land management and soil characteristics on infiltration and the occurrence of overland flow. J. of Hydrology. 13:163-181.

Hopkins, R. M., and W. H., Patrick, Jr. 1969. Combined effect of oxygen content and soil compaction on root penetration. Soil Sci. 108:408-413.

Howard, R. F., K. Trott, and M. J. Singer. 1979. Final report to the United States Forest Service - soil compaction and relative erodibility studies. 50 p.

Hsiao, T. C., E. Acevedo, E. Fereres, and D. W. Henderson. 1976. Stress metabolism- water stress, growth, and osmotic adjustment. Phil. Trans. R. Soc. Lond. B. 273:479-500.

Huberty, M. R. 1944. Compaction in cultivated soils. Transactions of the American Geophysical Union. 25:896-899.

Hyder, D. N., and F. A. Sneva. 1956. Seed- and plant-soil relations as affected by seedbed firmness on a sandy loam range land soil. Soil Sci. Soc. Am. Proc. 20:416-419.

Jennrich, R., and P. Sampson. 1979. Analysis of variance and covariance including repeated measures. p. 540-580. In W. J. Dixon and M. B. Brown (ed.) Biomedical computer programs, P-series. Univ. of California Press, Los Angeles.

Jenny, H. 1941. Factors of soil formation. McGraw-Hill Book Company. 281 p.

Johnson, A. J. 1963. A field method for measurement of infiltration. Geological survey water-supply paper 1544-F. U. S. Dept. of the Interior. Geologic Survey.

Klages, M. G. 1980. Personal communication. Montana State Univ., Bozeman.

Klute, A. 1972. Laboratory measurement of hydraulic conductivity of saturated soil. In C. A. Black et al., (eds) Methods of soil analysis. Part 1. Agronomy 9:210-221. Am. Soc. of Agron., Madison, Wis.

Krynine, D. P. 1951. Some comments on earth compaction. National Resource Council Highway Research Board bulletin. 42:14-20.

Kuennen, L., G. Edson, and T. V. Tolle. 1979. Soil compaction due to timber harvest activities. In-service publ. USDA Forest Service, Northern Region. 6 p.

Langston, R. B., P. D. Trask, and P. A. Pask. 1958. Effect of mineral composition on strength of central California sediments. Calif. JJ. Mines Geol. 54:215-235.

Li, C. Y. 1956. Basic concepts on the compaction of soil. Proceedings of the American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division. Paper 862. 82:1-20.

Lull, H. W. 1959. Soil compaction on forest and range lands. U. S. Dept. of Agric. Forest Service. Misc. Pub. No. 768. 33 p.

Mace, A. C., Jr., T. Williams, and J. C. Trappeiner. 1971. Effect of winter harvesting methods on soil bulk density and infiltration rates. Minn. Forest. Res. Note. No. 228.

Mattson, W. J., and N. D. Addy. 1975. Phytophagus insects as regulators of forest primary production. Science 190:515-520.

Means, R. E., and J. V. Parcher. 1963. Physical properties of soils. Charles E. Merrill Books, Inc. Columbus, Ohio. 464 p.

Minore, D., C. E. Smith, and R. F. Woolward. 1969. Effects of high soil density on seedling growth of seven northwestern tree species. PNW Forest and Range Exp. Sta. Res. Note, PNW-112. 6 p.

Mitchell, D. J., and J. E. Mitchell. 1973. Oxygen and carbon dioxide concentration effects on the growth and reproduction of Aphanomyces enteiches and certain other soil-borne plant pathogens. Phytopath. 63:1053-1059.

Munn, L. C., G. A. Nielsen, and W. F. Mueggler. 1978. Relationships of soils to mountain and foothill range habitat types and production in western Montana. Soil Sci. Soc. Amer. Proc. 42:135-139.

Ottersberg, R. J. 1977. Amorphous character in twenty western Montana forest soils with apparent eolian influence. M.S. thesis. Montana State Univ., Bozeman.

Peach, M. 1965. Exchange acidity. In C. A. Black et al., (eds) Methods of soil analysis. Part 2. Agronomy 9:905-907. Am. Soc. of Agron., Madison, Wis.

Pfister, R. D., B. L. Kovalchik, S. F. Arno, and R. C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service General Tech. Rpt., INT-34. 174 p.

Raney, W. A., T. W. Edminster, and W. H. Allaway. 1955. Current status of research in soil compaction. Soil Sci. Soc. of Am. Proc. 19:423-428.

Rashid, S., and K. H. Sheikh. 1977. Response of wheat to different levels of soil compactions. Phyton (Austria) 18(1-2):43-56.

Richards, L. A. 1972. Physical condition of water in soil. In C. A. Black et al., (eds) Methods of soil analysis. Part 1. Agronomy 9:210-221. Am. Soc. of Agron., Madison, Wis.

Rickman, R. W. 1966. Plant responses to oxygen supply and root resistance. Soil Sci. Soc. Am. Proc. 30:304-307.

Rosenthal, W. D., E. T. Kanemasu, R. J. Raney, and L. R. Stone. 1977. Evaluation of an evapotranspiration model for corn. Agron. J. 69:461-464.

Russell, E. W. 1973. Soil conditions and plant growth. William Clowes and Sons, Ltd., London.

Schroeder, W. L. 1975. Soils in construction. John Wiley and Sons, Inc. 242 p.

Sims, J. R., and V. A. Haby. 1971. Simplified colorimetric determination of soil organic matter. Soil Sci. 112:137-141.

Snedecor, G. W., and W. G. Cochran. 1973. Statistical methods. Iowa State Univ. Press., Ames, Iowa. 593 p.

Soil Conservation Service. 1967. Soil survey laboratory methods and procedures for collecting soil samples. U.S. Dept. of Agric. 50 p.

Soil Survey Staff. 1975. Soil Taxonomy. Agric. Handbook No. 436. U.S. Dept. of Agric. Soil Conserv. Service. 754 p.

Steinbrenner, E. C. 1955. The effect of repeated tractor trips on the physical properties of forest soils. Northwest Sci. 29:4:155-159.

___________________, and S. P. Gessel. 1955. The effect of tractor logging on physical properties of some forest soils in southwestern Washington. Soil Sci. Soc. Am. Proc. 19:372-376.

Tackle, D. 1962. Infiltration in a western Larch-Douglas-Fir stand following cutting and slash treatment. USDA Forest Service. Intermountain Forest and Range Exp. Sta. Res. No. 89.

Taylor, H. M., and H. R. Gardner. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of soil. Soil Sci. 96:153-156.

_____________, G. M. Roberson, and J. J., Jr., Parker. 1966. Soil strength-root penetration relations for medium- to coarse-textured soil materials. Soil Sci. 102:1:18-22.

Taylor, S. A., and G. L. Ashcroft. 1972. Physical edaphology: the physics of irrigated and nonirrigated soils. W. H. Freeman and Company. 533 p.

Thiesen, A. A., and M. E. Harward. 1962. A paste method for preparation of slides for clay mineral identification by x-ray diffraction. Soil Sci. Soc. Am. Proc. 26:90-91.

Trask, P. D. 1959. Effect of grain size on strength of mixtures of clay, sand and water. Bulletin of the Geologic Soc. of Amer. 70:569-580.

__________, and J. E. H. Close. 1958. Effect of day content on strength of soils. Conf. on Coastal Eng., Proc. Sixth (Gainesville, Fla.). p. 827-843.

Trimble, G. R., Jr., and Sidney Weitzman. 1953. Soil erosion on logging roads. Soil Sci. Soc. Am. Proc. 17:152-154.

Trouse, A. C., Jr., and R. P. Humbert. 1961. Some effects of soil compaction on the development of sugar cane roots. Soil Sci. 91:208-217.

Veihmeyer, F. J., and A. H. Hendrickson. 1948. Soil density and root penetration. Soil Sci. 65:487-493.

Whittig, L. D. 1965. X-ray diffraction techniques for mineral identification and mineralogical composition. In C. A. Black et al., (eds) Methods of soil analysis. Part 1. Agronomy. 9:671-698. Am. Soc. of Agron., Madison, Wis.

Zimmerman, R. P., and L. T. Kardos. 1961. Effect of bulk density on root growth. Soil Sci. 91:280-288.

APPENDICES

APPENDIX I

SOIL PEDON CODING SCHEME

Each pedon is identified by a four-symbol code. The first symbol identifies the national forest that the pedon is located in. This is followed by a number designating the subsite, then by the letter A or B designating the replication, and finally by the letter C, M or S designating the degree of trafficking (treatment) to which the pedon was exposed.

<u>Forest Code (first symbol)</u>

B = Bitterroot National Forest

F = Flathead National Forest

K = Kootenai National Forest

<u>Subsite Code (second symbol)</u>

1 = subsite 1

2 = subsite 2

3 = subsite 3

<u>Replication Code (third symbol)</u>

A = replication A

B = replication B

<u>Treatment Code (fourth symbol)</u>

C = control

M = moderate amount of disturbance

S = severe amount of disturbance

APPENDIX II

SOIL PROFILE DESCRIPTIONS

FOR PEDONS FORMING IN TERTIARY VOLCANIC PARENT MATERIAL

B1AC

CLASSIFICATION: fine, montmorillonitic, frigid Eutric Glossoboralf
DATE DESCRIBED: 8-1-79
LOCATION: Bitterroot Nat. For., site 1, control, first replication; NW¼, Sec. 17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/LIBO/SYAL
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 9% East to Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01	4-0 cm
A2	0-29 cm Gray-light brownish gray (2.5Y 6/1) silt loam, brown-dark brown (10YR 4/3) moist; weak medium subangular blocky; slightly hard-hard, firm, slightly sticky, nonplastic; few fine, medium & coarse roots; slightly acid (6.3 pH); abrupt-smooth boundary.
B21t	29-102 cm Olive brown (2.5Y 4/6) silty clay loam, brownish yellow (10YR 6/6) moist, strong medium prismatic and columnar; very firm, sticky, plastic; many thick clay films on face of peds and lining pores; few fine medium and coarse roots; medium acid (6.0 pH); gradual, irregular boundary.
B22t	102-123 cm Pale yellow (2.5Y 7/4) clay loam, pink-reddish yellow (7.5YR 7/6) moist; angular blocky; very firm, sticky to very sticky, slightly plastic; common thin clay films on faces of peds; few fine, medium and coarse roots; neutral (7.0 pH).

B1BC

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-3-79
LOCATION: Bitterroot Nat. For., site 1; control, second replication; NW¼, Sec.17, T.1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/LIBO/SYAL
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 10% East
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 5-0 cm

A21 0-17 cm Light brownish gray (10YR 6/2) loam, dark brown (10YR 3/3) moist; weak fine angular blocky structure; soft, very friable, slightly sticky, slightly plastic; many fine, common medium, few coarse roots; medium acidity (6.0 pH); clear smooth boundary.

A22 17-29 cm Pinkish gray-pink (7.5Y 7/3) sandy clay loam; weak fine angular blocky; soft, very friable, slightly sticky, slightly plastic; common fine roots; strongly acidic (5.5 pH); clear wavy boundary.

B21t 29-52 cm Yellowish brown (10YR 5/8) moist silty clay loam; moderate medium columnar prismatic breaking to angular blocky structure; firm, sticky, plastic; common moderately thick clay films on faces of peds; few fine roots; strongly acidic (5.5 pH); clear smooth boundary.

B22t 52-102 cm Strong brown (7.5 YR 5/6) moist clay loam; many yellowish red (5YR 5/8) mottles; strong medium angular blocky structure; firm, sticky, slightly plastic; continuous moderately thick clay films on faces of peds; few fine roots; strongly acidic (5.5 pH); clear wavy boundary.

B3 102-150 cm Yellowish red (5YR 5/6) moist clay loam; many yellowish red (5YR 5/8) mottles; moderate medium angular blocky structure; firm, slightly sticky, slightly plastic, common moderately thick clay films on face of peds and lining pores; few fine roots; slightly acidic (6.5 pH).

B1AM

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-2-79
LOCATION: Bitterroot Nat. For., site 1; moderate disturbance, first replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/SYAL/CARV
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 9% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 5-0 cm

A2 0-15 cm Light brownish grey (10YR 6/2) silty clay loam, brown (10YR 4/3) moist; moderate fine subangular blocky breaking to platy structure; hard, firm, slightly sticky, slightly plastic; common fine, few medium roots; strongly acid (pH 5.5); clear smooth boundary.

B21t 15-41 cm Light brownish grey (10YR 6/2) silty clay; dark brown (7.5YR 4/3) moist; strong coarse columnar structure; very firm, sticky, slightly plastic; common moderately thick clay films line pores; few fine roots; medium acid (pH 6.0); clear wavy boundary.

B22t 41-93 cm Silty clay, brown (7.5YR 4/3) moist; strong medium subangular blocky structure; firm, sticky, plastic; many moderately thick clay films on face of peds; few fine roots; medium acid (pH 6.0); clear wavy boundary.

B31 93-133 cm Silty clay loam, yellowish red (5YR 4/6) moist; strong medium subangular blocky structure; friable, very sticky, plastic; many thick clay films on face of peds and lining pores; few fine roots; moderately alkaline (pH 8.0); abrupt smooth boundary.

B32 133-150 cm Silty clay loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; soft, very friable, slightly sticky, slightly plastic; common clay films on faces of peds; few fine roots; moderately alkaline (pH 8.0).

B1BM

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-4-79
LOCATION: Bitterroot Nat. For., site 1, moderate disturbance, second replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/SYAL/CARU
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 10% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 5-0 cm

A2 0-15 cm Light grey (10YR 7/2) silty clay loam, very dark greyish brown (10YR 3/2) moist; moderate medium subangular blocky breaking to platy structure; slightly hard, friable, sticky, slightly plastic; common fine, few coarse roots; medium acid (pH 6.0); clear wavy boundary.

B21t 15-36 cm Silty clay, dark yellowish brown (10YR 4/4) moist; strong coarse columnar structure; firm, very sticky, very plastic; many moderately thick clay films on face of peds; few fine roots; very strongly acid (pH 4.5); clear wavy boundary.

B22t 36-78 cm Silty clay, dark brown (7.5YR 4/3) moist; strong coarse subangular blocky structure; firm, very sticky, very plastic; continuous thick clay films on face of peds; few fine roots; neutral acid (pH 7.0); clear wavy boundary.

B23t 78-112 cm Silty clay, brown (7.5YR 5/4) moist; moderate coarse angular and subangular blocky structure; friable, very sticky, very plastic; many moderately thick clay films on face of peds and lining pores; few fine roots; moderately alkaline (pH 8.0); clear smooth boundary.

B24t 112-164 cm Silty clay loam, brown (7.5YR 5/3) moist; many yellowish red (5YR 5/8) mottles; moderate medium subangular blocky structure; slightly hard, very firm, sticky, plastic; many medium clay films on face of peds and line pores; few fine roots; moderately alkaline (pH 8.0).

B1AS

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-2-79
LOCATION: Bitterroot Nat. For., site 1, severe disturbance, first replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/SYAL/CARU
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 6% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 5-0 cm

A2 0-15 cm White (10YR 8/2) silty clay loam, brown (7.5YR 2/2) moist; moderate medium platy structure; extremely hard, firm, slightly sticky, slightly plastic; few fine roots; strongly acid (5.5 pH); gradual irregular boundary.

B21t 15-36 cm Clay loam, light olive brown (2.5Y 5/4) moist; moderate medium columnar structure; very firm, sticky, plastic; many moderately thick clay films on ped faces; few fine roots; medium acid (6.0 pH); gradual irregular boundary.

B22t 36-90 cm Silty clay, light olive brown (2.5Y 5/4) moist; strong coarse angular blocky structure; friable, sticky, slightly plastic; many thick clay films on faces of peds; few fine roots; neutral (7.0 pH); clear wavy boundary.

B3 90-140 cm Silty clay, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, sticky, plastic; common moderately thick clay films line pores; few fine roots; moderately alkaline (8.0 pH).

B1BS

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-3-79
LOCATION: Bitterroot Nat. For., site 1, severe disturbance, second replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/SYAL/CARU
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 5.5% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

O1 2-0 cm

A2 0-41 cm Pinkish white (5YR 8/2), silty clay loam, brown to dark brown (7.5YR 4/4) moist; weak moderate subangular blocky breaking to platy structure; slightly hard, firm, slightly sticky, slightly plastic; common fine, few medium roots; strongly acid (pH 5.3); clear smooth boundary.

B21t 41-58 cm Silty clay, brown-dark brown (7.5YR 4/4) moist; strong medium columnar structure; firm, sticky, plastic; few moderately thick clay films on face of peds and lining pores; few fine roots; slightly acid (pH 6.2); clear smooth boundary.

B22t 58-105 cm Silty clay, reddish brown (5YR 4/4) moist; moderate medium angular blocky structure; firm, very sticky, very plastic; many moderately thick clay films on face of peds; few fine roots; neutral (pH 7.0); clear wavy boundary.

B3 105-156 cm Silty clay loam, reddish brown (5YR 5/4) moist; moderate medium subangular blocky structure; friable, very sticky, plastic; common moderately thick clay film line pores; neutral (pH 7.0).

B2AC

CLASSIFICATION: fine loamy, montmorillonitic, Mollic Cryoboralf
DATE DESCRIBED: 8-19-80
LOCATION: Bitterroot Nat. For., site 2, control, first replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: AF/LIBO/VASC
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 8% Northeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 6-0 cm

A2 0-28 cm Light brown (7.5YR 6/4) silty clay loam, dark yellowish brown (10YR 3/4) moist; weak, very fine angular blocky structure; soft, friable, slightly sticky, slightly plastic; common fine and few medium and coarse roots; medium acid (pH 5.8); clear wavy boundary.

B21t 28-54 cm Light brown (7.5YR 6/4 with 30% clayey network 7.5YR 3/2) sandy clay loam, reddish brown (5YR 4/4 with 30% clayey network 10YR 2/3) moist; moderate fine angular blocky; firm, sticky, plastic; common moderately thick clay films line pores; few fine and medium roots; strongly acid (pH 5.5 with pH 6.0 in matrix); clear wavy boundary.

B22t 54-83 cm Yellowish brown (10YR 5/8) sandy loam, strong brown (7.5 YR 4/6) moist; weak fine angular blocky; very friable, nonsticky, nonplastic; few thin clay films line pores; few fine roots; very strongly acid (pH 5.0); clear wavy boundary.

B23t 83-160 cm Yellowish red (5YR 5/6) sandy clay loam, strong brown (7.5 YR 4/6) moist; moderate fine subangular blocky; firm, slightly sticky, slightly plastic; few thin clay films line pores; few fine roots; medium acid (pH 6.0).

NOTE: Texture in B21t is sandy clay but horizon has network of clayey material. The matrix is light brown (7.5YR 6/4) loamy sand, reddish brown moist. The clay network occupies 30% of the horizon and is dark brown (7.5YR 3/2) silty clay, very dark brown (10YR 3/2) moist.

B2BC

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-2-79
LOCATION: Bitterroot Nat. For., site 2, control, second replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/LIBO/SYAL
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 14% South
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

O1 5-0 cm

A2 0-25 cm Light brownish gray (2.5Y 6/2) silty clay loam, dark yellowish brown (10YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky, slightly plastic; many fine, common medium and few coarse roots; very strongly acid (5.0 pH); clear wavy boundary.

B21t 25-40 cm Silty clay, strong brown (7.5YR 4/6) moist; strong medium angular blocky structure; firm, very sticky, very plastic; common moderately thick clay films on face of peds; few fine, few medium roots; medium acid (6.0 pH); clear smooth boundary.

B22t 40-61 cm Silty clay, yellowish brown (10YR 5/6) moist; strong medium subangular blocky structure; firm, sticky, plastic; common moderately thick clay films on faces of peds; few fine roots; neutral acidity (7.0 pH); clear wavy boundary.

B3 61-102 cm Sandy clay loam, strong brown (7.5YR 5/6) moist; moderate medium angular blocky structure; firm, sticky, plastic; common moderately thick clay films on faces of peds and lining pores; few fine roots; neutral acid (7.0 pH); clear irregular boundary.

C 102-127 cm 85% stony quartzite coarse fragments.

B2AM

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-3-79
LOCATION: Bitterroot Nat. For., site 2, moderate disturbance, second replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/LIBO/SYAL
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 6% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 21-0 cm

A2 0-20 cm Very pale brown (10YR 7/3) clay loam, brown (7.5YR 5/4) moist; weak fine angular blocky to platy structure; hard, firm, slightly sticky, slightly plastic; few fine roots; slightly acid (pH 6.5); abrupt, smooth boundary.

B21t 20-42 cm Silty clay, brown-dark brown (7.5YR 4/3) moist; strong coarse columnar structure; firm, sticky, plastic; many thick clay films on face of peds; few fine roots; strongly acid (pH 5.5); clear, smooth boundary.

B22t 42-99 cm Silty clay, brown (10YR 5/3) moist; moderate medium angular blocky structure; firm, very sticky plastic; many moderately thick clay films on face of peds and lining pores; medium acid (pH 6.0); clear wavy boundary.

B3 99-132 cm Clay, brown (7.5YR 5/4) moist; moderate medium angular blocky structure; friable, sticky, plastic; many moderately thick clay films on face of peds and lining pores; medium acid (pH 6.0).

B2BM

CLASSIFICATION: fine, montmorillonitic, frigid Typic Eutroboralf
DATE DESCRIBED: 8-2-79
LOCATION: Bitterroot Nat. For., site 2, moderate disturbance, second replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/SYAL/CARU
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 10% South
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 14-0 cm

A2 0-18 cm Light yellowish brown (2.5Y 6/4) silt loam, dark yellowish brown (10YR 4/4) moist; moderate coarse, angular blocky structure; very hard, very firm, slightly sticky, slightly plastic; few fine roots; very strongly acid (pH 5.0); abrupt, smooth boundary.

B21t 18-38 cm Silty clay loam, yellowish red (5YR 4/6) moist; strong very coarse columnar structure; firm, sticky plastic; common moderately thick clay films on face of peds; few fine roots; medium acid (pH 6.0); clear, smooth boundary.

B22t 38-94 cm Silty clay, dark reddish brown (5YR 3/2) moist; moderate medium angular blocky to sub-angular blocky structure; firm, very sticky, very plastic; strong, moderately thick clay films on face of peds; few fine roots; neutral (pH 7.0); clear smooth boundary.

B31 94-180 cm Silty clay, olive (5Y 5/4) moist; moderate medium angular blocky structure; firm, very sticky, very plastic; many thick clay films on face of peds and lining pores; moderately alkaline (pH 8.0); abrupt, wavy boundary.

B32 180-210 cm Silty clay loam, light brown (7.5YR 6/4) moist; weak fine angular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; very few clay films; moderately alkaline (pH 8.0).

B2AS

CLASSIFICATION: fine, montmorillonitic, Mollic Cryoboralf
DATE DESCRIBED: 8-2-79
LOCATION: Bitterroot Nat. For., site 2, severe disturbance, first replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: AF/LIBO/VASC
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 9% Northeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 11-0 cm

A2 0-23 cm Light brownish grey (2.5Y 6/2) silty clay loam, very dark greyish brown (10YR 3/2) moist; moderate medium platy structure; slightly hard, firm, slightly sticky, slightly plastic; few fine roots; very strongly acid (pH 4.7); gradual wavy boundary.

B21t 23-44 cm Gravelly silty clay, dark reddish brown (5YR 3/3) moist; strong, coarse, columnar structure; extremely firm, sticky plastic; common moderately thick clay films on face of peds and lining pores; few fine roots; medium acid (pH 6.0); clear wavy boundary.

B22t 44-97 cm Silty clay, weak red to reddish brown (2.5YR 4/3) moist; moderate medium subangular blocky structure; very firm, sticky, very plastic, common moderately thick clay films on face of peds; few fine roots; slightly acid (pH 6.5); clear wavy boundary.

B23t 97-122 cm Silty clay, reddish brown (2.5YR 5/4) many brownish yellow (10YR 6/8) mottles; moderate medium subangular blocky structure; firm, sticky, plastic; strong moderately thick clav films on face of peds and lining pores; slightly acid (pH 6.5); clear wavy boundary.

B3 122-167 cm Silty clay loam, brown (7.5YR 5/3) moist; weak fine angular blocky structure; friable, sticky, plastic; common moderately thick clay films on peds and lining pores; slightly acid (pH 6.5).

B2BS

CLASSIFICATION: fine, montmorillonitic, frigid Mollic Eutroboralf
DATE DESCRIBED: 8-3-79
LOCATION: Bitterroot Nat. For., site 2, severe disturbance, second replication; NW¼, Sec.17, T1S, R22W
ELEVATION: 1585 m
VEGETATION: DF/SYAL/CARU
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 8% South
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

0 2-0 cm Mixed with A1; many very fine roots; abrupt smooth boundary.

A1 0-3 cm Dark grey (10YR 4/1) loam, very dark brown (10YR 2/2) moist; moderate fine platy and weak fine granular structure; slightly hard, very firm; many, very fine roots; abrupt smooth boundary.

A21 3-13 cm Dark grey (10YR 4/1) silt loam, very dark brown (10YR 2/2) moist; strong, medium platy structure; hard, very firm; many very fine roots; clear smooth boundary.

A22 13-27 cm Grey (10YR 6/1) silty clay loam, very dark greyish brown (10YR 3/2) moist; moderate medium platy and strong medium subangular blocky structure; many very fine roots; abrupt smooth boundary.

B21t 27-52 cm Silty clay, very dark greyish brown (10YR 3/2) moist; strong coarse columnar and strong medium angular blocky structure; very hard, very sticky, very plastic; thick continuous clay films; common very fine roots; clear smooth boundary.

B22t 52-83cm Silty clay, dark brown (10YR 4/3) moist; moderate coarse prismatic to moderate medium angular blocky structure; very hard, very sticky, very plastic; thick continuous clay films, slickensides evident; few very fine roots; clear smooth boundary.

B2BS Continued -

B31t 83-128 cm Silty clay, dark brown (10YR 4/3) moist; very coarse prismatic, moderate medium subangular blocky structure; very hard, sticky, very plastic; thick continuous clay films; slickensides evident; clear smooth boundary.

B32t 128-186 cm Clay, yellowish brown (10YR 5/4) moist; weak very coarse prismatic to weak medium subangular blocky structure; very hard, sticky, very plastic.

B3AC

CLASSIFICATION: fine loamy, kaolinitic, frigid, Eutric Glossoboralf
DATE DESCRIBED: 8-3-79
LOCATION: Bitterroot Nat. For., site 3, control, first replication; NE¼, NE¼, Sec. 17, T1S, R22W
ELEVATION: 1780 m
VEGETATION: DF/VAGL/ARUV
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 2% Southwest
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

O1 6-0 cm

A2 0-24 cm Pink (7.5YR 7/4) silt loam, red (2.5YR 4/8) moist; moderate medium angular blocky structure; hard, firm, non-sticky, non-plastic; many fine common medium, few coarse roots; very strongly acid (pH 5.0); clear wavy boundary.

B21t 24-50 cm Reddish yellow (5 YR 6/8) silty clay loam, red (2.5YR 4/8) moist; moderate medium angular blocky structure; extremely hard, extremely firm, sticky, slightly plastic; very few clay films; few fine, few coarse roots; very strongly acid (pH 5.0); clear smooth boundary.

B22t 50-108 cm Reddish yellow (7.5 YR 7/6) silty clay loam, red (10YR 4/8) moist; moderate medium angular blocky structure; extremely hard, extremely firm, slightly sticky, slightly plastic; common, moderately thick clay films; few fine roots; very strongly acid (pH 5.0); clear wavy boundary.

B23t 108-147 cm Red (2.5YR 4/8) silty clay, strong brown (7.5 YR 4/8) moist; moderate medium angular blocky structure; very hard, very firm, sticky, plastic; many thick clay films on faces of peds and lining pores; few fine roots; very strongly acid (pH 5.0).

B3BC

CLASSIFICATION: fine, montmorillonitic, frigid, Eutric Glossoboralf
DATE DESCRIBED: 8-3-79
LOCATION: Bitterroot Nat., For., site 3, control, second replication; NE¼, NE¼, Sec.29, T15, R22W
ELEVATION: 1780 m
VEGETATION: DF/VAGL/ARUV
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 5% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 5-0 cm

A21 0-8 cm Light grey to pale yellow (2.5Y 7/3) silty clay loam, dark yellowish brown (10YR 3/4) moist; weak, very fine angular blocky breaking to granular; soft, very friable, slightly sticky, slightly plastic; common fine, common coarse roots; very strongly acid (pH 5.0); clear smooth boundary.

A22 8-19 cm Pinkish grey to pink (7.5YR 7/3) silty clay loam, yellowish red (5YR 4/6) moist; moderate medium angular blocky structure; very hard, very firm, sticky, plastic; common fine roots; very strongly acid (pH 5.0); clear, smooth boundary.

A23 19-22 cm Very pale brown (10YR 8/3) silty clay loam, yellowish brown (10YR 5/8) moist; moderate medium angular blocky structure; hard, firm, slightly sticky, plastic; common fine roots; strongly acid (pH 5.5); clear wavy boundary.

B21t 22-40 cm Silty clay, strong brown (7.5YR 5/6) moist; strong, coarse columnar structure; very firm, sticky, plastic, many thick clay films on faces of peds and line pores; common fine roots; slightly acid (pH 6.5); clear wavy boundary.

B22t 40-97 cm Silty clay, yellowish brown (10YR 5/8) moist; strong, medium subangular and angular blocky structure; very firm, very sticky, very plastic; continuous moderately thick clay films on faces of peds; few fine roots; medium acid (pH 6.0); gradual wavy boundary.

B3BC Continued -

B23t 97-140 cm Silty clay, brownish yellow (10YR 6/8) moist; strong, coarse, angular blocky structure; very firm, very sticky, very plastic; strong, moderately thick clay films on faces of peds; few fine roots; neutral acid (pH 7.0); gradual, wavy boundary.

IIB31 140-165 cm Silty clay, red (10YR 4/8) moist; moderate, medium angular blocky structure; very hard, very firm, very sticky, very plastic; continuous, thick, clay film on faces of peds and line pores; few fine roots; moderately alkaline (pH 8.0); clear smooth boundary.

IIB32 165-195+ cm Gravelly silty clay, red (2.5YR 4/8) moist; weak, fine angular blocky breaking to granular structure; hard, firm, sticky, plastic; few fine roots; mildly alkaline (pH 7.5).

NOTE: Small black nodules uniformly disseminated throughout IIB31 horizon.

B3AM

CLASSIFICATION: fine, kaolinitic, frigid, Eutric Glossoboralf
DATE DESCRIBED: 8-3-79
LOCATION: Bitterroot Nat. For., site 3, moderate disturbance, first replication; NE¼, NE¼, Sec.29, T25, R22W
ELEVATION: 1780 m
VEGETATION: DF/VAGL/ARUV
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 2% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 6-0 cm

A21 0-13 cm Pinkish grey to light brown (7.5YR 6/3) silty clay loam, reddish brown (5YR 4/4) moist; moderate medium angular blocky structure; slightly hard, friable, slightly sticky, non-plastic; common fine, common medium, few coarse roots; strongly acid (pH 5.5); clear, smooth boundary.

A22 13-36 cm Reddish brown (5YR 5/3) silty clay loam, yellowish red (5YR 4/8) moist; moderate, medium angular blocky structure; slightly hard, friable, sticky, plastic; few fine, few coarse roots; strongly acid (pH 5.5); clear, smooth boundary.

B21 36-71 cm Silty clay, red (2.5YR 4/8) moist; moderate medium prismatic angular blocky structure; friable, very sticky, very plastic; many thick clay films on faces of peds; few fine roots; strongly acid (pH 5.5); clear wavy boundary.

B22 71-126 cm Silty clay, red (10YR 4/8) moist; moderate medium subangular blocky breaking to angular blocky structure; very hard, firm, very sticky, very plastic; many thick clay films on faces of peds; few fine roots; slightly acid (pH 6.5); clear, wavy boundary.

B23 126-152 cm Red (2.5YR 4/8) silty clay, red (10YR 4/8) moist; moderate medium angular blocky structure; very hard, very firm, very sticky, very plastic; many thick clay films on face of peds; slightly acid (pH 6.5); clear wavy boundary.

<u>B3AM</u> Continued -

B3 152-182 cm Red (2.5YR 5/8) silty clay, red (10YR 4/8) moist; moderate medium angular blocky structure; extremely hard, extremely firm, very sticky, very plastic; common moderately thick clay films on face of peds; slightly acid (pH 6.5).

B3BM

CLASSIFICATION: fine, kaolinitic, frigid, Eutric Glossoboralf
DATE DESCRIBED: 8-4-79
LOCATION: Bitterroot Nat. For., site 3, moderate disturbance, second replication; NE¼, NE¼, Sec.29, T25,R22W
ELEVATION: 1780 m
VEGETATION: DF/VAGL/ARUV
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 10% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

01 7-0 cm

A1 0-14 cm Pinkish grey to light brown (7.5YR 6/3) silty clay loam, yellowish brown (10YR 5/4) moist; moderate medium angular blocky breaking to platy structure; hard firm, non-sticky, non-plastic; many fine, common medium roots; very strongly acid (pH 5.0); clear wavy boundary.

A2 14-24 cm Light grey (10YR 7/2) silty clay loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky, slightly plastic; few fine roots; strongly acid (pH 5.0); clear wavy boundary.

B21t 24-41 cm Silty clay, reddish brown (2.5YR 4/4) moist; many reddish yellow (7.5YR 6/8) mottles; strong, coarse columnar structure; firm, very sticky, very plastic; continuous thick clay films on face of peds and line pores; few fine roots; medium acid (pH 6.0); clear smooth boundary.

B22t 41-79 cm Silty clay, red (2.5YR 4/3) moist; many reddish yellow (7.5YR 6/8) mottles; strong, coarse subangular blocky structure; firm, very sticky, very plastic; continuous thick clay films on face of peds; few fine roots; medium acid (pH 6.0); clear wavy boundary.

B23t 79-127 cm Silty clay, light reddish brown (2.5YR 6/4) moist; many reddish yellow (7.5YR 6/8) mottles; moderate medium subangular blocky structure; firm, very sticky, very plastic; strong very thick clay films on face of peds and lining pores; few fine roots; neutral acid (pH 7.0); clear wavy boundary.

B3AS Continued -

B3 191-241 cm Red (clayey matrix 2.5YR 4/8), red (sandy mixture 2.5YR 4/6) silty clay, red (10YR 4/8) moist; moderate medium subangular blocky structure; soft, friable, sticky, plastic; strong very thick clay films on face of peds and lining pores; few fine roots; medium acid (clay matrix pH 6.0) to very strongly acid (sandy mixture pH 4.5).

B3BS

CLASSIFICATION: fine, montmorillonitic, frigid, Eutric Glossoboralf
DATE DESCRIBED: 8-4-79
LOCATION: Bitterroot Nat. For., site 3, severe disturbance, second replication; NE¼, NE¼, Sec.29, T25, R22W
ELEVATION: 1780 m
VEGETATION: DF/VAGL/ARUV
PARENT MATERIAL: Tertiary Volcanic
SLOPE and ASPECT: 9% Southeast
DRAINAGE: Moderately well drained

PROFILE DESCRIPTION

A1 0-20 cm Very pale brown (10YR 7/3) silty clay loam; dark greyish brown (10YR 4/2) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common fine, common medium roots; strongly acid (pH 5.5); clear wavy boundary.

A2 20-27 cm White (2.5Y 8/2) silty clay loam, brown (7.5YR 5/3) moist; moderate medium subangular blocky and platy structure; hard, firm, slightly sticky, plastic; few fine roots; very strongly acid (pH 5.0); clear smooth boundary.

B21t 27-51 cm Silty clay, yellowish brown (10YR 5/6) moist; many reddish yellow (7.5YR 6.8) mottles; strong coarse columnar structure; firm, very sticky, plastic; continuous thick clay films on face of peds; few fine few medium roots; very strongly acid (pH 5.0); clear, wavy boundary.

B22t 51-78 cm Silty clay, reddish brown (5YR 5/4) moist; many reddish yellow (7.5YR 6/8) mottles; strong medium angular blocky structure; firm, very sticky, very plastic; continuous thick clay film on face of peds; few fine roots; very strongly acid (pH 5.0); clear smooth boundary.

B23t 78-106 cm Silty clay, light yellowish brown (10YR 6/4) moist; many reddish yellow (7.5YR 6/8) mottles; strong coarse subangular blocky structure; friable, very sticky, very plastic; many medium thick clay films on face of ped and lining pores; few fine roots; medium acid (pH 6.0); clear smooth boundary.

<u>B3BS</u> Continued -

B24t 106-138 cm Silty clay, light grey (10YR 7/2) moist; common reddish yellow (7.5YR 6/8) mottles; strong coarse subangular blocky structure; friable, very sticky, plastic; continuous thick clay films on face of peds and lining pores; medium acid (pH 6.0); clear wavy boundary.

B3 138-183 cm Very pale brown (10YR 7/2) silt loam, light yellowish brown (10YR 6/4) moist; moderate medium subangular blocky structure; soft, friable, non-sticky, non-plastic; common moderately thick clay films on face of peds; extremely acid (pH 4.0).

APPENDIX III

SOIL PROFILE DESCRIPTIONS FOR PEDONS FORMING IN LIMESTONE DOMINATED GLACIAL TILL PARENT MATERIAL

F1AC

CLASSIFICATION: coarse loamy, mixed, cryic Paleboralf (propose andic subgroup)
DATE DESCRIBED: 8-22-79
LOCATION: Flathead Nat. For., site 1, control replication; SE¼, NW¼, Sec. 2, T31N, R26W
ELEVATION: 1475 m
VEGETATION: AF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 16% North to northeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 6-0 cm.

A2 0-7 cm Gray-light gray (10YR 6/1) silt, brown-dark brown (10YR 4/3) moist; weak fine subangular blocky to granular structure; loose, very friable, nonsticky, nonplastic; many fine and common medium and coarse roots; strongly acid (pH 5.5); clear smooth boundary.

B2ir 7-26 cm Yellowish brown (10YR 5/6) silt, brown-dark brown (7.5YR 4/4) moist; moderate medium subangular blocky to granular structure; loose, very friable, nonsticky, nonplastic; 20% cobbles, 5% stones; common fine, medium and coarse roots; medium acid (pH 6.0); gradual wavy boundary with tongues.

IIA2 26-46 cm Very pale brown (10YR 7/3) silt, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; slightly hard, friable nonsticky, nonplastic; 10% gravels, 5% cobbles; many fine roots; neutral (pH 7.0); gradual irregular boundary.

IIA&B 46-61 cm Silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; many moderate thick clay films on face of peds and lining pores; 10% gravels; few fine roots; mildly alkaline (pH 7.5); clear wavy boundary; horizon 60% IIA2, 50% IIB2.

<u>F1AC</u> Continued -

IIB&A 61-75 cm Silty clay loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; friable, sticky; many moderately thick clay films on face of peds; 5% gravels, 5% cobbles; few fine roots; mildly alkaline (pH 7.5); gradual wavy boundary; horizon 70% IIB2, 30% IIA2.

B21t 75-101 cm Clay loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, sticky, plastic; continuous thick clay films on face of peds; 5% gravels, 5% stones; few fine roots; mildly alkaline (pH 7.5); gradual wavy boundary.

IIB22t 101-140 cm Clay loam, olive yellow (5Y 6/6) moist; strong coarse subangular blocky to angular blocky structure; friable, sticky, plastic; continuous thick clay films on face of peds; 10% gravels, 5% cobbles; mildly alkaline (pH 7.5); gradual wavy boundary.

IIClca 140-180 cm Silt loam to clay loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; many thick clay films on face of peds; 5% gravels, 10% cobbles; strongly effervescent; moderately alkaline (pH 8.0).

F1BC

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 8-24-79
LOCATION: Flathead Nat. For., site 1, control, second replication; SE¼, NW¼, Sec. 2, T31N, R26W
ELEVATION: 1475 m
VEGETATION: AF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 22.5% North to northeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 5-0 cm.

A2 0-5 cm White (2.5Y 8/1) silt, very dark greyish brown (10YR 3/2) moist; appreciable amounts of organic matter; weak fine subangular blocky structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; extremely acid (pH 4.3); clear wavy boundary.

B2ir 5-26 cm Yellowish brown (10YR 5/8) silt, dark yellowish brown (10YR 4/6) moist; moderate medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; trace gravels; many fine, common medium and few coarse roots; slightly acid (pH 6.5); clear wavy boundary.

IIA2 26-55 cm Light grey to pale yellow (2.5Y 7/3) gravelly silt, light yellowish brown (2.5Y 6/4) moist; mottles scattered, indistinct, and masked by soil colors, weathered rock (10YR 7/8); weak very fine subangular blocky to granular structure; soft, friable, nonsticky, nonplastic; 20% gravels, 5% cobbles, 5% stones; few fine roots; slightly acid (pH 6.5); clear smooth boundary.

IIA&B 55-72 cm Silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; common moderately thick clay films on face of peds scattered throughout; 5% gravels, 10% cobbles; few fine roots; neutral (pH 7.0); clear wavy boundary; horizon 60% IIA2, 40% IIB2.

<u>F1BC</u> Continued -

IIB&A 72-92 cm Silt loam, olive yellow 2.5Y 6/6) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; 5% gravels, 5% cobbles, 5% stones; few fine roots; neutral (pH 7.0); gradual wavy boundary; horizon 60% IIB2, 40% IIA2.

IIB21t 92-136 cm Clay loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky and angular blocky structure; friable, sticky, plastic; many thick clay films on ped faces; 5% gravels, 5% cobbles, 5% stones; neutral (pH 7.3); gradual wavy boundary.

IIB22t 136-160 cm Clay loam, olive (5Y 5/6) moist; strong coarse subangular blocky structure; friable, sticky, plastic; continuous thick clay films on face of peds; 5% gravels, 5% cobbles; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC1ca 160-180 cm Silt loam to clay loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; many thick clay films on face of peds; 5% gravels, 10% cobbles; strongly effervescent; moderately alkaline (pH 8.0).

F1AM

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 8-22-79
LOCATION: Flathead Nat. For., site 1, moderate disturbance, first replication; SE¼, NW¼, Sec. 2, T31N, R26W
ELEVATION: 1475 m
VEGETATION: AF/Clun
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 18% North to northeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

O1 9-0 cm

A2 0-2 cm Very thin, broken.

B2ir 2-19 cm Brownish yellow (10YR 6/8) silt, brown to dark brown (7.5YR 4/4) moist; moderate medium subangular blocky to platy structure; soft, friable, nonsticky, nonplastic; trace cobbles, 5% stones, 20% boulders; many fine and common medium roots; neutral (pH 7.0); clear wavy boundary.

IIA2 19-42 cm White (10YR 8/1 with mottles 10YR 7/6) gravelly silt, light olive brown (2.5Y 5/6) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 10% gravels, trace cobbles, 20% boulders; few fine and medium roots; neutral (pH 7.0); gradual irregular boundary.

IIA&B 42-64 cm Silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky structure; firm, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; 20% gravels; few fine roots; neutral (pH 7.0); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIB+A 64-87 cm Silty clay loam, light olive brown (2.5Y 5/6) moist; moderate medium subangular blocky structure; firm, slightly sticky, slightly plastic; many moderately thick clay films on faces of peds; 10% gravels; few fine roots; mildly alkaline (pH 7.5); gradual wavy boundary; horizon 70% IIB2, 30% IIA2.

FlAM Continued -

IIB21t 87-116 cm Silty clay loam, light olive brown (2.5Y 5/6) moist; strong coarse prismatic to subangular blocky structure; very firm, slightly sticky, slightly plastic; continuous thick clay films on face of peds; 5% gravels, 5% boulders; neutral (pH 7.0); gradual wavy boundary.

IIB22t 116-131 cm Silty clay loam, olive yellow (2.5Y 6/8) moist; moderate medium subangular blocky structure; friable, sticky, plastic; continuous thick clay films on face of peds; 5% gravels, 5% stones; neutral (pH 7.0).

F1BM

CLASSIFICATION: coarse loamy, mixed Typic Cryoboralf
DATE DESCRIBED: 8-24-79
LOCATION: Flathead Nat. For., site 1, moderate disturbance, second replication; SE¼, NW¼, Sec. 2, T31N, R26W
ELEVATION: 1475 m
VEGETATION: AF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 15% North to northeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

O1 5-0 cm.

A2 Thin and discontinuous.

B2ir 0-17 cm Dark yellowish brown (10YR 4/8) silt, brownish yellow (10YR 6/8) moist; moderate medium subangular blocky and platy structure; slightly hard, firm, nonsticky, nonplastic; trace gravels, trace cobbles; many fine and common medium roots; neutral (pH 7.0); clear broken boundary.

IIA2 17-30 cm Pinkish white (7.5YR 8/2) gravelly silt, yellowish brown (10YR 5/4) moist; moderate medium subangular blocky and platy structure; friable, nonsticky, nonplastic; 20% gravels, 5% cobbles; many fine and few medium roots; neutral (pH 7.0); clear broken boundary.

IIA&B 30-40 cm Olive yellow (2.5Y 6/6) silt loam, very pale brown (10YR 7/3) moist; moderate medium subangular blocky structure; slightly sticky, slightly plastic; common moderately thick clay films on face of peds; 10% gravels; common medium roots; neutral (pH 7.0); gradual wavy boundary; horizons 60% IIA2, 40% IIB2.

IIB&A 40-57 cm Silty clay loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; firm, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; 10% cobbles, 5% stones, trace boulders; few fine roots; mildly alkaline (pH 7.5); clear wavy boundary; horizon 70% IIB2, 30% IIA2.

F1BM Continued -

IIB21t 57-112 cm Silty clay, olive (5Y 5/6) moist; moderate medium subangular blocky structure; friable, sticky, plastic; many thick clay films on face of peds; 5% gravels, 5% cobbles, trace stones; few fine roots; mildly alkaline (pH 7.5); gradual wavy boundary.

IIB22t 112-138 cm Silty clay, olive yellow (5Y 6/6) moist; strong coarse subangular blocky structure; sticky, plastic; continuous thick clay films on face of peds; 5% gravels, 5% cobbles; mildly alkaline (pH 7.5).

F1AS

CLASSIFICATION: coarse loamy, mixed Typic Paleboralf (andic phase)
DATE DESCRIBED: 8-22-79
LOCATION: Flathead Nat. For., site 1, severe disturbance, first replication; SE¼, NW¼, Sec. 2, T31N, R26W
ELEVATION: 1475 m
VEGETATION: AF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 15% North to northeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 6-0 cm.

B2ir 0-20 cm Very pale brown (10YR 7/4) silt, strong brown (7 (7.5YR 4/6) moist; strong coarse platy and moderate medium subangular blocky structure; extremely hard, extremely firm, nonsticky, nonplastic; 5% gravels, 10% cobbles, 10% stones; many fine and few medium roots; mildly alkaline (pH 7.5); clear wavy boundary.

IIA2 20-38 cm Pink to pinkish white (7.5YR 8/3) gravelly silt, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; hard, firm, nonsticky, nonplastic; 20% gravels, 5% cobbles, 5% stones, 10% boulders; few fine roots; mildly alkaline (pH 7.5); diffuse irregular boundary.

IIA&B 38-51 cm Pink to pinkish white (7.5YR 8/3) silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky and angular blocky structure; hard, firm, slightly sticky, slightly plastic; very few clay films; 10% gravels; few fine roots; mildly alkaline (pH 7.5); gradual wavy boundary; horizon 70% IIA2, 30% IIB2.

IIB&A 51-86 cm Silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; 10% gravels, 5% cobbles; few fine roots; mildly alkaline (pH 7.5); gradual wavy boundary; horizon 70% IIB2, 30% IIA2.

F1AS Continued -

IIB21t 86-109 cm Gravelly silt loam, olive (5Y 5/6 with very few mottles 10YR 5/8) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; 20% gravels, 5% cobbles; few fine roots; mildly alkaline (pH 7.5); gradual wavy boundary.

IIB22t 109-140 cm Silt loam, olive (5Y 5/6) moist; moderate medium subangular blocky structure; friable, sticky, plastic; many moderately thick clay films on face of peds; 5% gravels, 5% cobbles; moderately alkaline (pH 8.0); gradual wavy boundary.

C1ca 140-143 cm Silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky structure; friable, sticky, plastic; many moderately thick clay films on face of peds; 5% gravels, 5% cobbles; slightly effervescent; moderately alkaline (pH 8.0).

F1BS

CLASSIFICATION: coarse loamy, mixed Typic Cryoboralf
DATE DESCRIBED: 8-22-79
LOCATION: Flathead Nat. For., site 1, severe disturbance, second replication; SE¼, NW¼, Sec. 2, T31N, R26W
ELEVATION: 1475 m
VEGETATION: AF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 11% North to northeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 4-0 cm.

A2 0-2 cm Light grey (2.5Y 7/2) silt, olive brown to dark greyish brown (2.5Y 4/3) moist; weak fine granular structure; loose, very friable, nonsticky, nonplastic; 5% gravels; many fine and common medium roots; slightly acid (pH 6.5); clear wavy boundary.

B2ir 2-10 cm Pink (7.5YR 7/4) silt tending toward silt loam where platy structure dominates, yellowish brown (10YR 5/4) moist; moderate medium platy structure; soft, friable, nonsticky to slightly sticky where mixed with organic matter, nonplastic; 5% gravels, 5% cobbles; many fine and common medium roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA2 10-47 cm White to pinkish white (7.5YR 8/1) gravelly silt, light olive brown (2.5Y 5/4) moist; 5% mottles (10YR 7/8); moderate medium subangular blocky and strong coarse platy structure; soft, firm, nonsticky, nonplastic; 25% gravels, 5% cobbles; few fine roots; medium acid (pH 6.0); gradual wavy boundary.

IIA&B 47-68 cm White to pale yellow (2.5Y 8/3) gravelly silt, yellow (5Y 7/6) moist; 20% mottles (10YR 7/8); moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; very few clay films; 20% gravels, 5% cobbles; neutral (pH 7.0); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

<u>F1BS</u> Continued -

IIB&A 68-100 cm Silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky structure; slightly hard, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; 10% gravels, 5% cobbles; neutral (pH 7.0); gradual wavy boundary; horizon 70% IIB2, 30% IIA2.

IIB21t 100-123 cm Silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; firm, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; 5% gravels, trace cobbles; neutral (pH 7.0); clear wavy boundary.

IIB22t 123-150 cm Silt loam, olive (5Y 5/6) moist; moderate medium subangular blocky structure; friable, sticky, plastic; continuous thick clay films on face of peds; neutral (pH 7.0).

K2AC

CLASSIFICATION: coarse loamy skeletal, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-11-79
LOCATION: Kootenai Nat. For., site 2, control, first replication; SW¼, SW¼, Sec. 15, T32N, R26W
ELEVATION: 1356 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 5% West
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 8-0 cm

A2 0-6 cm Very pale brown (10YR 7/3) silt, brown (10YR 5/3) moist; moderate medium subangular blocky with trace of platy structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; very strongy acid (pH 4.5); clear wavy boundary.

B2ir 6-20 cm Brownish yellow (10YR 6/8) silt, yellowish brown (10YR 5/6) moist; moderate medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA2 20-40 cm White (10YR 8/2) gravelly silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 15% gravels, 5% cobbles; common fine, medium and coarse roots; medium acid (pH 5.7); gradual wavy boundary.

IIA&B 40-58 cm Silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; 10% gravels, trace cobbles, trace stones; few fine, medium and coarse roots; slightly acid (pH 6.5); gradual wavy boundary; horizon 70% IIA2, 30% IIB2.

IIB&A 58-75 cm Silt loam, pale olive (5Y 6/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels; few fine, medium and coarse roots; slightly acid (pH 6.5); gradual wavy boundary; horizon 60% IIB2, 40% IIA2.

K2AC Continued -

IIB3ca 75-85 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; 5% gravels, 5% cobbles; few fine, medium, coarse roots; slightly effervescent; neutral (pH 7.0); clear wavy boundary.

IIC1ca 85-115 cm Gravelly silt loam, olive yellow (5Y 6/8) moist; 20% of ped faces dark yellowish brown (10YR 4/4); moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 15% gravels, 5% cobbles, 5% stones, 5% boulders; few fine and medium roots; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 115-150 cm Gravelly silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 20% gravels, 10% cobbles, 5% stones, 5% boulders; few fine roots; strongly effervescent; moderatley alkaline (pH 8.0); gradual wavy boundary.

IIC3ca 150-200 cm Gravelly silt loam, olive (5Y 5/6) moist; weak medium subangular blocky to angular blocky structure; friable, nonsticky, nonplastic; 25% gravels, 5% cobbles, 5% stones, 5% boulders; strongly effervescent; moderately alkaline (pH 8.0).

K2BC

CLASSIFICATION: fine loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-11-79
LOCATION: Kootenai Nat. For., site 2, control, second replication; SW¼, NW¼, Sec. 22, T32N, R26W
ELEVATION: 1356 m
VEGETATION: SAF/LIBO/CARU
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 11% West
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 10-0 cm

A2 0-6 cm Light grey (10YR 7/2) silt, brown-dark brown (10YR 4/3) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

B2ir 6-28 cm Yellow (10YR 7/6) silt, yellowish brown (10YR 5/8) moist; moderate medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; medium acid (pH 6.0); gradual wavy boundary.

IIA2 28-50 cm White (2.5Y 5/8) gravelly silt, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 15% gravels, 5% cobbles, trace stones; common fine, medium and coarse roots; slightly acid (pH 6.5); clear wavy boundary.

IIA&B 50-66 cm Very pale brown (10YR 7/4) silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky and angular blocky structure; slightly hard, friable, slightly sticky, nonplastic; very few clay films; 10% gravels, 5% cobbles; common fine and medium and few coarse roots; slightly acid (pH 6.5); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIB2t 65-80 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky; friable, slightly sticky, slightly plastic; very few clay films; 5% gravels, 5% cobbles; few fine, medium and coarse roots; neutral (pH 7.0); gradual wavy boundary.

K2BC Continued -

IIC1ca 80-120 cm Silt loam, olive yellow (5Y 6/6 with 30% of ped faces 10YR 4/4 and 5% 7.5 YR 7/8) moist; moderate medium subangular blocky to angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; few fine and medium roots; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 120-163 cm Silt loam, olive yellow (5Y 6/6 with 10% of ped faces 10YR 4/4) moist; moderate medium subangular blocky to angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; strongly effervescent; moderately alkaline (pH 8.0); clear wavy boundary.

IIC3ca 163-230 cm Silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky and angular blocky structure; firm, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones, trace boulders; strongly effervescent; moderately alkaline (pH 8.0).

K2AM

CLASSIFICATION: coarse loamy, mixed Typic Cryoboralf
DATE DESCRIBED: 9-11-79
LOCATION: Kootenai Nat. For., site 2, moderate disturbance, first replication; SW¼, SW¼, Sec. 15, T32N, R26W
ELEVATION: 1356 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 18% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 2-0 cm

B2ir 0-17 cm Light yellowish brown (10YR 6/4) silt, yellowish brown (10YR 5/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; many fine, common medium and few coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA2 17-22 cm White (10YR 8/2) silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 5% gravels, 5% cobbles; common fine and few medium roots; slightly acid (pH 6.5); diffuse irregular boundary.

IIA&B 33-40 cm Very pale brown (10YR 7/4) silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles; few fine, medium and coarse roots; neutral (pH 6.7); diffuse irregular boundary; horizon 70% IIA2, 30% IIB2.

IIB2t 40-50 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; 5% gravels, 5% cobbles, trace stones; few fine, medium and coarse roots; neutral (pH 7.0); gradual wavy boundary.

IIC1ca 50-90 cm Silt loam, olive yellow (5Y 6/6 with 25% of ped faces 10YR 4/4) moist; moderate fine and medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones and

K2AM Continued -

boulders; few fine and medium roots; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 90-220 cm Silt loam, olive yellow (5Y 6/6 with 40% of ped faces 10YR 4/4) moist; moderate medium subangular blocky structure; friable, slightly soluble, nonplastic; very few clay films; 5% gravels, 5% cobbles, 10% stones, 10% boulders; strongly effervescent; moderately alkaline (pH 8.0).

K2BM

CLASSIFICATION: coarse loamy, mixed Typic Cryoboralf
DATE DESCRIBED: 9-11-79
LOCATION: Kootenai Nat. For., site 2, moderate disturbance, second replication; SW¼, NW¼, Sec. 22, T32N, R26W
ELEVATION: 1356 m
VEGETATION: SAF/LIBO/CARU
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 18% South to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 2-0 cm

A2 0-2 cm White (10YR 8/2) silt, yellowish brown (10YR 5/4) moist; moderate medium platy and subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; many fine and few medium and coarse roots; strongly acid (pH 5.5); clear smooth boundary; horizon mixed with organic material and B2ir.

B2ir 2-17 cm Brownish yellow (10YR 6/8) silt, yellowish brown (10YR 5/8) moist; moderate medium platy to subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; common fine and few medium and coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA2 17-38 cm Light gray-pale yellow (2.5Y 7/3) silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 5% gravels, 5% cobbles; few fine medium and coarse roots; slightly acid (pH 6.5); clear wavy boundary.

IIA&B 38-59 cm Silt loam, yellow (5Y 7/8) moist; moderate fine and medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; 5% gravels, 5% cobbles; few fine, medium and coarse roots; slightly acid (pH 6.5); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIB2t 59-78 cm Heavy silt loam, light olive brown (2.5Y 5/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; trace gravels, 5% cobbles; few fine, medium and coarse roots; neutral (pH 7.0); gradual wavy boundary.

K2BM Continued -

IIC1ca 78-110 cm Silt loam, olive yellow (5Y 6/6 with 25% of ped faces 10YR 4/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; trace gravels, 5% cobbles, 5% stones, 5% boulders; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy.

IIC2ca 110-120 cm Silt loam, olive yellow (5Y 6/6 with 20% of ped faces 10YR 4/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 10% stones, 10% boulders; strongly effervescent; moderately alkaline (pH 8.0).

K2AS

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-11-79
LOCATION: Kootenai Nat. For., site 2, severe disturbance, first replication; SW¼, SW¼, Sec. 15, T32N, R26W
ELEVATION: 1356 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 18% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 4-0 cm

B2ir 0-18 cm Brownish yellow (10YR 6/6) silt, yellowish brown (10YR 5/8) moist; moderate medium subangular blocky and platy structure; soft, very friable, nonsticky, nonplastic; many fine, common medium and few coarse roots; slightly acid (pH 6.3); gradual wavy boundary.

IIA2 18-34 cm White (2.5Y 8/2) silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; slightly hard, firm, nonsticky, nonplastic; 10% gravels, 5% cobbles, trace stones; common fine and medium and few coarse roots; medium acid (pH 6.0); diffuse irregular boundary.

IIA&B 34-48 cm Very pale brown (10YR 8/3) silt loam, olive yellow 2.5Y 6/6) moist; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky, nonplastic; very few clay films; 10% gravels, 5% cobbles; few fine and medium roots; neutral (pH 7.0); diffuse irregular boundary; horizon 60% IIA2, 40% IIB2.

IIB2t 48-60 cm Silt loam, olive yellow (5Y 6/6) moist; strong coarse subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; trace gravels, 5% cobbles; few fine roots; neutral (pH 7.0); gradual wavy boundary.

IIC1ca 60-82 cm Silt loam, yellow (5Y 7/8 with 15-20% of ped faces 10YR 4/4) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; few fine and medium roots;

K2AS Continued -

strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 82-120 cm Silt loam, olive yellow (5Y 6/6 with 20% of ped faces 10YR 4/4) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC3ca 120-190 cm Silt loam, olive yellow (2.5Y 6/6 with 50% of ped faces 10YR 4/4) moist; moderate fine and medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; strongly effervescent; moderately alkaline (pH 8.0); indistinct wavy boundary.

IIC4ca 190-200 cm Fine sand or silt, olive (5Y 5/6) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; strongly effervescent; moderately alkaline (pH 8.0).

K2BS

CLASSIFICATION: coarse loamy, mixed Typic Cryoboralf
DATE DESCRIBED: 9-11-79
LOCATION: Kootenai Nat. For., site 2, severe disturbance, second replication; SW¼, NW¼, Sec. 22, T32N, R26W
ELEVATION: 1356 m
VEGETATION: SAF/LIBO/CARU
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 20% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 4-0 cm

B2ir 0-8 cm Yellowish brown (10YR 5/6) silt, yellowish brown (10YR 5/8) moist; moderate medium platy and subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; common fine and few medium roots; medium acid (pH 6.0); gradual wavy boundary.

IIA2 8-22 cm Silt loam, light yellowish brown (2.5Y 6/4) moist; moderate, medium subangular blocky structure; friable, nonsticky, nonplastic; 5% gravels, 5% cobbles, trace stones; few fine and medium roots; slightly acid (pH 6.5); gradual wavy boundary.

IIA&B 22-32 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; few fine and medium roots; slightly acid (pH 6.5); diffuse irregular boundary; horizon 60% IIA2, 40% IIB2.

IIB2t 32-47 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; trace gravels, 5% cobbles, 5% stones; few fine and medium roots; neutral (pH 7.0); gradual wavy boundary.

IIC1ca 47-97 cm Silt loam, olive yellow (5Y 6/6 with 15% of ped faces 10YR 4/4) moist; strong medium and coarse subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic;

<u>K2BS</u> Continued -

very few clay films; 5% gravels, 5% cobbles; few fine roots; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 97-200 cm Silt, olive yellow (5Y 6/6 with less than 5% of ped faces 10YR 4/4); moist; moderate medium subangular blocky and angular blocky structure; friable, nonsticky, nonplastic; very few clay films; trace gravels, trace cobbles, trace stones; strongly effervescent; moderately alkaline (pH 8.0).

K3AC

CLASSIFICATION: fine loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-10-79
LOCATION: Kootenai Nat. For., site 3, control, first replication; NE¼, SW¼, Sec. 11, T32N, R26W
ELEVATION: 1530 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 9% South to southwest
DRAINAGE: Well drained

PROFILE DESCRIPTION

01	8-0 cm
A2	0-5 cm White (10YR 8/1) silt, dark yellowish brown (10YR 4/4) mixed with organic material) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; medium acid (pH 5.8); abrupt wavy boundary.
B2ir	5-20 cm Brownish yellow (10YR 6/8) silt, yellowish brown (10YR 5/8) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; trace gravel, trace cobbles; common fine, medium and coarse roots; medium acid (pH 6.0); clear wavy boundary.
IIA2	20-50 cm Very pale brown (10YR 8/3) silt, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 5% gravels, trace cobbles, trace stones; few fine and medium roots; slightly acid (pH 6.5); clear wavy boundary.
IIA&B	50-73 cm Silt loam, light olive brown (2.5Y 5/4) moist; moderate medium subangular blocky structure; firm, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles; few fine roots; neutral (pH 6.7); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.
IIB3ca	73-85 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; trace gravels, 5% cobbles, trace stones, trace boulders; few fine and medium roots; neutral (pH 6.8); gradual wavy boundary.

<u>K3AC</u> Continued -

IIClca 85-140 cm Silt loam, olive yellow (5Y 6/6 with 30% of ped faces 10YR 4/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; few fine roots; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 140-160 cm Silt loam, olive (5Y 5/6 with 50% of ped faces 10YR 4/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles; trace stones, trace boulders; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC3ca 160-220 cm Silt loam, olive yellow (5YR 6/8 with 20% of ped faces 10YR 4/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, trace cobbles, 5% stones; strongly effervescent; moderately alkaline (pH 8.0).

K3BC

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-10-79
LOCATION: Kootenai Nat. For., site 3, control, second replication; SE¼, NW¼, Sec. 11, T32N, R26W
ELEVATION: 1530 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 9% South to southwest
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 6-0 cm

A2 0-5 cm Light grey (10YR 7/2) silt, dark yellowish brown (10YR 4/4) moist; moderate fine and medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; very strongly acid (pH 5.0); clear smooth boundary.

B2ir 5-23cm Yellowish brown (10YR 5/8) silt, dark yellowish brown (10YR 4/6) moist; weak medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; trace cobbles, trace stones; many fine and common medium and coarse roots; strongly acid (pH 5.5); clear wavy boundary.

IIA2 23-42 cm Silt loam, light yellowish brown (10YR 6/4) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; 5% gravels, 5% cobbles, 5% stones; few fine and medium roots; slightly acid (pH 6.5); clear wavy boundary.

IIA&B 42-65 cm Silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, trace cobbles, trace stones; few fine and medium roots; neutral (pH 7.0); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIB2t 65-80 cm Silt loam, light olive brown (2.5Y 5/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; few fine roots; neutral (pH 7.0); gradual wavy boundary.

K3BC Continued -

IIC1ca 80-120 cm Silt loam, olive yellow (5Y 6/6) with 15% of ped faces (10YR 4/4) moist; moderate fine and medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; few fine roots; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 120-175 cm Silt loam, olive yellow (5Y 6/8 with 50% of ped faces 10YR 4/4 and 40% bands of weathered lime) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles; very strongly effervescent; moderately alkaline (pH 8.0); clear wavy boundary.

IIC3ca 175-230 cm Gravelly silt loam, olive yellow (5Y 6/8 with 50% of ped faces 10YR 4/4) moist; strong medium and coarse subangular blocky structure; very firm, slightly sticky, nonplastic; very few clay films; 15% gravels, 5% cobbles, trace stones; very strongly effervescent; moderately alkaline (pH 8.0).

K3AM

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-10-79
LOCATION: Kootenai Nat. For., site 3, moderate disturbance, first replication; NE¼, SW¼, Sec. 11, T32N, R26W
ELEVATION: 1530 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 11% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

O1 2-0 cm

B2ir 0-21 cm Silt, yellowish brown (10YR 5/8) moist; moderate medium and coarse subangular blocky structure; very friable, nonsticky, nonplastic; many fine, medium and coarse roots; strongly acid (pH 5.5); clear wavy boundary.

IIA2 21-43 cm Silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; 5% gravels, 5% cobbles, trace stones; common fine and few medium roots; medium acid (pH 6.0); gradual wavy boundary.

IIA&B 43-70 cm Silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 10% gravels, 5% cobbles; few fine roots; neutral (pH 7.0); gradual wavy boundary; horizon 70% IIA2, 30% IIB2.

IIB2t 70-95 cm Silt loam, olive yellow (5Y 6/6) moist; strong medium and coarse subangular blocky structure; friable, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; trace gravels, trace cobbles; few fine and medium roots; mildly alkaline (pH 7.5); clear wavy boundary.

IIC1ca 95-125 cm Gravelly silt loam, olive yellow (5Y 6/6) moist; 20% of ped faces dark yellowish brown (10YR 4/4); moderate medium subangular blocky structure; friable, slightly sticky, nonplastic, very few clay films; 15% gravels, 5% cobbles, 5%

K3AM Continued -

stones; few fine roots; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 125-230 cm Gravelley silt loam, olive yellow (5Y 6/6) moist; less than 5% of ped faces dark yellowish brown (10YR 4/4); moderately medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 15% gravels, 10% cobbles, 5% stones; strongly effervescent; moderately alkaline (pH 8.0).

K3BM

CLASSIFICATION: coarse loamy, mixed, cryic Typic Paleboralf (propose Ardic subgroup)
DATE DESCRIBED: 9-10-79
LOCATION: Kootenai Nat. For., site 3, moderate disturbance, second replication; SE¼, NW¼, Sec. 11, T32N, R26W
ELEVATION: 1530 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 11% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 20 cm

A2 0-2 cm Horizon very thin and discontinuous.

B2ir 2-23 cm Silt, yellowish brown (10YR 5/8) moist; moderate medium subangular blocky structure; very friable, nonsticky, nonplastic; trace gravels; many medium and coarse and common fine roots; medium acid (pH 6.0); clear wavy boundary.

IIA2 23-56 cm Silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; friable, non-sticky, nonplastic; 10% gravels, 5% cobbles, trace stones; few fine and medium roots; slightly acid (pH 6.5); gradual wavy boundary.

IIA&B 56-85 cm Silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; friable, non-sticky, nonplastic; very few clay films; 10% gravels, trace cobbles; few fine and medium roots; slightly acid (pH 6.5); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIB2t 85-125 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, slightly plastic; many moderately thick clay films on face of peds; 5% gravels, 5% cobbles; few fine and medium roots; neutral (pH 6.7); diffuse irregular boundary.

IIC1ca 125-160 cm Silt loam, light olive brown (2.5Y 5/4) moist; 60% of ped faces dark yellowish brown (10YR 4/4); moderate medium subangular blocky structure; firm, slightly sticky, slightly

K3BM Continued -

plastic; very few clay films; 5% gravels, 5% cobbles; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 160-230 cm Silt loam, olive (5Y 5/6) moist; 20% of ped faces dark yellowish brown (10YR 4/4); moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles; strongly effervescent; moderately alkaline (pH 8.0).

K3AS

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-10-79
LOCATION: Kootenai Nat. For., site 3, severe disturbance, first replication; NE¼, SW¼, Sec. 11, T32N, R26W
ELEVATION: 1530 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

B2ir 0-25 cm Silt, yellowish brown (10YR 5/8) moist; strong coarse subangular blocky and platy structure; friable, nonsticky, nonplastic; few fine, medium and coarse roots; strongly acid (pH 5.3).

IIA2 25-55 cm White (2.5Y 8/2) silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; soft, friable, nonsticky, nonplastic; 10% gravels, 5% cobbles; few fine, medium and coarse roots; strongly acid (pH 5.5).

IIA&B 55-80 cm Silt loam, light yellowish brown (2.5Y 6/4) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles; few fine and medium roots; medium acid (pH 6.0); horizon 60% IIA2, 40% IIB2.

IIB2t 80-110 cm Silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; few fine and medium roots; slightly acid (pH 6.5).

IIC1ca 110-140 cm Silt loam, olive yellow (5Y 6/6); 70% ped faces coated dark yellowish brown (10YR 4/4); moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; strongly effervescent; neutral (pH 7.3).

<u>K3AS</u> Continued -

IIC2ca 140-230 cm Gravelly silt loam, olive yellow (5Y 6/6) moist; 25% ped faces dark yellowish brown (10YR 4/4); moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 15% gravels, 10% cobbles, 5% stones; strongly effervescent; mildly alkaline (pH 7.5).

K3BS

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-10-79
LOCATION: Kootenai For., site 3, severe disturbance, second replication; SE¼, NW¼, Sec. 11, T32N, R26W
ELEVATION: 1530 m
VEGETATION: SAF/CLUN
PARENT MATERIAL: Limestone dominated glacial till
SLOPE and ASPECT: 11% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 5-0 cm

B2ir 0-20 cm Silt, yellowish brown (10YR 5/8) moist; strong coarse subangular blocky and platy structure; friable, nonsticky, nonplastic; trace cobbles; common fine and many medium and coarse roots; slightly acid (pH 6.5); clear wavy boundary.

IIA2 20-37 cm Silt loam, light olive brown (2.5Y 5/4) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; 5% gravels, 5% cobbles; few fine, medium and coarse roots; neutral (pH 6.7); gradual wavy (broken) boundary.

IIA&B 37-52 cm Silt loam, pale olive (5Y 6/4) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; trace gravels, 5% cobbles; few fine and medium roots; mildly alkaline (pH 7.5); diffuse irregular boundary; horizon 60% IIA2, 40% IIB2.

IIB2t 52-88 cm Heavy silt loam, light olive brown (2.5Y 5/6) moist; moderate medium subangular blocky structure; friable, sticky, slightly plastic; very few clay films; 5% gravels; few fine and medium roots; mildly alkaline (pH 7.5); gradual wavy boundary.

IIC1ca 88-110 cm Heavy silt loam, olive yellow (5Y 6/6) moist; 10% ped faces dark yellowish brown (10YR 4/4); moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; trace gravels, 5% cobbles; strongly effervescent; moderately akaline (pH 8.0); clear wavy boundary.

K3BS Continued -

IIC2ca 110-140 cm Silt loam, olive yellow (5Y 6/6 with 60% of ped faces 10YR 4/4) moist; moderate fine and medium subangular block and angular blocky structure; firm, slightly sticky, slightly plastic; trace gravels, trace cobbles; strongly effervescent; moderately alkaline (pH 8.0); clear wavy boundary.

IIC3ca 140-200 cm Silt loam, olive (5Y 5/6) moist; 25% ped faces dark yellowish brown (10YR 4/4); moderate medium subangular blocky and angular blocky structure; firm, slightly sticky, slightly plastic;; 5% gravels, trace cobbles; strongly effervescent; moderately alkaline (pH 8.0).

APPENDIX IV

SOIL PROFILE DESCRIPTIONS FOR PEDONS FORMING IN QUARTZITE DOMINATED GLACIAL TILL PARENT MATERIAL

F2AC

CLASSIFICATION: coarse loamy, mixed, cryic Andeptic Cryoboralf
DATE DESCRIBED: 8-19-79
LOCATION: Flathead Nat. For., site 2, control, first replication; SW¼, NE¼, Sec. 16, T29N, R25E
ELEVATION: 1402 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8-10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

O1 9-0 cm.

B2ir 0-29 cm Silt loam, dark yellowish brown (10YR 3/4) moist; moderate medium subangular blocky structure; soft friable, nonsticky, nonplastic; 10% cobbles, 5% stones, 10% boulders; common fine, medium and coarse roots; very strongly acid (pH 4.7); clear smooth boundary.

IIA2 29-69 cm White (2.5Y 8/1) silt, pale olive (5Y 6/4) moist; weak fine subangular blocky to granular structure; soft, friable, nonsticky; 15% gravels, trace cobbles, trace stones; few fine, medium and coarse roots; extremely acid (pH 4.5); gradual irregular boundary.

IIA&B 69-116 cm Silt, reddish brown (5YR 5/3) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; many moderately thick clay films on face of peds; few fine and medium roots; strongly acid (pH 5.5); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC1 116-163 cm Silt, greyish brown (10YR 5/2) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; many moderately thick clay films on face of peds and line pores; neutral (pH 7.0).

F2BC

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 8-18-79
LOCATION: Flathead Nat. For., site 2, control, second replication; SW¼, NE¼, Sec. 16, T29N, R25W
ELEVATION: 1402 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8-10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 8-0 cm.

B2ir 0-20 cm Light brown to pinkish grey (7.5YR 6/3) silt loam, dark yellowish brown (10YR 4/4) moist; moderate medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; many fine and few medium and coarse roots; extremely acid (pH 4.5); gradual wavy boundary.

IIA2 20-70 cm White to pinkish white (7.5YR 8/1) cobbly silt loam, pale olive (5Y 6/4) moist; weak fine subangular blocky to granular structure; slightly hard, friable, nonsticky, nonplastic; few fine and medium roots; slightly acid (pH 6.3); gradual irregular boundary.

IIA&B 70-113 cm Gravelly silt loam, olive brown to dark greyish brown (2.5Y 4/3) moist; moderate medium subangular blocky structure; firm, slightly sticky, nonplastic; many moderately thick clay films on face of peds and lining pores; few fine roots; neutral (pH 7.0); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC1 113-150 cm Silt loam, brown (7.5YR 5/3) moist; strong coarse subangular blocky structure; firm, slightly sticky, slightly plastic; continuous thick clay films on face of peds; moderately alkaline (pH 8.0).

F2AM

CLASSIFICATION: coarse loamy, mixed cryic Typic Paleboralf
DATE DESCRIBED: 8-18-79
LOCATION: Flathead Nat. For., site 2, moderate disturbance, first replication; SW¼, NE¼, Sec. 16, T29N, R25W
ELEVATION: 1402 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8-10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 7-0 cm.

B2ir 0-12 cm Very pale brown (10YR 7/3) silt loam, dark yellowish brown (10YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky, slightly plastic; 10% gravels, 5% cobbles, 10% stones; many fine and common medium and coarse roots; strongly acid (pH 5.3); clear wavy boundary.

IIA2 12-76 cm White (2.5Y 8/1) gravelly silt loam, light brown to pinkish grey (7.5YR 6/3) moist; weak fine subangular blocky to granular structure; loose, friable, nonsticky, nonplastic; few fine roots; medium acid (pH 6.0); diffuse irregular boundary.

IIA&B 76-103 cm Silt loam, pale olive (5Y 6/4) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; common thin clay films on face of peds; neutral (pH 7.0); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC1 103-155 cm Silt loam, pale olive (5Y 6/3) moist; strong coarse subangular blocky structure; firm, nonsticky, nonplastic; continuous thick clay films on face of peds; mildly alkaline (pH 7.5).

F2BM

CLASSIFICATION: coarse loamy, mixed Typic Cryoboralf
DATE DESCRIBED: 8-18-79
LOCATION: Flathead Nat. For., site 2, moderate disturbance, second replication; SW¼, NE¼, Sec. 16, T29N, R25W
ELEVATION: 1402 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8-10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

O1 7-0 cm.

B2ir 0-15 cm Light brown (7.5YR 6/4) silt loam, brown to dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; common fine and medium and few coarse roots; strongly acid (pH 5.3); clear wavy boundary.

IIA2 15-71 cm White (2.5Y 8/1) gravelly silt loam, light brown to pinkish grey (7.5YR 6/3) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; some cobbles; few fine medium and coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA&B 71-115 cm Silt loam, brown (7.5YR 5/3) moist; moderate medium subangular blocky structure; firm, slightly sticky, slightly plastic; many moderately thick clay films on face of peds and lining pores; neutral (pH 7.0); clear wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC1 115-157 cm Silty clay, pale olive (5Y 6/3) moist; strong medium subangular blocky structure; firm, sticky, slightly plastic; continuous moderately thick clay films on face of peds; mildly alkaline (pH 7.5).

F2AS

CLASSIFICATION: coarse loamy, mixed, Andeptic Cryoboralf
DATE DESCRIBED: 8-19-79
LOCATION: Flathead Nat. For., site 2, severe disturbance, first replication; SW¼, NE¼, Sec. 16, T29N, R25W
ELEVATION: 1402 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8-10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 2-0 cm.

B21ir 0-6 cm Pink to pinkish grey (7.5YR 7/3) silt loam, dark yellowish brown (10YR 4/4) moist; weak medium platy and strong coarse subangular blocky structure; soft, friable, nonsticky, nonplastic; 10% cobbles; common fine and few medium and coarse roots; extremely acid (pH 4.3); clear smooth boundary.

B22ir 6-30 cm Brown (7.5YR 5/4) silt loam, yellowish brown (10YR 5/4) moist; moderate medium subangular blocky and angular blocky structure; slightly hard, firm, nonsticky, nonplastic; 10% gravels, 15% cobbles; common fine and few medium and coarse roots; very strongly acid (pH 4.7); clear smooth boundary.

IIA2 30-78 cm White (2.5Y 8/1) gravelly silt, pale olive (5Y 6/3) moist; moderate medium subangular blocky to granular structure; slightly hard, friable, nonsticky, nonplastic; trace cobbles; few fine, medium and coarse roots; very strongly acid (pH 5.0); clear wavy boundary.

IIA&B 78-121 cm Gravelly silt, olive (5Y 5/3) moist; moderate medium subangular blocky structure; friable, nonsticky; many thin clay films on face of peds and line pores; strongly acid (pH 5.5); clear wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC 121-168 cm Silt loam, brown (7.5YR 5/2) moist; strong medium subangular blocky structure; friable, slightly sticky, slightly plastic; many thin clay films on face of peds; medium acid (pH 6.0).

F2BS

CLASSIFICATION: coarse loamy, mixed Typic Cryochrept
DATE DESCRIBED: 8-19-79
LOCATION: Flathead Nat. For., site 2, severe disturbance, second replication; SW¼, NE¼, Sec. 16, T29N, R25W
ELEVATION: 1402 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8-10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 2-0 cm.

B2ir 0-11 cm Light grey to pale yellow (2.5Y 7/3) silt loam, dark yellowish brown (10YR 4/4) moist; moderate medium platy structure; slightly hard, firm, slight sticky, slightly plastic; many fine and common medium roots; strongly acid (pH 5.5); clear smooth boundary.

IIA2 11-62 cm White (2.5Y 8/1) gravelly silt, pale olive (5Y 6/4) moist; moderate medium subangular blocky structure; hard, firm, nonsticky, nonplastic; 10% cobbles, trace stones, trace boulders; few fine roots; very strongly acid (pH 4.7); diffuse irregular boundary.

IIA&B 62-112 cm Gravelly silt, brown (7.5YR 5/3) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; common thin clay films of face of peds; 10% cobbles, 5% stones; medium acid (pH 6.0); clear smooth boundary; horizon 60% IIA2, 40% IIB2.

IIC1 112-124 cm Silt, light brownish gray (10YR 6/2) moist; weak medium angular blocky structure; friable, nonsticky, nonplastic; neutral (pH 7.0); clear wavy boundary.

IIC2 124-184 cm Silt, greyish brown (10YR 5/2) moist; strong coarse subangular blocky structure; firm, nonsticky, nonplastic; many thin clay films on face of peds; trace gravels, 5% cobbles, 5% boulders; neutral (pH 7.0).

F3AC

CLASSIFICATION: coarse loamy, mixed Andic Cryochrept
DATE DESCRIBED: 8-19-79
LOCATION: Flathead Nat. For., site 3, control, first replication; NW¼, SE¼, Sec. 9, T29N, R25W
ELEVATION: 1402 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8-10% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 4-0 cm.

A2 0-4 cm Pale brown (10YR 6/3) silt, dark yellowish brown (10YR 4/4) moist; weak fine subangular blocky to granular structure; soft, very friable; nonsticky, nonplastic; many fine, medium and coarse roots; very strongly acid; clear smooth boundary.

B2ir 4-20 cm Yellowish brown (10YR 5/8) silt, strong brown (7.5 YR 4/6) moist; moderate medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; trace cobbles; common fine, medium and coarse roots; slightly acid (pH 6.5); clear wavy boundary.

IIA2 20-80 cm White (10YR 8/1) gravelly silt loam, light yellowish brown (10YR 6/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 15% gravels, 5% cobbles; few fine and medium roots; very strongly acid (pH 4.5) gradual irregular boundary.

IIA&B 80-130 cm Light grey (2.5Y 7/2) gravelly silt loam, light olive brown (2.5Y 5/4) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; very few clay films; 15% gravels, 5% cobbles, 5% stones, 5% boulders; few fine and medium roots; medium acid (pH 6.0); gradual irregular boundary; horizon 80% IIA2, 20% IIB2.

IIC1 130-200 cm Gravelly silt loam, yellowish brown (10YR 5/4) moist; moderate medium subangular blocky structure; friable, slightly sticky; common moderately thick clay films on face of peds; mildly alkaline (pH 7.5).

F3BC

CLASSIFICATION: coarse loamy, mixed Dystric Cryochrept
DATE DESCRIBED: 8-19-79
LOCATION: Flathead Nat. For., site 3, control, second replication; NW¼, SE¼, Sec. 9, T29N, R25W
ELEVATION: 1463 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 15% East to northeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 6-0 cm.

A2 0-3 cm Light grey (10YR 7/2) silt, very dark greyish brown (10YR 3/2) moist; weak fine subangular blocky structure; soft, very friable; nonsticky, nonplastic; many fine, medium and coarse roots; very strongly acid (pH 5.0); clear smooth boundary.

B2ir 3-15 cm Light yellowish brown (10YR 6/4) silt, dark yellowish brown (10YR 4/4) moist; moderately fine subangular blocky structure; soft, very friable, nonsticky, nonplastic; 10% gravels; many fine, medium and coarse roots; medium acid (pH 6.0); clear smooth boundary.

IIA2 15-53 cm White (2.5Y 8/2) silt loam, light yellowish brown (2.5Y 6/4) moist; moderate fine angular blocky structure; slightly hard, firm, sticky, slightly plastic; 5% gravels, 5% cobbles; few fine medium and coarse roots; very strongly acid (pH 4.5); clear wavy boundary.

IIA&B 53-92 cm Very gravelly silt, olive (5Y 5/4) moist; weak very fine subangular blocky to granular structure; friable, nonsticky, nonplastic; 60% gravels, 15% cobbles, 5% stones; few fine roots; slightly acid (pH 6.3); clear wavy boundary; horizon 80% IIA2, 20% IIB2.

IIC 92-148 cm Very gravelly silt, pink to pinkish grey (7.5YR 7/3) moist; weak fine granular structure; very friable, nonsticky, nonplastic; 50% gravels, 15% cobbles, 10% stones, 5% boulders; slightly acid (pH 6.5).

F3AM

CLASSIFICATION: coarse loamy, mixed Andic Cryochrept
DATE DESCRIBED: 8-20-79
LOCATION: Flathead Nat. For., site 3, moderate disturbance, first replication; NW¼, SE¼, Sec. 9, T29N, R25W
ELEVATION: 1463 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 14% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 6-0 cm.

A2 0-3 cm Pinkish white (7.5 YR 8/2) silt, dark brown (7.5YR 3/4) moist; moderate coarse platy structure; soft, friable, nonsticky, nonplastic; many fine and common medium and coarse roots; very strongly acid (pH 5.0); clear smooth boundary.

B2ir 3-32 cm Yellowish brown (10YR 5/6) silt, yellowish red (5YR 4/6) moist; moderate medium subangular blocky structure; loose, friable, nonsticky, nonplastic; 5% cobbles, 5% stones; common fine and few medium and coarse roots; strongly acid (pH 5.5); clear smooth boundary.

IIA2 32-74 cm Gravelly silt, light brown to pinkish grey (7.5YR 6/3) moist; moderate medium subangular blocky and angular blocky structure; friable, nonsticky, nonplastic; 20% gravels, 10% cobbles, 5% stones; few fine, medium and coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA&B 74-124 cm Gravelly silt, olive (5Y 5/4) moist; moderate medium subangular blocky and angular blocky structure; firm, nonsticky, nonplastic; 25% gravels, 5% cobbles, 5% stones; few fine roots; strongly acid (pH 5.5); clear wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC 124-176 cm Gravelly silt, olive (5Y 5/4) moist; moderate medium angular blocky structure; friable, nonsticky, nonplastic; 15% gravels, 5% cobbles, 5% stones, trace boulders; strongly acid (pH 5.5).

F3BM

CLASSIFICATION: coarse loamy, mixed Andic Cryochrept
DATE DESCRIBED: 8-20-79
LOCATION: Flathead Nat. For., site 3, moderate disturbance, second replication; NW¼, SE¼, Sec. 9, T29N, R25W
ELEVATION: 1463 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 15% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 3-0 cm

B21r 0-30 cm Yellow (10YR 7/6) silt, olive brown (2.5Y 4/6) moist; moderate medium subangular blocky structure; loose, very friable, nonsticky, nonplastic; trace stones, trace boulders; many fine and common medium and coarse roots; very strongly acid (pH 4.7); clear smooth boundary.

IIA2 30-75 cm Silt, pale olive (5Y 6/4) moist; moderate medium subangular blocky structure; very hard, very firm, nonsticky; partially rounded, 5% cobbles, trace stones; few fine and medium roots; extremely acid (pH 4.3); clear wavy boundary.

IIA&B 75-125 cm Silt, light brown to pinkish grey (7.5YR 6/3) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; 10% gravels, 5% cobbles, 5% stones; few fine roots; strongly acid (pH 5.5); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC1 125-140 cm Gravelly silt loam, olive (5Y 5/4) moist; mottles of 5YR 7/8; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; few thin clay films on face of peds; 20% gravels, 10% cobbles, 5% stones, 5% boulders; strongly acid (pH 5.5); clear smooth boundary.

IIC2 140-165 cm Silt, olive (5Y 5/4) moist; weak medium subangular blocky structure; very friable, nonsticky, nonplastic; very few clay films; 5% gravels; slightly acid (pH 6.3).

NOTE: 20% stones and boulders on surface.

F3AS

CLASSIFICATION: coarse loamy, mixed Dystric Cryochrept
DATE DESCRIBED: 8-20-79
LOCATION: Flathead Nat. For., site 3, severe disturbance, first replication; NW¼, SE¼, Sec. 9, T29N, R25W
ELEVATION: 1463 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 8% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 7-0 cm.

A2 0-3 cm Light grey (10YR 7/2) silt, dark yellowish brown (10YR 3/4) moist; weak medium platy structure; very strongly acid (pH 4.5).

B2ir 3-16 cm Silt, dark yellowish brown (10YR 4/4) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; many fine and few medium and coarse roots; strongly acid (pH 5.5); clear smooth boundary.

IIA2 16-92 cm White to pinkish white (7.5YR 8/1) gravelly silt, pale olive (5Y 6/4) moist; moderate medium subangular blocky and angular blocky structure; slightly hard, firm, nonsticky, nonplastic; 15% gravels, 5% cobbles, 5% stones; few fine and medium roots; slightly acid (pH 6.3); clear wavy boundary.

IIA&B 92-135 cm Gravelly silt loam, olive (5Y 5/4) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 15% gravels, 5% cobbles, 5% stones; few fine roots; strongly acid (pH 5.5); clear wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC1 135-150 cm Gravelly silt loam, pale olive (5Y 6/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky; very few clay films; trace gravels; neutral (pH 7.0); clear smooth boundary.

F3AS Continued -

IIC2 150-192 cm Gravelly silt, pale olive (5Y 6/4) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; 15% gravels, 5% cobbles; neutral (pH 7.0).

F3BS

CLASSIFICATION: coarse loamy, mixed Andic Cryochrept
DATE DESCRIBED: 8-20-79
LOCATION: Flathead Nat. For., site 3, severe disturbance, second replication; NW¼, SE¼, Sec. 9, T29N, R25W
ELEVATION: 1463 m
VEGETATION: AF/VACA
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 14% East to southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 5-0 cm.

A2 0-2 cm Light grey (10YR 7/2) silt, dark yellowish brown (10YR 3/4) moist; mottles 10YR 5/6; moderate medium platy structure; slightly hard, firm, nonsticky, nonplastic; many fine, common medium and few coarse roots; very strongly acid (pH 5.0); clear smooth boundary.

B2ir 2-29 cm Light brown (7.5 YR 6/4) silt, dark yellowish brown (10YR 4/4) moist; moderate medium subangular blocky structure; soft, friable, nonsticky, nonplastic; 5% gravels, 5% cobbles; common fine and few medium and coarse roots; medium acid (pH 6.0); clear smooth boundary.

IIA2 29-62 cm White to pinkish white (7.5YR 8/1) gravelly silt, olive (5Y 5/4) moist; weak fine angular blocky and subangular blocky structure; soft, friable, nonsticky, nonplastic; 15% gravels, 5% cobbles, 5% stones; slightly acid (pH 6.2); clear wavy boundary.

IIA&B 62-121 cm Gravelly silt, brown (7.5YR 5/3) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; 20% gravels, 5% cobbles, 5% stones, 5% boulders; very strongly acid (pH 5.0); gradual wavy boundary; horizon 60% IIA2, 40% IIB2.

IIC1 121-175 cm Gravelly silt, brown (7.5YR 5/3) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; 20% gravels, 5% cobbles, 5% stones; strongly acid (pH 5.5).

K1AC

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-9-79
LOCATION: Kootenai Nat. For., site 1, control, first replication; SE¼, SW¼, Sec.12, T32N, R27W
ELEVATION: 1402 m
VEGETATION: SAF/LIBO/XETE
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 5% South to Southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

O1 10-0 cm

A2 0-5 cm Light gray (10YR 7/1) silt, grayish brown (10YR 5/2) moist; weak fine subangular blocky and angular blocky structure; soft, very friable, nonsticky, nonplastic; many fine, medium and coarse roots; very strongly acid (pH 4.5); clear smooth boundary.

B2ir 5-30 cm Yellow (10YR 7/6) silt, brownish yellow (10YR 6/8) moist; weak fine subangular blocky to granular structure; loose, very friable, nonsticky, nonplastic; 5% gravels, 5% cobbles; many fine, medium and common coarse roots; neutral (pH 6.8); clear smooth boundary.

IIA2 30-58 cm White (10YR 8/2) silt, light yellowish brown (10YR 6/4) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; 10% gravels, 5% cobbles, 5% stones, 5% boulders; common fine and medium, few coarse roots; slightly acid (pH 6.2); gradual wavy boundary.

IIA&B 58-98 cm Yellow (2.5Y 7/8 with 15-20% 7.5YR 7/8) silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; 5% gravels, 5% cobbles, 5% stones, 5% boulders; few fine and medium roots; slightly acid (pH 6.5); clear wavy boundary.

IIC1ca 98-150 cm Silt loam, olive yellow (2.5Y 6/6) moist; weak fine subangular blocky and moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay

K1AC Continued -

films; 10% gravels, trace stones; few fine, medium and coarse roots; violently effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 150-180 cm Silt loam, olive Yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, trace stones; violently effervescent; moderately alkaline (pH 8.0); clear wavy boundary.

KlBC

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-9-79
LOCATION: Kootenai Nat. For., site 1, control, second replication; NW½, Sec. 13, T32N, R27W
ELEVATION: 1402 m
VEGETATION: SAF/LIBO/XETE
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 14% South to Southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 6-0 cm

A2 0-5 cm Light grey (2.5Y 7/2) silt, dark yellowish brown (10YR 4/4) moist; weak fine subangular blocky to granular structure; soft, very friable, nonsticky, nonplastic; many fine, medium, and coarse roots; very strongly acid (pH 5.0); clear smooth boundary.

B2ir 5-22 cm Brownish yellow (10YR 6/6), silt, dark yellowish brown (10YR 4/6) moist; weak fine subangular blocky to granular structure; soft, very friable, nonsticky, nonplastic; trace gravels, 5% cobbles; many fine, medium, and coarse roots; medium acid (pH 6.0); gradual wavy boundary.

IIA2 22-43 cm White (2.5Y 8/2) silt loam, very pale brown (10YR 7/4) moist; moderate medium subangular blocky structure; slightly hard, firm, nonsticky, nonplastic; 5% gravels, 5% cobbles, 5% stones, 5% boulders; common fine and medium and few coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA&B 43-115 cm Yellow (2.5Y 7/6) silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky, slightly plastic; very few clay films; 5% gravels, 5% cobbles, 5% stones, 5% boulders; common fine and few medium roots; mildly alkaline (pH 7.5); diffuse irregular boundary.

IIClca 115-175 cm Silt loam, olive yellow (2.5Y 6/6, with 10YR 5/6 on 50% of ped faces) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, slightly

K1BC Continued -

plastic; very few clay films; trace gravels, 5% cobbles, 5% stones, 5% boulders; few fine and medium roots; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2ca 175-200 cm Silt loam, olive yellow (2.5Y 6/6 with 20% of ped faces 10YR 5/6) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; trace gravel, 5% cobbles, 5% stones; moderately alkaline (pH 8.0); indistinct wavy boundary.

K1AM

CLASSIFICATION: coarse loamy, mixed Andic Cryochrept
DATE DESCRIBED: 9-9-79
LOCATION: Kootenai Nat. For., site 1, moderate disturbance, first replication; SE¼, SW¼, Sec. 12, T32N, R27W
ELEVATION: 1402 m
VEGETATION: SAF/LIBO/XETE
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 10% East to Southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 8-0 cm

A2 0-7 cm Light gray (10YR 7/2) silt, brown (10YR 5/3) moist; weak fine subangular blocky to platy structure; soft, very friable, nonsticky, nonplastic; very few clay films; many fine and medium and few coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

B2ir 7-22 cm Yellowish brown (10YR 5/8) silt, dark yellowish brown (10YR 4/6) moist; moderate medium subangular blocky to granular structure; soft, very friable, nonsticky, nonplastic; very few clay films; trace gravels, trace cobbles; many fine, common medium and few coarse roots; medium acid (pH 6.0); gradual wavy boundary.

IIA2 22-50 cm Very pale brown (10YR 8/3), gravelly silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; very few clay films; 15% gravels, 5% cobbles; few fine and medium roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA&B 50-130 cm Silt loam, olive yellow (5Y 6/8) moist; strong fine to medium subangular block structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; few fine roots; neutral (pH 7.0); diffuse wavy boundary; horizon 70% IIA2, 30% IIB2.

IIC1 130-145 cm Silt loam, olive yellow (5Y 6/8 with 15% 10YR 5/4); moist; moderate fine subangular blocky and angular blocky structure; friable, slightly sticky, nonplastic; very few

<u>K1AM</u> Continued -

clay films; 5% gravels, 5% cobbles, 5% stones; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2 145-190 cm Silt loam, olive yellow (5Y 6/8 with trace of brown coatings) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; 5% gravels, 5% cobbles, trace stones; strongly effervescent; moderately alkaline (pH 8.0); clear wavy boundary.

K1BM

CLASSIFICATION: coarse loamy, mixed Andic Cryochrept
DATE DESCRIBED: 9-9-79
LOCATION: Kootenai Nat. For., site 1, moderate disturbance, second replication; E½, NW¼, Sec. 13, T32N, R27W
ELEVATION: 1402 m
VEGETATION: SAF/LIBO/XETE
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 7% East to Southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 8-0 cm

A2 0-6 cm White (2.5Y 8/2 with mixed organic material) silt, brown (10YR 5/3) moist; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; many fine, medium and coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

B2ir 6-21 cm Silt, yellowish brown (10YR 5/6) moist; moderate medium subangular blocky and angular blocky structure; loose, very friable, nonsticky, nonplastic; trace gravel, trace cobbles; many fine and medium and common coarse roots; strongly acid (pH 5.5); gradual wavy boundary.

IIA2 21-40 cm Very pale brown (10YR 8/3) silt loam, light olive brown (2.5Y 5/6) moist; moderate medium subangular blocky structure; hard, firm, nonsticky, nonplastic; 10% gravels, 5% cobbles, trace stones; common fine and few medium and fine roots; neutral (pH 7.0); diffuse wavy boundary.

IIA&B 40-115 cm Silt loam, light olive brown (2.5Y 5/6) moist; strong medium and coarse subangular blocky structure; friable, slightly sticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones and boulders; few fine and medium roots; neutral (pH 7.0); diffuse irregular boundary; horizon 60% IIA2, 40% IIB2.

IIC1ca 115-165 cm Gravelly silt loam, olive yellow (5Y 6/8) with 20% of ped faces 10YR 5/4) moist; moderate medium subangular blocky and angular blocky structure; friable, slightly sticky, non-

K1BM Continued -

plastic; very few clay films; 15% gravels, 5% cobbles; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2 165-200 cm Silt loam, olive yellow (5Y 6/8) moist; moderate medium subangular blocky and angular blocky structure; firm, nonsticky, nonplastic; 10% gravels, 5% cobbles; moderately alkaline (pH 8.0); gradual wavy boundary.

K1AS

CLASSIFICATION: coarse loamy, mixed Andeptic Cryoboralf
DATE DESCRIBED: 9-9-79
LOCATION: Kootenai Nat. For., site 1, severe disturbance, first replication; SE¼, SW¼, Sec. 12, T32N, R27W
ELEVATION: 1402 m
VEGETATION: SAF/LIBO/XETE
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 15% South to Southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01	4-0 cm
A2	0-2 cm Light grey (2.5Y 7/2) silt, dark yellowish brown (10YR 4/4) moist; weak very fine subangular blocky and granular structure; slightly hard, nonsticky, nonplastic; common fine, medium and coarse roots; very strongly acid (pH 4.5); clear wavy boundary.
B2ir	2-22 cm Brownish yellow (10YR 6/8) silt, yellowish brown (10YR 5/8) moist; strong coarse subangular blocky structure; soft, very friable nonsticky, nonplastic; 5% cobbles, 5% stones, 10% boulders; common few, medium, and coarse roots; strongly acid (pH 5.5); clear wavy boundary.
IIA2	22-42 cm Very pale brown (10YR 8/3) silt loam, yellow (2.5Y 7/6); moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; trace gravels, 5% cobbles, 5% stones, trace boulders; few fine, medium, and coarse roots; medium acid (pH 6.0); gradual wavy boundary.
IIA&B	42-100 cm Silt loam, olive yellow (5Y 6/6) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; trace gravels, 5% cobbles, 5% stones; few fine, medium, coarse roots; slightly acid (pH 6.5); diffuse irregular boundary; horizon 60% IIA2, 40% IIB2.
IIC1	100-130 cm Silt loam, olive yellow (5Y 6/8 with 15% having brown stain) moist; moderate fine and medium subangular blocky structure; friable, slightly sticky, nonplastic; very few clay

<u>KlAS</u> Continued -

films; 5% gravels, 5% cobbles, trace stones; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

IIC2 130-200 cm Silt loam, olive yellow (5Y 6/8 with 5% brown coating) moist; moderate fine and medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; strongly effervescent; moderately alkaline (pH 8.0).

K1BS

CLASSIFICATION: coarse loamy, mixed Andic Cryochrept
DATE DESCRIBED: 9-9-79
LOCATION: Kootenai Nat. For., site 1, severe disturbance, second replication; E½, NW¼, Sec. 13, T32N, R27W
ELEVATION: 1402 m
VEGETATION: SAF/LIBO/XETE
PARENT MATERIAL: Quartzite dominated glacial till
SLOPE and ASPECT: 5% South to Southeast
DRAINAGE: Well drained

PROFILE DESCRIPTION

01 4-0 cm

A2 0-2 cm Light grey (2.5Y 7/2) silt, dark yellowish brown (10YR 4/4) moist; weak very fine subangular blocky to granular structure; slightly hard, nonsticky, nonplastic; many fine, medium and coarse roots; strongly acid (pH 5.5); abrupt broken boundary.

B2ir 2-18 cm Brownish yellow (10YR 6/8) silt, yellowish brown (10YR 5/8) moist; strong coarse subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; trace gravels, 5% cobbles, 5% stones; many fine, common medium, few coarse roots; medium acid (pH 6.0); gradual wavy boundary.

IIA2 18-40 cm Very pale brown (10YR 8/3) silt loam, olive yellow (2.5Y 6/6) moist; moderate medium subangular blocky structure; slightly hard friable, nonsticky, nonplastic; 10% gravels, 5% cobbles, 5% stones; few fine and medium roots; medium acid (pH 6.0); diffuse irregular boundary.

IIA&B 40-110 cm Silt loam, yellow (5Y 7/6 with 10% 7.5YR 7/8) moist; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; no clay films; 5% gravels, 5% cobbles, 5% stones; few fine roots; neutral (pH 7.0); diffuse irregular boundary; horizon 60% IIA2, 40% IIB2.

IIC1ca 110-135 cm Silt loam, olive yellow (5Y 6/6 with 10-15% of ped faces 7.5 YR 7/8)moist; strong medium subangular blocky structure; friable, slightly sticky, slightly plastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

<u>K1BS</u> Continued -

IIC2ca 135-190 cm Silt loam, olive yellow (5Y 6/6 with less than 5% ped faces 7.5YR 7/8) moist; moderate medium subangular blocky structure; friable, nonsticky, nonplastic; very few clay films; 5% gravels, 5% cobbles, 5% stones; strongly effervescent; moderately alkaline (pH 8.0).

APPENDIX V

LABORATORY CHARACTERIZATION DATA FOR CONTROL SOIL PEDONS IN TERTIARY VOLCANIC PARENT MATERIAL

B1AC

Horizon	Sample depth	Particle Size Analysis				Textural class	Proctor Analysis		Bulk density	Plastic limit	Liquid limit	Plastic index
		Sand	Silt	Clay	<2 mm		Optimum moisture content	Maximum density achieved				
	cm	%					% wt	g/cc	g/cc	%		
A2	15	50	39	11	97.5	l	13.0	1.83	1.33	25.2	26.4	1.2
B21t	30	26	30	44	97.0	c	17.3	1.97	1.82	61.6	74.0	12.4
B22t	45	22	32	46	97.0	c	25.0	1.57	1.84	24.0	70.0	46.0
B3	110	9	38	53	98.0	c	26.3	1.57	ND	24.1	74.3	50.2

Horizon	O.M.	O.C.	1:1 Extract		Exchangeable Cations					Base saturation	CEC	Particle density	Porosity
			pH	EC	Ca	Mg	Na	K	H				
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A2	2.0	1.2	6.1	0.07	5.81	1.98	0.11	0.57	3.06	73.5	11.53	2.57	48.2
B21t	1.1	.6	6.4	0.09	10.06	9.58	0.13	1.00	15.35	57.5	36.12	2.64	31.1
B22t	1.2	.7	6.6	0.17	21.47	12.64	0.21	1.08	4.42	88.9	39.82	2.69	31.6
B3	1.6	.9	7.3	0.30	24.03	11.72	0.30	1.02	8.62	81.1	45.69	2.73	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance						
				Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	18.3	7.2							
B21t	ND	60.1	26.2							
B22t	ND	76.3	30.0							
B3	ND	ND	32.5							

ND = not determined.

B1BC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
A21	15	45	35	20	92.0	l	14.0	1.89	1.23	23.7	25.0	1.3
A22	30	66	28	6	56.0	sl	13.0	2.00	1.27	20.5	22.5	2.0
B21t	45	17	29	54	90.5	c	30.8	1.46	1.64	32.4	83.6	51.2
B22t	75	22	34	44	96.5	c	26.4	1.58	ND	28.7	60.7	32.0
B3	110	32	28	40	97.0	cl	31.5	1.48	ND	29.0	62.0	33.0

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A21	1.7	1.00	5.4	0.08	6.39	1.02	0.10	0.34	1.07	88.0	8.92	2.66	56.4
A22	1.0	.6	6.7	0.05	2.59	0.72	0.06	0.19	2.67	54.5	6.53	2.57	50.8
B21t	0.5	.3	6.3	0.28	23.79	10.24	0.12	0.92	9.75	78.3	44.82	2.63	37.6
B22t	1.0	.6	6.8	0.10	21.91	11.59	0.10	0.86	4.05	89.5	38.51	2.68	ND
B3	0.4	.2	6.2	0.11	22.91	10.11	0.13	0.69	6.19	84.5	40.03	2.52	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A21	ND	35.1	8.0							
A22	ND	39.4	5.3	Lo	Hi			T		
B21t	ND	49.0	32.0							
B22t	ND	ND	26.6	T	T			Hi		
B3	ND	ND	25.4							

ND = Not determined.

B2AC

Horizon	Sample depth	Particle Size Analysis Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	---------- %			----------		% wt	g/cc	g/cc	---------- %		----------
A2	15	57	38	5	99.8	sl	15.0	1.72	1.42	20.3	23.6	3.3
B21t	30	58	20	22	99.3	scl	14.0	1.87	1.61	22.8	37.8	15.0
B21t	45	73	20	7	99.3	sl	15.4	1.90	1.62	25.7	52.0	26.3
B22t	65	61	19	20	99.7	sl	15.5	1.90	ND	25.2	30.5	5.3

Horizon	O.M.	O.C.	1:1 Extract pH	EC	Exchangeable Cations Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	----------		meq/100g		----------	%	meq/100g	g/cc	%
A2	1.4	.8	5.3	0.25	5.87	1.68	0.09	0.71	3.40	71.1	11.75	2.53	43.9
B21t	.9	.5	5.7	0.24	10.10	4.44	0.09	0.65	4.08	78.9	19.36	2.98	46.0
B21t	.6	.3	5.8	0.15	7.68	3.31	0.10	0.42	4.81	70.5	16.32	2.65	38.9
B22t	.6	.3	5.9	0.16	9.62	2.27	0.15	0.54	5.91	68.0	18.49	2.61	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	25.9	10.3							
B21t	ND	30.3	14.7							
B21t	ND	40.7	9.6							
B22t	ND	ND	12.6							

ND = Not determined.

B2BC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	----------- %			-----------		% wt	g/cc	g/cc	----------- %		-----------
A2	15	50	35	15	88.7	l	17.0	1.78	1.30	21.2	24.7	3.5
B21t	30	23	23	54	95.2	c	27.2	1.43	1.78	27.3	88.3	61.0
B22t	45	31	23	46	95.2	c	23.5	1.47	1.49	31.5	140.0	108.5
B3	75	38	31	31	95.7	cl	19.9	1.70	ND	18.9	56.5	37.6
C1	105	58	19	23	70.1	sl	ND	ND	ND	20.9	44.3	23.4

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	-----------		meq/100g		-----------	%	meq/100g	g/cc	%
A2	1.4	.8	6.4	0.06	5.99	2.24	0.14	0.34	3.91	69.0	12.62	2.58	38.0
B21t	1.7	1.0	6.1	0.13	22.75	12.74	0.37	0.71	9.56	79.3	46.13	2.65	32.8
B22t	1.2	.7	6.4	0.18	20.87	11.36	0.28	0.75	6.34	84.0	39.60	2.66	44.4
B3	1.4	.8	6.5	0.14	8.82	8.86	0.26	0.53	12.21	60.2	30.68	2.57	ND
C1	.6	.3	7.1	0.07	10.34	6.29	0.20	0.32	4.61	78.8	21.76	2.57	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	24.1	10.1	Lo	Med			Lo-Med		
B21t	ND	44.8	35.0							
B22t	ND	44.6	28.9	Lo	Med			Hi		
B3	ND	ND	18.1							
C1	ND	ND	11.1	LO	Med			Hi		

ND = Not determined.

B3AC

Horizon	Sample depth	Particle Size Analysis Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	---------- %			----------		% wt	g/cc	g/cc	---------- %		----------
A2	15	33	50	17	98.6	sil	18.0	1.75	1.29	20.7	23.6	2.9
B21t	30	36	44	20	99.4	l	16.0	1.88	1.71	20.6	28.8	8.2
B21t	45	31	43	26	99.8	cl	20.0	1.73	1.67	21.5	29.3	7.8
B22t	75	41	33	26	99.6	l	20.7	1.80	ND	22.3	32.2	9.9
B23t	125	17	41	42	99.2	l	18.3	1.95	ND	22.3	36.4	14.1

Horizon	O.M.	O.C.	1:1 Extract pH	EC	Exchangeable Cations Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	----------		meq/100g		----------	%	meq/100g	g/cc	%
A2	2.2	1.3	5.6	0.10	4.01	1.22	0.07	0.26	4.88	53.3	10.44	2.62	39.3
B21t	1.0	.6	5.5	0.03	2.65	1.45	0.09	0.19	5.85	42.8	10.23	2.76	38.0
B21t	.9	.5	5.8	0.06	2.55	1.35	0.08	0.15	3.49	54.2	7.62	2.72	42.3
B22t	.2	.1	6.6	0.04	2.63	1.28	0.06	0.11	5.49	42.6	9.57	2.84	ND
B23t	.4	.2	5.9	0.03	2.31	1.42	0.30	0.07	4.60	47.1	8.70	2.77	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	27.1	13.6							
B21t	ND	28.4	15.2							
B21t	ND	27.0	17.8							
B22t	ND	ND	17.0							
B23t	ND	ND	19.2							

ND = Not determined.

B3BC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%	%	%	%		% wt	g/cc	g/cc	%	%	%
A21	8	37	40	23	98.3	l	ND	ND	1.24	33.8	38.3	4.5
A22	15	47	40	13	91.4	l	15.7	1.87	1.26	20.6	24.1	3.5
B21t	30	16	19	65	98.1	c	25.4	1.53	1.49	27.3	89.0	61.7
B21t	45	16	22	62	95.7	c	28.6	1.50	1.62	27.9	69.2	41.3
B22t	75	16	17	67	93.0	c	30.0	1.50	ND	23.3	84.0	60.7
B23t	110	17	18	65	95.5	c	26.2	1.53	ND	24.7	78.0	53.3
IIB31t	150	9	46	45	99.5	sic	21.3	1.72	ND	16.1	36.0	19.9
IIB32t	175	24	50	26	99.7	sil	16.0	1.92	ND	17.3	24.7	7.4

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	g/cc	%
A21	6.0	3.5	5.6	0.16	4.61	1.61	0.06	0.28	9.76	40.2	16.32	2.44	32.8
A22	2.4	1.4	6.3	0.10	5.36	1.91	0.07	0.30	3.46	68.8	11.10	2.63	36.9
B21t	.3	.2	6.8	0.11	18.36	9.68	0.19	0.54	9.74	74.7	38.51	2.44	38.9
B21t	.4	.2	7.0	0.13	18.44	10.11	0.24	0.46	10.57	73.5	39.82	2.62	38.0
B22t	1.5	.9	6.4	0.13	10.36	10.40	0.25	0.59	27.36	44.1	48.96	2.64	ND
B23t	.8	.5	6.5	0.18	23.98	13.76	0.31	0.42	11.14	77.5	49.61	2.65	ND
IIB31t	1.5	.9	6.5	0.15	8.20	4.31	0.19	0.15	5.21	71.2	18.06	2.61	ND
IIB32t	.4	.2	6.6	0.12	4.57	1.98	0.11	0.09	1.30	83.8	8.05	2.55	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A21	ND	ND	11.7							
A22	ND	22.4	12.9	Lo	Lo-Med			T		
B21t	ND	42.2	31.2							
B21t	ND	50.1	29.8							
B22t	ND	ND	30.0	Lo				Hi		
B23t	ND	ND	30.2							
IIB31t	ND	ND	17.1							
IIB32t	ND	ND	14.1	Hi				T		

ND = Not determined.

APPENDIX VI

LABORATORY CHARACTERIZATION DATA FOR CONTROL SOIL PEDONS IN LIMESTONE DOMINATED GLACIAL TILL PARENT MATERIAL

FlAC

Horizon	Sample depth	Particle Size Analysis Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
B2ir	15	31	65	4	72.7	sil	27.5	1.31	.49	NP	NP	NP
IIA2	30	23	66	11	71.2	sil	15.8	1.88	1.60	21.3	23.3	2.0
IIA2	45	25	59	16	50.3	sil	15.0	1.93	1.72	21.4	25.1	3.7
IIA+B	54	44	50	6	69.4	l	16.5	1.87	1.41	21.3	27.3	6.0
IIB+A	71	21	58	21	78.5	sil	16.5	1.88	1.36	22.2	27.9	5.7
IIB21t	88	26	52	22	76.6	sil	14.9	1.89	1.62	20.9	28.0	7.1
IIB22t	110	27	53	20	76.9	sil	16.6	1.88	ND	21.1	26.9	5.8
IIClca	120	33	48	19	70.3	l	12.7	2.00	ND	19.4	26.0	6.6

Horizon	O.M.	O.C.	1:1 Extract pH	EC	Exchangeable Cations Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
B2ir	4.9	2.8	5.5	0.11	2.08	0.23	0.12	0.19	19.36	11.9	21.98	2.53	80.6
IIA2	.8	.5	6.4	0.07	4.95	0.82	0.05	0.15	1.65	78.3	7.62	2.79	42.6
IIA2	.8	.5	6.3	0.06	5.31	0.99	0.06	0.23	1.68	79.7	8.27	2.73	37.0
IIA+B	.6	.3	6.0	0.05	6.71	1.28	0.17	0.13	2.59	76.2	10.88	2.67	47.2
IIB+A	.8	.5	6.7	0.11	7.20	1.32	0.17	0.15	3.34	72.6	12.18	2.77	50.9
IIB21t	1.3	.7	6.8	0.07	7.40	1.38	0.06	0.19	1.20	88.3	10.23	2.62	38.2
IIB22t	.5	.3	6.7	0.10	6.67	1.35	0.05	0.15	0.48	94.5	8.70	2.67	ND
IIClca	.7	.4	6.9	0.20	26.46	1.22	0.09	0.24	0.00	100.0	7.18	2.75	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
B2ir	ND	75.5	15.8						Hi	
IIA2	ND	29.6	13.6							
IIA2	ND	29.4	10.5							
IIA+B	ND	ND	15.4							
IIB+A	ND	28.8	14.2							
IIB21t	ND	32.4	12.4							
IIB22t	ND	ND	12.7							
IIClca	5.6	ND	11.6							

ND = Not determined.
NP = Nonplastic.

FIBC

Horizon	Sample depth	Particle Size Analysis Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
A2	3	27	54	19	ND	sil	ND	ND	ND	ND	ND	ND
B2ir	15	28	59	3	53.9	sil	19.7	1.44	.52	NP	NP	NP
IIA2	30	43	52	5	47.1	sil	12.2	1.85	1.56	NP	NP	NP
IIA2	45	37	57	6	37.8	sil	12.0	1.87	1.47	NP	NP	NP
IIA+B	65	28	58	14	65.5	sil	12.8	1.84	1.46	22.3	22.8	0.5
IIB+A	82	30	54	16	71.6	sil	15.3	1.84	1.42	21.2	25.6	4.4
IIB21t	115	27	57	16	62.9	sil	11.8	1.96	1.46	20.1	28.3	8.2
IIB22t	148	31	52	17	68.2	sil	13.5	1.83	1.59	20.7	28.2	7.5
IIC1ca	170	24	56	20	72.4	sil	13.0	1.92	ND	20.2	26.6	6.4

Horizon	O.M.	O.C.	1:1 Extract pH	EC	Exchangeable Cations Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A2	4.5	2.6	4.7	0.14	2.89	0.86	0.05	0.21	11.22	26.3	15.23	2.52	ND
B2ir	3.4	1.9	5.7	0.05	0.72	0.16	0.06	0.23	16.89	6.5	18.06	2.37	78.1
IIA2	1.0	.6	5.9	0.03	5.45	0.56	0.05	0.13	0.34	94.8	6.53	2.65	41.1
IIA2	.4	.2	6.0	0.03	2.41	0.69	0.23	0.07	1.82	65.1	5.22	2.66	44.7
IIA+B	.3	.2	5.9	0.03	5.69	1.68	0.08	0.13	0.91	89.3	8.49	2.75	46.9
IIB+A	.3	.2	5.7	0.07	7.02	1.28	0.16	0.19	3.02	71.7	10.66	2.65	46.4
IIB21t	.2	.1	6.1	0.05	5.97	1.45	0.17	0.23	3.28	70.5	11.10	2.71	46.1
IIB22t	.6	.3	6.7	0.08	5.93	1.09	0.02	0.15	1.73	80.6	8.92	2.73	41.8
IIC1ca	.3	.2	6.5	0.16	27.66	1.74	0.06	0.24	0	100.0	6.09	2.71	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	ND	11.5	T	T				Hi	T**
B2ir	ND	93.9	14.8						Hi	
IIA2	ND	28.5	5.95							
IIA2	ND	28.2	2.3							
IIA+B	ND	29.2	12.7							
IIB+A	ND	32.2	13.9							
IIB21t	ND	ND	14.8							
IIB22t	ND	33.7	12.6	Lo	Hi	T	Lo			
IIC1ca	7.2	ND	13.2	Lo	Hi	T	Lo	T-Lo		

ND = Not determined.
NP = Nonplastic.
** Vermiculite-Chlorite.

K2AC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
A2	3	29	61	10	90.0	sil	ND	ND	.67	NP	NP	NP
B2ir	15	32	65	3	87.6	sil	30.1	1.28	.43	NP	NP	NP
IIA2	30	27	68	5	56.4	sil	11.3	1.90	1.43	NP	NP	NP
IIA+B	45	20	74	6	68.1	sil	11.0	1.95	1.68	NP	NP	NP
IIB+A	67	24	60	16	66.8	sil	12.0	1.91	1.43	20.5	23.7	3.2
IIB21t	80	22	61	17	71.7	sil	15.3	1.91	1.20	19.1	28.2	9.1
IIC1ca	100	42	52	6	42.2	sil	9.7	2.03	1.64	NP	NP	NP
IIC2ca	133	47	44	9	47.9	l	10.0	2.07	ND	NP	NP	NP
IIC3ca	175	41	50	9	45.2	sil	5.9	2.17	ND	17.3	17.6	0.3

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A2	5.5	3.2	5.3	0.18	2.57	0.82	0.10	0.19	14.60	20.1	18.28	2.52	73.4
B2ir	3.5	2.0	5.8	0.17	2.00	0.53	0.06	0.63	21.80	12.9	25.02	2.95	85.4
IIA2	.5	.3	6.3	0.07	3.69	0.43	0.04	0.17	0.89	82.9	5.22	2.65	46.0
IIA+B	.4	.2	6.3	0.03	3.47	0.49	0.06	0.19	1.88	69.1	6.09	2.64	34.4
IIB+A	.8	.5	6.3	0.04	7.00	0.95	0.06	0.21	5.05	61.9	13.27	2.67	46.4
IIB21t	.8	.5	6.7	0.17	11.97	1.25	0.07	0.23	3.02	81.7	16.54	2.61	54.0
IIC1ca	.3	.2	6.9	0.10	25.78	0.56	0.04	0.06	0	100	4.13	2.64	37.9
IIC2ca	.2	.1	6.8	0.10	27.62	0.53	0.10	0.13	0	100	3.48	2.74	ND
IIC3ca	.6	.3	6.9	0.10	25.78	0.56	0.04	0.07	0	100	4.13	2.68	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	ND	18.1						Hi	
B2ir	ND	78.7	16.7						Hi	
IIA2	ND	22.6	4.8							
IIA+B	ND	28.9	4.5							
IIB+A	ND	29.2	11.3							
IIB21t	ND	33.5	14.2							
IIC1ca	11.7	ND	4.5							
IIC2ca	11.5	29.1	11.7							
IIC3ca	11.4	ND	5.9							

ND = Not determined.
NP = Nonplastic.

K2BC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Proctor Analysis: Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
A2	3	26	69	5	95.0	sil	ND	ND	.53	NP	NP	NP
B2ir	15	31	66	3	93.4	sil	28.0	1.31	.67	NP	NP	NP
IIA2	30	36	60	4	70.0	sil	11.0	1.84	1.59	NP	NP	NP
IIA2	45	32	57	11	60.8	sil	11.9	1.99	1.70	16.9	18.1	1.2
IIA+B	58	33	52	15	62.7	sil	13.5	1.96	1.53	18.7	20.1	1.4
IIB21t	73	20	58	22	70.1	sil	14.0	1.91	1.47	19.8	25.8	6.0
IIC1ca	100	28	61	11	69.2	sil	12.5	1.94	1.59	21.9	24.7	2.8
IIC2ca	141	26	57	17	71.7	sil	11.8	2.00	ND	22.3	22.5	0.2
IIC3ca	197	40	62	4	55.4	sil	10.5	2.11	ND	18.3	20.1	1.8

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A2	6.0	3.5	5.1	0.17	1.84	0.63	0.10	0.34	11.67	20.0	14.58	2.39	77.8
B2ir	4.4	2.5	6.1	0.07	2.67	0.79	0.11	0.32	21.13	15.5	25.02	2.47	72.9
IIA2	.9	.5	6.2	0.06	3.19	0.53	0.06	0.15	1.51	72.2	5.44	2.58	38.4
IIA2	.2	.1	7.2	0.03	3.39	3.23	0.06	0.19	0	100	6.70	2.73	37.7
IIA+B	.6	.3	6.3	0.06	6.59	1.09	0.09	0.17	2.50	76.1	10.44	2.70	37.0
IIB2t	.5	.3	7.1	0.21	10.74	1.32	0.05	0.26	1.56	88.8	13.93	2.64	44.3
IIC1ca	.5	.3	7.0	0.14	28.58	0.99	0.06	0.15	0	100	7.62	2.73	41.8
IIC2ca	.2	.1	7.2	0.13	28.54	1.84	0.07	0.15	0	100	6.74	2.67	ND
IIC3ca	.2	.1	6.6	0.12	27.42	1.91	0.09	0.11	0	100	6.96	2.69	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	ND	17.5						Hi	
B2ir	ND	57.3	14.8	T	T				Hi	T**
IIA2	ND	21.4	7.0							
IIA2	ND	20.8	7.4							
IIA+B	ND	23.7	12.2	Lo	Hi			Lo		
IIB2t	ND	35.6	11.3	Lo	Hi		Lo	Lo		
IIC1ca	12.5	29.7	10.9							
IIC2ca	12.5	ND	9.8	Lo	Hi		Lo	Lo		
IIC3ca	11.2	ND	8.7							

ND = Not determined.
NP = Nonplastic.
** Vermiculite Chlo.ite.

K3AC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%	%	%	%		% wt	g/cc	g/cc	%	%	%
B2ir	15	32	60	8	69.1	sil	20.5	1.54	.72	NP	NP	NP
IIA2	30	34	62	4	62.6	sil	11.3	1.88	1.59	NP	NP	NP
IIA2	45	30	62	8	61.0	sil	12.0	1.91	1.60	NP	NP	NP
IIA+B	62	23	55	22	59.6	sil	13.0	1.97	1.18	18.2	24.3	6.1
IIB3ca	69	29	57	14	59.2	sil	13.9	1.89	1.45	23.4	29.0	5.6
IIC1ca	113	27	58	15	65.7	sil	12.3	2.00	1.72	18.0	22.3	4.3
IIC2ca	150	31	53	16	57.6	sil	8.3	2.09	ND	18.4	21.6	3.2
IIC3ca	190	23	60	17	58.8	sil	12.5	1.95	ND	16.8	25.2	8.4

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	g/cc	%
B2ir	4.2	2.4	6.6	0.05	2.16	0.53	0.09	0.19	9.65	23.5	12.62	2.58	72.1
IIA2	.8	.5	5.8	0.04	2.79	0.56	0.06	0.19	2.27	61.3	5.87	2.63	39.5
IIA2	.5	.3	6.4	0.03	4.71	0.99	0.05	0.11	.01	99.8	5.87	2.62	38.9
IIA+B	.5	.3	6.3	0.07	7.86	1.12	0.04	0.24	3.79	71.0	13.05	2.62	55.0
IIB3ca	.8	.5	7.1	0.14	28.02	0.89	0.06	0.17	0	100.0	11.75	2.70	46.3
IIC1ca	.5	.3	7.0	0.12	28.30	0.79	0.07	0.15	0	100.0	7.18	2.70	36.3
IIC2ca	.4	.2	6.9	0.12	28.95	2.04	0.28	0.16	0	100.0	7.72	2.63	ND
IIC3ca	.4	.2	6.9	0.15	29.40	2.05	0.05	0.20	0	100.0	7.94	2.71	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
B2ir	ND	67.8	11.9	T	T	T			Hi	
IIA2	ND	26.5	8.5							
IIA2	ND	22.5	6.3							
IIA+B	ND	68.2	10.2							
IIB3ca	4.7	31.1	14.1							
IIC1ca	11.9	22.5	9.4							
IIC2ca	12.3	ND	10.9							
IIC3ca	12.4	ND	12.7							

ND = Not determined.
NP = Nonplastic.

K3BC

Horizon	Sample depth	Particle Size Analysis Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
A2	3	24	67	9	90.0	sil	ND	ND	ND	NP	NP	NP
B2ir	15	31	66	3	79.4	sil	28.0	1.29	.36	NP	NP	NP
IIA2	30	34	58	8	53.2	sil	14.5	1.88	1.61	NP	NP	NP
IIA+B	45	31	57	12	52.5	sil	12.9	1.93	1.64	21.5	24.1	2.6
IIB21t	73	26	58	16	62.4	sil	17.9	1.85	1.47	21.0	26.1	5.1
IIC1ca	100	39	51	10	65.1	sil	11.5	2.01	1.59	19.0	19.2	0.2
IIC2ca	148	25	56	19	71.6	sil	12.6	2.00	ND	20.8	21.1	0.3
IIC3ca	203	21	53	26	56.6	sil	13.4	1.98	ND	20.3	23.6	3.3

Horizon	O.M.	O.C.	1:1 Extract pH	EC	Exchangeable Cations Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A2	7.1	4.1	5.4	0.25	7.54	0.63	0.09	0.46	15.87	35.5	24.59	2.27	ND
B2ir	3.8	2.2	5.2	0.06	3.01	0.56	0.08	0.13	15.36	19.7	19.14	2.52	85.7
IIA2	.8	.5	6.9	0.03	4.15	0.66	0.06	0.13	2.18	69.6	7.18	2.74	41.2
IIA+B	.6	.4	7.1	0.03	5.49	0.76	0.04	0.19	3.53	64.7	10.01	2.72	39.7
IIB2t	.5	.3	6.7	0.16	11.85	0.72	0.09	0.17	0	100.0	9.57	2.76	46.7
IIC1ca	.4	.2	6.8	0.13	27.98	0.59	0.17	0.11	0	100.0	4.57	2.72	41.5
IIC2ca	.3	.2	6.5	0.14	13.83	1.02	0.06	0.15	0	100.0	6.09	2.68	ND
IIC3ca	.2	.1	6.7	0.14	29.22	1.78	0.06	0.19	0	100.0	9.79	2.21	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	ND	17.9						Hi	
B2ir	ND	69.2	14.8	T	T				Hi	
IIA2	ND	23.6	8.0							
IIA+B	ND	23.3	7.9							
IIB2t	11.3	31.9	8.1	Lo	Hi		Lo-Med	Lo		
IIC1ca	11.3	29.7	7.6	Lo	Hi		Med	Lo		
IIC2ca	11.8	ND	8.4	Lo	Hi		Med	Lo		Lo-Med**
IIC3ca	11.8	ND	4.1							

ND = Not determined.
NP = Nonplastic.
** Interstratified smectite, vermiculite and chlorite.

APPENDIX VII

LABORATORY CHARACTERIZATION DATA FOR CONTROL SOIL PEDONS IN QUARTZITE DOMINATED GLACIAL TILL PARENT MATERIAL

F2AC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
B2ir	15	19	66	15	65.9	sil	19.5	1.63	.66	NP	NP	NP
IIA2	30	30	67	3	58.5	sil	11.5	1.98	1.64	NP	NP	NP
IIA2	45	28	71	1	52.6	sil	10.1	2.06	1.86	NP	NP	NP
IIA+B	80	27	67	6	66.0	sil	11.3	1.96	1.65	NP	NP	NP
IIC1	120	26	70	4	58.7	sil	9.5	2.04	1.87	NP	NP	NP

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
B2ir	3.6	2.1	6.7	0.07	2.95	1.19	0.09	0.48	13.57	25.8	18.28	2.63	60.3
IIA2	.4	.2	6.6	0.02	0.56	0.16	0.05	0.09	1.32	39.5	2.18	1.96	16.3
IIA2	.4	.2	6.9	0.02	0.58	0.13	0.03	0.13	1.31	39.9	2.18	2.77	32.8
IIA+B	.1	.1	6.6	0.03	2.04	0.69	0.05	0.13	2.31	55.7	5.22	2.74	39.8
IIC1	.2	.1	6.8	0.02	1.68	0.46	0.08	0.09	1.82	55.9	4.13	2.81	33.5

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Interstratification
	%	% wt	% wt							
B2ir	ND	33.2	14.8						Hi	
IIA2	ND	25.2	3.3							
IIA2	ND	22.5	3.2							
IIA+B	ND	21.5	6.4							
IIC1	ND	19.0	7.1							

ND = Not determined.
NP = Nonplastic.

F2BC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	---------- %	----------				% wt	g/cc	g/cc	---------- %		----------
B2ir	15	11	76	13	67.3	sil	23.8	1.56	.79	NP	NP	NP
IIA2	30	15	79	6	55.8	sil	10.8	1.97	1.66	NP	NP	NP
IIA2	45	20	76	4	58.6	sil	10.0	1.99	1.90	NP	NP	NP
IIA+B	80	20	64	16	68.1	sil	10.5	2.24	1.95	NP	NP	NP
IIC1	120	19	71	10	69.0	sil	11.1	2.07	1.72	16.8	18.5	1.7

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	----------		meq/100g		----------	%	meq/100g	g/cc	%
B2ir	2.7	1.6	5.5	0.10	2.37	1.12	0.10	0.32	10.89	26.4	14.80	2.62	60.0
IIA2	.8	.5	5.5	0.04	0.98	0.30	0.17	0.15	2.10	43.2	3.70	2.67	37.6
IIA2	.5	.3	6.0	0.03	1.34	0.46	0.06	0.13	0.84	70.3	2.83	2.73	30.5
IIA+B	.5	.3	6.9	0.03	3.05	1.45	0.10	0.21	3.02	61.4	7.83	2.72	28.2
IIC1	.7	.4	7.1	0.04	1.72	0.43	0.10	0.13	3.71	39.1	6.09	2.73	37.0

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
B2ir	ND	49.3	13.3	T	T				Hi	T**
IIA2	ND	29.6	5.0							
IIA2	ND	22.1	8.7							
IIA+B	ND	15.1	8.0	T	Hi		T			
IIC1	ND	15.6	9.6	T	Hi		T			

ND = Not determined.
NP = Nonplastic.
** Vermiculite-Chlorite.

F3AC

Horizon	Sample depth	Particle Size Analysis: Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	----------- %			-----------		% wt	g/cc	g/cc	----------- %		-----------
B2ir	15	28	62	10	77.5	sil	24.0	1.35	.72	NP	NP	NP
IIA2	30	18	72	10	80.2	sil	12.7	1.99	1.74	NP	NP	NP
IIA2	45	30	67	3	62.8	sil	12.4	2.00	1.89	NP	NP	NP
IIA+B	105	20	76	4	42.1	sil	9.0	2.00	1.68	NP	NP	NP
IIC1	165	26	70	4	62.5	sil	11.7	1.96	1.62	21.3	23.7	2.4

Horizon	O.M.	O.C.	1:1 Extract: pH	EC	Exchangeable Cations: Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	-----------		meq/100g		-----------	%	meq/100g	g/cc	%
B2ir	4.0	2.3	5.2	0.12	2.20	0.53	0.11	0.42	15.02	17.8	18.28	2.54	71.7
IIA2	.6	.3	6.5	0.07	1.78	0.66	0.12	0.09	3.01	46.8	5.66	2.71	35.8
IIA2	.4	.2	6.0	0.03	1.78	0.66	0.06	0.13	2.16	54.9	4.79	2.72	30.5
IIA+B	.5	.3	6.4	0.03	2.29	0.79	0.10	0.09	2.17	60.1	5.44	2.80	40.0
IIC1	.5	.3	6.9	0.06	2.49	0.92	0.10	0.11	4.87	42.6	8.49	2.83	42.6

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
B2ir	ND	33.6	18.8						Hi	
IIA2	ND	27.4	8.0							
IIA2	ND	49.6	4.2							
IIA+B	ND	34.8	4.0							
IIC1	ND	36.5	5.0							

ND = Not determined.
NP = Nonplastic.

F3BC

Horizon	Sample depth	Particle Size Analysis Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis: Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	---------- %	----------				% wt	g/cc	g/cc	---------- %		----------
A2	3	19	75	6	94.0	sil	ND	ND	ND	NP	NP	NP
B2ir	15	29	65	6	90.0	sil	30.5	1.35	.75	NP	NP	NP
IIA2	30	12	62	26	75.3	sil	13.7	1.80	1.81	25.5	29.5	4.0
IIA2	45	11	80	9	64.9	si	14.7	1.89	1.80	NP	NP	NP
IIA+B[1]	73	ND	ND	ND	8.1	ND	ND	ND	1.86	ND	ND	ND
IIC1	120	57	41	2	32.2	sl	ND	ND	1.82	NP	NP	NP

Horizon	O.M.	O.C.	1:1 Extract pH	EC	Exchangeable Cations Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	----------		meq/100g		----------	%	meq/100g	g/cc	%
A2	6.6	3.8	5.2	0.25	6.31	1.15	0.10	0.40	9.23	46.3	17.19	2.40	ND
B2ir	4.9	2.8	6.8	0.05	0.72	0.16	0.08	0.28	18.78	6.2	20.02	2.51	70.1
IIA2	1.4	.8	6.8	0.03	1.20	0.99	0.07	0.13	4.35	35.5	6.74	2.82	35.8
IIA2	0.7	.4	6.7	0.02	0.92	0.53	0.06	0.15	4.43	27.3	6.09	2.73	34.1
IIA+B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
IIC1	0.5	.3	6.8	.02	1.78	0.53	0.08	0.11	2.07	54.7	4.57	2.75	33.6

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance: Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	ND	19.4	T	T				Hi	T**
B2ir	ND	37.0	18.7						Hi	
IIA2	ND	23.5	18.9							
IIA2	ND	19.7	8.1							
IIA+B	ND	41.6	ND							
IIC1	ND	37.4	3.5	Lo	Hi			T-Lo		

ND = Not determined.
NP = Nonplastic.
[1] IIA+B - 73 cm not enough <2 mm to conduct analyses.
** Vermiculite - Chlorite intergrade.

KlAC

Horizon	Sample depth	Particle Size Analysis				Textural class	Proctor Analysis		Bulk density	Plastic limit	Liquid limit	Plastic index
		Sand	Silt	Clay	<2 mm		Optimum moisture content	Maximum density achieved				
	cm	%					% wt	g/cc	g/cc	%		
A2	3	24	68	8	ND	sil	ND	ND	.36	NP	NP	NP
B2ir	15	26	64	10	70.7	sil	20.1	1.54	.72	NP	NP	NP
IIA2	30	29	62	9	68.2	sil	7.3	2.03	1.72	18.3	19.3	1.00
IIA2	45	33	55	12	70.5	sil	12.7	1.98	1.77	20.2	21.2	1.00
IIA+B	78	24	57	19	54.1	sil	14.9	1.88	1.63	20.6	26.0	5.4
IIClca	124	31	58	11	61.9	sil	12.1	1.98	1.82	19.1	23.8	4.7
IIC2ca	165	38	54	8	50.2	sil	11.7	2.10	ND	18.7	21.0	2.3

Horizon	O.M.	O.C.	1:1 Extract		Exchangeable Cations					Base saturation	CEC	Particle density	Porosity
			pH	EC	Ca	Mg	Na	K	H				
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A2	5.3	3.1	4.4	0.16	3.59	0.79	0.14	0.32	16.27	22.9	21.11	2.38	84.9
B2ir	2.7	1.6	5.5	0.12	2.55	0.66	0.08	0.28	11.66	23.4	15.23	2.57	69.3
IIA2	.9	.5	6.2	0.05	2.58	1.98	0.05	0.13	1.79	72.6	6.53	2.66	35.3
IIA2	.6	.3	6.1	0.06	4.39	0.86	0.02	0.15	1.98	73.2	7.40	2.84	37.7
IIA+B	1.2	.7	6.7	.05	7.08	1.61	0.04	0.19	3.70	70.7	12.62	2.75	40.7
IIClca	.4	.2	6.7	0.13	27.26	1.22	0.05	0.15	0	100	7.62	2.75	33.8
IIC2ca	.2	.1	7.1	0.11	25.10	1.22	0.05	0.11	0	100	4.13	2.72	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance						
				Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND		14.7						Hi	
B2ir	ND	78.1	12.7						Hi	
IIA2	ND	17.0	8.2							
IIA2	ND	20.8	7.7							
IIA+B	ND	32.1	6.4							
IIClca	6.3	20.9	8.2							
IIC2ca	7.1	ND	10.9							

ND = Not determined.
NP = Nonplastic.

K1BC

Horizon	Sample depth	Particle Size Analysis Sand	Silt	Clay	<2 mm	Textural class	Proctor Analysis Optimum moisture content	Maximum density achieved	Bulk density	Plastic limit	Liquid limit	Plastic index
	cm	%					% wt	g/cc	g/cc	%		
A2	3	20	70	10	ND	sil	ND	ND	.33	ND	ND	ND
B2ir	15	31	63	6	59.1	sil	19.0	1.55	.98	NP	NP	NP
IIA2	30	28	61	11	51.6	sil	12.5	1.93	1.72	17.3	19.5	2.2
IIA+B	45	25	55	20	60.2	sil	14.5	1.94	1.56	19.3	28.9	9.6
IIC1ca	145	27	55	18	53.0	sil	9.7	1.99	1.68	20.3	25.0	4.7
IIC2ca	183	33	51	16	48.8	sil	8.4	2.12	ND	20.0	25.0	5.0

Horizon	O.M.	O.C.	1:1 Extract pH	EC	Exchangeable Cations Ca	Mg	Na	K	H	Base saturation	CEC	Particle density	Porosity
	% wt	% wt		mmhos/cm	meq/100g					%	meq/100g	g/cc	%
A2	5.5	3.2	5.2	0.15	3.79	1.38	0.10	0.42	10.85	34.4	16.54	2.48	86.5
B2ir	2.6	1.5	6.5	0.05	2.55	0.56	0.07	0.23	12.41	21.5	15.82	2.56	66.4
IIA2	.5	.3	6.0	0.05	3.49	0.76	0.11	0.11	2.06	68.5	6.53	2.73	36.8
IIA+B	.9	.5	6.9	0.10	7.28	1.74	0.06	0.13	3.63	71.7	12.84	2.69	42.0
IIC1ca	.4	.2	7.0	0.13	27.30	1.65	0.04	0.19	0	100.0	5.87	2.77	39.1
IIC2ca	.2	.1	6.8	0.12	27.30	1.19	0.06	0.13	0	100.0	7.62	2.70	ND

Horizon	$CaCO_3$	1/3 Bar water	15 Bar water	Estimated Abundance Kaolinite	Illite	Chlorite	Vermiculite	Smectite	Amorphous	Inter-stratification
	%	% wt	% wt							
A2	ND	ND	13.1						Hi	
B2ir	ND	55.5	15.5	T	T				Hi	T**
IIA2	ND	21.4	7.5							
IIA+B	ND	24.7	13.3	Lo	Hi			Lo-Med		
IIC1ca	12.5	ND	8.5	Lo	Hi		Lo	Lo		
IIC2ca	7.0	ND	8.9							

ND = Not determined.
NP = Nonplastic.
** Vermiculite-Chlorite interstratification.

APPENDIX VIII

SIEVE ANALYSIS RAW DATA FOR

TERTIARY VOLCANIC CONTROL SOIL PEDONS

PEDON	HORI-ZON	DEPTH (CM)	SAMPLE SIZE (G)	------PERCENT (BY WT.) FINER THAN----- 38.1 MM	19.0 MM	9.5 MM	4.75 MM	2.0 MM	.42 MM
B1AC									
	A2	15	525.0	100.0	100.0	100.0	99.4	99.0	97.6
	B2T	30	578.0	100.0	100.0	100.0	100.0	99.0	96.9
	B22T	45	780.0	100.0	100.0	100.0	100.0	97.0	46.4
	B3	110	1382.0	100.0	100.0	100.0	100.0	97.0	38.9
B1BC									
	A21	15	1188.7	100.0	95.2	94.8	94.4	92.0	61.4
	A22	30	1450.3	80.8	61.6	58.6	58.0	56.0	36.5
	B21T	45	446.9	100.0	100.0	100.0	97.7	90.0	36.8
	B22T	75	1224.6	100.0	100.0	100.0	99.9	96.0	48.7
	B3	110	1006.1	100.0	100.0	100.0	99.8	97.0	67.5
B2AC									
	A2	15	1801.0	100.0	100.0	100.0	99.9	99.0	74.3
	B21T	30	847.3	100.0	100.0	100.0	99.8	99.0	45.8
	B21T	45	1204.0	100.0	100.0	100.0	100.0	99.0	46.4
	B22T	65	1492.0	100.0	100.0	100.0	99.9	99.0	61.4
B2BC									
	A2	15	990.0	100.0	91.0	90.7	90.3	88.0	60.8
	B21T	30	972.4	100.0	100.0	100.0	99.6	95.0	41.9
	B22T	45	1304.5	100.0	100.0	99.9	99.7	95.0	43.0
	B3	75	1332.9	100.0	100.0	99.9	99.6	95.0	45.6
	C1	105	572.4	100.0	80.9	77.9	74.1	70.0	32.1
B3AC									
	A2	15	678.7	100.0	100.0	99.0	99.0	98.0	56.0
	B21T	30	657.0	100.0	100.0	100.0	99.9	99.0	54.7
	B21T	45	927.5	100.0	100.0	100.0	99.9	99.0	60.4
	B22T	75	752.7	100.0	100.0	100.0	100.0	99.0	56.9
	B23T	125	570.0	100.0	100.0	100.0	99.9	99.0	58.2
B3BC									
	A21	8	631.9	100.0	100.0	99.7	99.6	98.0	73.0
	A22	15	930.1	100.0	92.5	92.5	92.3	91.0	62.0
	B21T	30	743.3	100.0	100.0	100.0	99.9	98.0	41.8
	B21T	45	860.9	100.0	100.0	99.1	98.7	95.0	43.3
	B22T	75	676.2	100.0	97.8	97.6	96.9	93.0	40.8
	B23T	110	857.5	100.0	98.3	98.3	98.1	95.0	42.4
	IIB31T	150	830.0	100.0	100.0	100.0	100.0	99.0	51.2
	IIB32T	175	775.8	100.0	100.0	100.0	100.0	99.0	65.4

APPENDIX IX

SIEVE ANALYSIS RAW DATA FOR

LIMESTONE DOMINATED GLACIAL TILL CONTROL SOIL PEDONS

PEDON	HORI-ZON	DEPTH (CM)	SAMPLE SIZE (G)	------PERCENT (BY WT.) FINER THAN----- 38.1 MM	19.0 MM	9.5 MM	4.75 MM	2.0 MM	.42 MM
FIAC									
	B2IR	15	1198.4	100.0	88.4	81.7	76.7	72.0	60.1
	IIA2	30	1685.1	95.3	88.0	81.3	77.0	71.0	55.1
	IIA2	45	2790.1	68.9	62.4	58.4	54.9	50.0	33.0
	IIA&B	54	1576.5	100.0	85.3	81.5	76.5	69.0	41.0
	IIB&A	71	1604.0	100.0	96.8	91.6	85.8	78.0	44.3
	IIB21T	88	2233.1	100.0	93.4	88.4	83.0	76.0	42.4
	IIB22T	110	1852.2	100.0	91.1	86.6	82.1	76.0	43.0
	IIC1CA	120	2496.5	100.0	96.2	90.3	81.4	70.0	34.7
F1BC									
	B2IR	15	659.0	100.0	82.1	71.9	62.7	53.0	40.5
	IIA2	30	685.5	90.2	82.2	70.1	57.4	47.0	35.7
	IIA2	45	743.0	78.5	67.9	57.5	46.8	37.0	28.9
	IIA&B	65	684.0	100.0	77.2	74.5	70.3	65.0	45.7
	IIB&A	82	619.0	100.0	88.0	80.4	76.2	71.0	45.4
	IIB21T	115	4178.0	87.6	76.9	71.6	67.6	62.0	33.1
	IIB22T	148	3959.0	94.0	83.6	78.1	73.8	68.0	36.4
	IIC1CA	170	3533.0	96.4	89.5	85.3	79.7	72.0	35.6
K2AC									
	B2IR	15	583.0	100.0	100.0	95.0	91.9	87.0	69.2
	IIA2	30	3520.0	93.6	83.6	76.3	66.2	56.0	45.1
	IIA&B	45	4133.0	95.6	93.4	89.4	81.7	68.0	46.1
	IIB&A	67	2167.0	100.0	93.8	89.5	82.1	66.0	36.2
	IIB21T	80	1598.0	100.0	90.8	87.8	83.6	71.0	37.9
	IIC1CA	100	4710.0	81.0	60.1	54.1	48.5	42.0	31.5
	IIC2CA	133	4430.0	89.4	74.9	67.3	57.7	47.0	33.2
	IIC3CA	175	4510.5	82.9	69.4	61.1	53.7	45.0	29.1
K2BC									
	B2IR	15	1089.0	100.0	100.0	99.5	97.2	93.0	78.6
	IIA2	30	2184.0	100.0	90.5	87.3	80.1	70.0	56.8
	IIA2	45	2135.0	100.0	92.8	87.5	80.8	60.0	50.6
	IIA&B	58	2257.0	100.0	82.6	78.0	72.8	62.0	38.3
	IIB21T	73	2373.0	100.0	91.1	88.8	83.9	70.0	34.4
	IIC1CA	100	2279.0	100.0	88.9	81.9	76.6	69.0	45.2
	IIC2CA	141	2307.0	94.4	90.6	85.2	80.7	71.0	43.3
	IIC3CA	197	2426.0	96.5	88.0	81.1	70.2	55.0	30.4
K3AC									
	B2IR	15	2392.0	100.0	91.9	84.2	76.7	69.0	52.9
	IIA2	30	3057.5	97.0	87.1	79.2	71.3	62.0	50.8
	IIA2	45	2310.0	89.7	82.2	74.8	68.9	61.0	45.9
	IIA&B	62	2134.0	99.4	84.9	78.7	72.1	59.0	29.8
	IIB3CA	69	2219.0	93.9	79.8	73.4	68.9	59.0	33.0
	IIC1CA	113	2036.0	100.0	86.3	81.6	76.2	65.0	35.3
	IIC2CA	150	2285.0	90.8	82.3	76.9	70.1	57.0	28.4
	IIC3CA	190	2258.0	100.0	93.2	88.5	81.5	58.0	23.5
K3BC									
	B2IR	15	1074.0	100.0	97.5	92.2	85.6	79.0	63.7
	IIA2	30	3557.0	100.0	84.9	74.4	63.5	53.0	38.0
	IIA&B	45	2470.0	96.2	86.1	77.5	66.8	52.0	28.4
	IIB21T	73	2077.0	100.0	82.1	77.9	73.3	62.0	34.4
	IIC1CA	100	2195.0	100.0	86.4	84.6	77.0	65.0	41.1
	IIC2CA	148	1973.0	100.0	96.8	94.3	88.0	71.0	37.1
	IIC3CA	203	2072.0	100.0	94.0	89.5	80.9	56.0	22.5

APPENDIX X

SIEVE ANALYSIS RAW DATA FOR

QUARTZITE DOMINATED GLACIAL TILL CONTROL SOIL PEDONS

PEDON	HORI-ZON	DEPTH (CM)	SAMPLE SIZE (G)	------PERCENT (BY WT.) FINER THAN----- 38.1 MM	19.0 MM	9.5 MM	4.75 MM	2.0 MM	.42 MM
F2AC									
	B2IR	15	5328.0	85.2	72.2	70.5	68.7	65.0	39.3
	IIA2	30	5323.0	93.9	81.5	73.1	65.7	58.0	46.1
	IIA2	45	5141.5	97.3	74.5	64.3	58.8	52.0	41.5
	IIA&B	80	3435.0	96.2	85.0	77.8	72.2	65.0	42.0
	IIC1	120	4762.0	66.6	72.0	67.5	63.7	58.0	40.1
F2BC									
	B2IR	15	3435.0	85.6	75.1	71.4	69.4	67.0	45.4
	IIA2	30	3440.0	84.9	76.1	68.4	61.8	55.0	45.2
	IIA2	45	3222.0	92.5	81.5	72.7	66.1	58.0	46.6
	IIA&B	80	3464.0	95.2	84.9	78.6	73.7	68.0	42.7
	IIC1	120	3291.0	85.6	83.4	78.9	74.4	69.0	46.3
F3AC									
	B2IR	15	2448.0	88.8	82.4	80.7	79.3	77.0	50.7
	IIA2	30	3165.0	93.4	88.7	84.4	82.7	80.0	51.1
	IIA2	45	4892.5	89.1	71.3	65.7	64.6	62.0	49.2
	IIA&B	105	5101.5	88.8	64.0	53.9	47.5	42.0	29.7
	IIC1	165	2810.3	100.0	77.1	70.6	66.4	62.0	45.8
F3BC									
	B2IR	15	1337.0	100.0	98.6	96.7	94.5	87.0	63.9
	IIA2	30	3022.0	89.7	82.0	79.9	78.2	75.0	33.2
	IIA2	45	3107.0	86.6	69.7	67.2	66.3	64.0	46.4
	IIA&B	73	5778.0	77.3	56.7	39.7	28.9	8.0	4.8
	IIC1	120	5156.0	82.4	66.5	57.6	46.3	32.0	15.5
K1AC									
	A2 †	3	597.0	.0	.0	.0	.0	.0	.0
	B2IR	15	3354.5	92.9	78.5	76.9	65.4	59.0	43.2
	IIA2	30	5194.0	95.5	86.4	82.0	76.3	68.0	48.4
	IIA2	45	5058.5	93.7	86.5	82.9	79.3	70.0	46.4
	IIA&B	78	3515.0	93.9	69.2	84.7	77.7	54.0	21.5
	IIC1CA	124	3490.0	91.4	64.1	79.2	72.9	61.0	33.4
	IIC2CA	165	5384.0	86.2	75.2	67.0	60.8	50.0	28.7
K1BC									
	B2IR	15	2102.0	100.0	84.7	81.8	77.0	70.0	51.7
	IIA2	30	4298.5	85.6	70.1	64.8	60.4	51.0	32.8
	IIA&B	45	2955.0	100.0	91.3	85.4	78.4	60.0	22.6
	IIC1CA	145	4867.0	90.5	79.4	72.2	65.2	52.0	26.3
	IIC2CA	133	4546.0	38.8	78.4	71.1	63.1	48.0	21.5

† **Analysis not performed.**

APPENDIX XI

INFILTRATION RAW DATA FOR

TERTIARY VOLCANIC STUDY SUBSITES

PEDON	............REPLICATION............			AGE GROUP
	1(MEDIAN)	2	3	
B1AC	8332.04	5906.73	10246.37	OLD
B1BC	5670.15	3774.02	6287.03	OLD
B1AM	1112.15	2078.46	165.11	OLD
B1BM	6909.94	12488.68	6285.04	OLD
B1AS	619.89	382.86	2041.98	OLD
B1BS	893.38	1567.93	729.28	OLD
B2AC	393.91	4490.08	3172.37	OLD
B2BC	348.07	6235.36	1075.69	OLD
B2AM	332.59	966.26	4339.21	OLD
B2BM	358.00	1130.38	13838.09	OLD
B2AS	313.17	2187.86	455.80	OLD
B2BS	309.38	911.58	893.39	OLD
B3AC	9690.31	22055.72	8755.86	YOUNG
B3BC	7256.34	5086.73	.00	YOUNG
B3AM	4011.82	5888.94	1093.92	YOUNG
B3BM	5688.40	455.80	7037.54	YOUNG
B3AS	1349.16	401.10	3117.67	YOUNG
B3BS	546.95	419.33	1002.76	YOUNG

APPENDIX XII

INFILTRATION RAW DATA FOR

LIMESTONE DOMINATED GLACIAL TILL STUDY SUBSITES

PEDON	............REPLICATION............			AGE GROUP
	1(MEDIAN)	2	3	
F1AC	10738.65	5433.19	16864.58	OLD
F1BC	4888.94	3372.92	13054.09	OLD
F1AM	1513.26	13601.07	1458.56	OLD
F1BM	2698.33	1220.92	3026.52	OLD
F1AS	802.21	4229.83	719.28	OLD
F1BS	1586.19	4448.10	1149.61	OLD
K2AC	7110.48	3263.53	18122.64	MEDIUM
K2BC	8022.08	10647.51	5429.51	MEDIUM
K2AM	911.59	5414.92	601.65	MEDIUM
K2BM	802.20	7901.26	255.24	MEDIUM
K2AS	1823.19	6217.16	1075.67	MEDIUM
K2BS	856.89	1768.51	273.48	MEDIUM
K3AC	6873.46	2279.00	10939.20	YOUNG
K3BC	4485.08	2497.79	5688.37	YOUNG
K3AM	2952.96	929.84	3081.20	YOUNG
K3BM	218.78	546.96	218.77	YOUNG
K3AS	291.70	656.34	164.09	YOUNG
K3BS	2643.65	8787.84	328.16	YOUNG

APPENDIX XIII

INFILTRATION RAW DATA FOR

QUARTZITE DOMINATED GLACIAL TILL STUDY SUBSITES

PEDON	..........REPLICATION..........			AGE GROUP
	1(MEDIAN)	2	3	
F2AC	13947.47	13728.70	15296.65	MEDIUM
F2BC	2625.40	2133.16	3518.79	MEDIUM
F2AM	1544.09	711.04	.00	MEDIUM
F2BM	583.42	2078.45	474.00	MEDIUM
F2AS	1677.42	2443.09	296.62	MEDIUM
F2BS	3190.60	5797.79	3099.41	MEDIUM
F3AC	2880.66	8076.86	2734.80	YOUNG
F3BC	8878.98	5360.21	15223.72	YOUNG
F3AM	996.28	765.74	1349.17	YOUNG
F3BM	3135.90	3555.25	1020.99	YOUNG
F3AS	656.35	2534.25	565.19	YOUNG
F3BS	783.98	1586.18	747.52	YOUNG
K1AC	4302.75	7183.39	3937.72	MEDIUM
K1BC	6837.00	13291.13	4266.29	MEDIUM
K1AM	1677.33	7866.84	1185.07	MEDIUM
K1BM	1823.23	6618.21	638.10	MEDIUM
K1AS	692.81	674.57	1567.96	MEDIUM
K1BS	1148.64	948.07	1330.94	MEDIUM

APPENDIX XIV

BULK DENSITY RAW DATA FOR

TERTIARY VOLCANIC STUDY SUBSITES

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
B1AC	A2	15.0	1.37	OLD
B1AC	A2	15.0	1.30	OLD
B1AC	B21T	30.0	1.77	OLD
B1AC	B21T	30.0	1.87	OLD
B1AC	B22T	45.0	1.84	OLD
B1BC	A2	15.0	1.19	OLD
B1BC	A2	30.0	1.26	OLD
B1BC	B21T	45.0	1.64	OLD
B1AM	A2	15.0	1.26	OLD
B1AM	A2	15.0	1.16	OLD
B1AM	B21T	30.0	1.72	OLD
B1AM	B22T	45.0	1.69	OLD
B1BM	A2	15.0	1.38	OLD
B1BM	B21T	30.0	1.65	OLD
B1BM	B22T	45.0	1.73	OLD
B1AS	A2	20.0	1.49	OLD
B1AS	B21T	30.0	2.28	OLD
B1AS	B21T	45.0	1.87	OLD
B1BS	A2	15.0	1.39	OLD
B1BS	A2	30.0	1.71	OLD
B1BS	B21T	45.0	1.77	OLD
B2AC	A2	15.0	1.42	OLD
B2AC	B21T	30.0	1.61	OLD
B2AC	B21T	45.0	1.62	OLD
B2BC	A2	15.0	1.30	OLD
B2BC	B21T	30.0	1.78	OLD
B2BC	B22T	45.0	1.49	OLD
B2AM	A2	15.0	1.74	OLD
B2AM	A2	30.0	1.63	OLD
B2AM	B22T	45.0	1.28	OLD
B2BM	A2	15.0	1.58	OLD
B2BM	B21T	30.0	1.73	OLD
B2BM	B22T	45.0	1.59	OLD
B2AS	A2	15.0	1.64	OLD
B2AS	B21T	30.0	1.78	OLD
B2AS	B22T	45.0	1.69	OLD
B2BS	A2	15.0	1.31	OLD

PEDON	HORIZON	DEPTH	BULK DENSITY	AGE GROUP
		CM	G/CC	
B2BS	A2	15.0	1.31	OLD
B2BS	B21T	30.0	1.77	OLD
B2BS	B22T	45.0	1.58	OLD
B3AC	A2	15.0	1.29	YOUNG
B3AC	B21T	30.0	1.71	YOUNG
B3AC	B21T	45.0	1.67	YOUNG
B3BC	A2	15.0	1.26	YOUNG
B3BC	B21T	30.0	1.61	YOUNG
B3BC	B21T	45.0	1.46	YOUNG
B3AM	A2	15.0	1.68	YOUNG
B3AM	A2	30.0	1.67	YOUNG
B3AM	B21T	45.0	1.55	YOUNG
B3BM	A2	15.0	1.68	YOUNG
B3BM	B21T	30.0	1.49	YOUNG
B3BM	B22T	45.0	1.62	YOUNG
B3AS	A2	15.0	1.78	YOUNG
B3AS	B21T	30.0	1.76	YOUNG
B3AS	B22T	45.0	1.89	YOUNG
B3BS	A2	15.0	1.71	YOUNG
B3BS	B21T	30.0	1.62	YOUNG
B3BS	B21T	45.0	1.63	YOUNG

APPENDIX XV

BULK DENSITY RAW DATA FOR

LIMESTONE DOMINATED GLACIAL TILL STUDY SUBSITES

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
K2AC	IIA&B	45.0	1.71	MEDIUM
K2AC	IIA&B	45.0	1.65	MEDIUM
K2AC	IIB&A	67.0	1.45	MEDIUM
K2AC	IIB&A	67.0	1.41	MEDIUM
K2AC	IIB2T	80.0	1.27	MEDIUM
K2AC	IIB2T	80.0	1.13	MEDIUM
K2AC	IIC1	100.0	1.61	MEDIUM
K2AC	IIC1	100.0	1.67	MEDIUM
K2BC	A2	3.0	.42	MEDIUM
K2BC	A2	3.0	.63	MEDIUM
K2BC	B2IR	5.0	.56	MEDIUM
K2BC	B2IR	5.0	.62	MEDIUM
K2BC	B2IR	15.0	.52	MEDIUM
K2BC	B2IR	15.0	.82	MEDIUM
K2BC	IIA2	30.0	1.59	MEDIUM
K2BC	IIA2	30.0	1.60	MEDIUM
K2BC	IIA2	45.0	1.69	MEDIUM
K2BC	IIA2	45.0	1.71	MEDIUM
K2BC	IIA&B	58.0	1.61	MEDIUM
K2BC	IIA&B	58.0	1.44	MEDIUM
K2BC	IIB2T	73.0	1.44	MEDIUM
K2BC	IIB2T	73.0	1.51	MEDIUM
K2BC	IIC1	100.0	1.59	MEDIUM
K2BC	IIC1	100.0	1.60	MEDIUM
K2AM	B2IR	5.0	1.13	MEDIUM
K2AM	B2IR	5.0	1.06	MEDIUM
K2AM	B2IR	15.0	1.29	MEDIUM
K2AM	B2IR	15.0	1.42	MEDIUM
K2AM	IIA2	30.0	1.55	MEDIUM
K2AM	IIA2	30.0	1.76	MEDIUM
K2AM	IIA&B	37.0	1.59	MEDIUM
K2AM	IIA&B	37.0	1.65	MEDIUM
K2AM	IIA2	45.0	1.64	MEDIUM
K2AM	IIA2	45.0	1.47	MEDIUM
K2AM	IIC2	155.0	1.79	MEDIUM
K2AM	IIC2	155.0	1.89	MEDIUM
K2BM	B2IR	5.0	.84	MEDIUM

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
K2BM	B2IR	5.0	.84	MEDIUM
K2BM	B2IR	5.0	.99	MEDIUM
K2BM	B2IR	15.0	1.45	MEDIUM
K2BM	B2IR	15.0	.87	MEDIUM
K2BM	IIA2	30.0	1.64	MEDIUM
K2BM	IIA2	30.0	1.62	MEDIUM
K2BM	IIA&B	45.0	1.61	MEDIUM
K2BM	IIA&B	45.0	1.54	MEDIUM
K2BM	IIB2T	69.0	1.51	MEDIUM
K2BM	IIB2T	69.0	1.39	MEDIUM
K2BM	IIC2	160.0	1.92	MEDIUM
K2BM	IIC2	160.0	1.90	MEDIUM
K2AS	B2IR	5.0	.98	MEDIUM
K2AS	B2IR	5.0	.98	MEDIUM
K2AS	B2IR	15.0	.96	MEDIUM
K2AS	B2IR	15.0	.95	MEDIUM
K2AS	IIA2	30.0	1.64	MEDIUM
K2AS	IIA2	30.0	1.31	MEDIUM
K2AS	IIA2	45.0	1.45	MEDIUM
K2AS	IIA2	45.0	1.52	MEDIUM
K2AS	IIB2T	54.0	1.40	MEDIUM
K2AS	IIB2T	54.0	1.42	MEDIUM
K2AS	IIC2	101.0	1.72	MEDIUM
K2AS	IIC2	101.0	1.70	MEDIUM
K2BS	B2IR	4.0	1.07	MEDIUM
K2BS	B2IR	4.0	.91	MEDIUM
K2BS	IIA2	15.0	1.34	MEDIUM
K2BS	IIA2	15.0	1.51	MEDIUM
K2BS	IIA&B	30.0	1.45	MEDIUM
K2BS	IIA&B	30.0	1.45	MEDIUM
K2BS	IIA2	45.0	1.28	MEDIUM
K2BS	IIA2	45.0	1.45	MEDIUM
K2BS	IIC2	148.0	1.69	MEDIUM
K2BS	IIC2	148.0	1.68	MEDIUM
K3AC	A2	3.0	1.09	YOUNG
K3AC	A2	3.0	.96	YOUNG
K3AC	B2IR	5.0	.91	YOUNG

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
K3AC	B2IR	5.0	.91	YOUNG
K3AC	B2IR	5.0	.30	YOUNG
K3AC	B2IR	15.0	.53	YOUNG
K3AC	B2IR	15.0	.91	YOUNG
K3AC	IIA2	30.0	1.62	YOUNG
K3AC	IIA2	30.0	1.57	YOUNG
K3AC	IIA2	45.0	1.59	YOUNG
K3AC	IIA2	45.0	1.62	YOUNG
K3AC	IIA&B	62.0	.95	YOUNG
K3AC	IIA&B	62.0	1.41	YOUNG
K3AC	IIB2T	69.0	1.42	YOUNG
K3AC	IIB2T	69.0	1.49	YOUNG
K3AC	IIC1	113.0	1.69	YOUNG
K3AC	IIC1	113.0	1.76	YOUNG
K3BC	B2IR	5.0	.58	YOUNG
K3BC	B2IR	5.0	.52	YOUNG
K3BC	B2IR	15.0	.37	YOUNG
K3BC	B2IR	15.0	.35	YOUNG
K3BC	IIA2	30.0	1.60	YOUNG
K3BC	IIA2	30.0	1.62	YOUNG
K3BC	IIA&B	45.0	1.67	YOUNG
K3BC	IIA&B	45.0	1.62	YOUNG
K3BC	IIB2T	73.0	1.49	YOUNG
K3BC	IIB2T	73.0	1.49	YOUNG
K3BC	IIC1	100.0	1.58	YOUNG
K3BC	IIC1	100.0	1.55	YOUNG
K3AM	B2IR	5.0	.89	YOUNG
K3AM	B2IR	5.0	.86	YOUNG
K3AM	B2IR	15.0	1.01	YOUNG
K3AM	B2IR	15.0	1.02	YOUNG
K3AM	IIA2	30.0	1.45	YOUNG
K3AM	IIA2	30.0	1.50	YOUNG
K3AM	IIA&B	45.0	1.58	YOUNG
K3AM	IIA&B	45.0	1.47	YOUNG
K3AM	IIB2T	78.0	1.39	YOUNG
K3AM	IIB2T	78.0	1.36	YOUNG
K3AM	IIC1	110.0	1.76	YOUNG

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
K3AM	IIC1	110.0	1.76	YOUNG
K3AM	IIC1	110.0	1.49	YOUNG
K3BM	B2IR	5.0	.42	YOUNG
K3BM	B2IR	5.0	.50	YOUNG
K3BM	B2IR	15.0	.99	YOUNG
K3BM	B2IR	15.0	.90	YOUNG
K3BM	IIA2	30.0	1.43	YOUNG
K3BM	IIA2	30.0	1.58	YOUNG
K3BM	IIA2	45.0	1.54	YOUNG
K3BM	IIA2	45.0	1.51	YOUNG
K3BM	IIA&B	71.0	1.59	YOUNG
K3BM	IIA&B	71.0	1.58	YOUNG
K3BM	IIB2T	105.0	1.57	YOUNG
K3BM	IIB2T	105.0	1.50	YOUNG
K3BM	IIC1	142.0	1.86	YOUNG
K3BM	IIC1	142.0	1.86	YOUNG
K3AS	B2IR	5.0	.87	YOUNG
K3AS	B2IR	5.0	.95	YOUNG
K3AS	B2IR	5.0	.87	YOUNG
K3AS	B2IR	5.0	.95	YOUNG
K3AS	B2IR	15.0	1.11	YOUNG
K3AS	B2IR	15.0	.91	YOUNG
K3AS	IIA2	30.0	1.53	YOUNG
K3AS	IIA2	30.0	1.44	YOUNG
K3AS	IIA2	45.0	1.42	YOUNG
K3AS	IIA2	45.0	1.51	YOUNG
K3AS	IIA&B	68.0	1.54	YOUNG
K3AS	IIA&B	68.0	1.36	YOUNG
K3AS	IIB2T	95.0	1.55	YOUNG
K3AS	IIB2T	95.0	1.56	YOUNG
K3AS	IIC1	125.0	1.74	YOUNG
K3AS	IIC1	125.0	1.78	YOUNG
K3BS	B2IR	5.0	.44	YOUNG
K3BS	B2IR	15.0	.93	YOUNG
K3BS	B2IR	15.0	.88	YOUNG
K3BS	IIA2	30.0	1.44	YOUNG
K3BS	IIA2	30.0	1.47	YOUNG

PEDON	HORIZON	DEPTH	BULK DENSITY	AGE GROUP
		CM	G/CC	
K3BS	IIA2	30.0	1.47	YOUNG
K3BS	IIA&B	45.0	1.38	YOUNG
K3BS	IIA&B	45.0	1.34	YOUNG
K3BS	IIB2T	70.0	1.43	YOUNG
K3BS	IIB2T	70.0	1.50	YOUNG
K3BS	IIC2	125.0	1.72	YOUNG
K3BS	IIC2	125.0	1.77	YOUNG

APPENDIX XVI

BULK DENSITY RAW DATA FOR

QUARTZITE DOMINATED GLACIAL TILL STUDY SUBSITES

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
F3AC	B2IR	5.0	.75	YOUNG
F3AC	B2IR	5.0	.70	YOUNG
F3AC	B2IR	15.0	.77	YOUNG
F3AC	B2IR	15.0	.68	YOUNG
F3AC	IIA2	30.0	1.72	YOUNG
F3AC	IIA2	30.0	1.77	YOUNG
F3AC	IIA2	45.0	1.93	YOUNG
F3AC	IIA2	45.0	1.85	YOUNG
F3AC	IIA&B	105.0	1.84	YOUNG
F3AC	IIA&B	105.0	1.64	YOUNG
F3AC	IIC1	165.0	1.52	YOUNG
F3AC	IIC1	165.0	1.73	YOUNG
F3BC	B2IR	5.0	.58	YOUNG
F3BC	B2IR	5.0	.83	YOUNG
F3BC	B2IR	15.0	1.13	YOUNG
F3BC	B2IR	15.0	.37	YOUNG
F3BC	IIA2	30.0	1.77	YOUNG
F3BC	IIA2	30.0	1.85	YOUNG
F3BC	IIA2	45.0	1.81	YOUNG
F3BC	IIA2	45.0	1.80	YOUNG
F3BC	IIA&B	73.0	1.91	YOUNG
F3BC	IIA&B	73.0	1.82	YOUNG
F3BC	IIC1	120.0	1.84	YOUNG
F3BC	IIC1	120.0	1.81	YOUNG
F3AM	B2IR	5.0	.36	YOUNG
F3AM	B2IR	5.0	.61	YOUNG
F3AM	B2IR	15.0	.50	YOUNG
F3AM	IIA2	15.0	.27	YOUNG
F3AM	IIA2	30.0	1.72	YOUNG
F3AM	IIA2	45.0	1.74	YOUNG
F3AM	IIA2	45.0	1.47	YOUNG
F3AM	IIA&B	90.0	1.65	YOUNG
F3AM	IIA&B	90.0	1.79	YOUNG
F3AM	IIC1	150.0	1.80	YOUNG
F3BM	B2IR	5.0	.57	YOUNG
F3BM	B2IR	5.0	.40	YOUNG
F3BM	B2IR	15.0	.40	YOUNG

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
F3BM	B2IR	15.0	.40	YOUNG
F3BM	B2IR	15.0	.29	YOUNG
F3BM	IIA2	30.0	1.85	YOUNG
F3BM	IIA2	30.0	1.76	YOUNG
F3BM	IIA2	45.0	1.75	YOUNG
F3BM	IIA2	45.0	1.80	YOUNG
F3BM	IIA&B	100.0	1.72	YOUNG
F3BM	IIC1	150.0	2.02	YOUNG
F3BM	IIC1	150.0	1.66	YOUNG
F3AS	B2IR	5.0	1.63	YOUNG
F3AS	B2IR	5.0	1.51	YOUNG
F3AS	B2IR	15.0	.96	YOUNG
F3AS	B2IR	15.0	1.04	YOUNG
F3AS	IIA2	30.0	1.83	YOUNG
F3AS	IIA2	30.0	1.73	YOUNG
F3AS	IIA2	45.0	2.36	YOUNG
F3AS	IIA2	45.0	1.82	YOUNG
F3AS	IIA&B	110.0	1.82	YOUNG
F3AS	IIA&B	110.0	1.85	YOUNG
F3AS	IIC2	175.0	1.70	YOUNG
F3AS	IIC2	175.0	1.89	YOUNG
F3BS	B2IR	5.0	.85	YOUNG
F3BS	B2IR	5.0	.77	YOUNG
F3BS	B2IR	15.0	.77	YOUNG
F3BS	B2IR	15.0	.81	YOUNG
F3BS	IIA2	30.0	1.81	YOUNG
F3BS	IIA2	30.0	1.77	YOUNG
F3BS	IIA2	45.0	1.75	YOUNG
F3BS	IIA2	45.0	1.91	YOUNG
F3BS	IIA&B	87.0	1.99	YOUNG
F3BS	IIA&B	87.0	2.03	YOUNG
F3BS	IIC1	148.0	1.20	YOUNG
K1AC	A2	3.0	.39	MEDIUM
K1AC	A2	3.0	.34	MEDIUM
K1AC	B2IR	5.0	.50	MEDIUM
K1AC	B2IR	5.0	.97	MEDIUM
K1AC	B2IR	15.0	.88	MEDIUM

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
K1AC	B2IR	15.0	.88	MEDIUM
K1AC	B2IR	15.0	.55	MEDIUM
K1AC	IIA2	30.0	1.75	MEDIUM
K1AC	IIA2	30.0	1.69	MEDIUM
K1AC	IIA2	45.0	1.82	MEDIUM
K1AC	IIA2	45.0	1.72	MEDIUM
K1AC	IIA&B	78.0	1.63	MEDIUM
K1AC	IIA&B	78.0	1.64	MEDIUM
K1AC	IIC1	124.0	1.79	MEDIUM
K1AC	IIC1	124.0	1.85	MEDIUM
K1BC	A2	3.0	.34	MEDIUM
K1BC	A2	3.0	.32	MEDIUM
K1BC	B2IR	5.0	.36	MEDIUM
K1BC	B2IR	5.0	.90	MEDIUM
K1BC	B2IR	15.0	.54	MEDIUM
K1BC	B2IR	15.0	.64	MEDIUM
K1BC	IIA2	30.0	1.83	MEDIUM
K1BC	IIA2	30.0	1.62	MEDIUM
K1BC	IIA2	45.0	1.80	MEDIUM
K1BC	IIA2	45.0	1.74	MEDIUM
K1BC	IIA&B	83.0	1.55	MEDIUM
K1BC	IIA&B	83.0	1.58	MEDIUM
K1BC	IIC1	145.0	1.71	MEDIUM
K1BC	IIC1	145.0	1.65	MEDIUM
K1AM	B2IR	5.0	.53	MEDIUM
K1AM	B2IR	5.0	.47	MEDIUM
K1AM	IIA2	15.0	.49	MEDIUM
K1AM	B2IR	15.0	.98	MEDIUM
K1AM	IIA2	30.0	1.59	MEDIUM
K1AM	IIA2	30.0	1.51	MEDIUM
K1AM	IIA2	45.0	1.65	MEDIUM
K1AM	IIA2	45.0	1.53	MEDIUM
K1AM	IIA&B	90.0	1.56	MEDIUM
K1AM	IIA&B	90.0	1.60	MEDIUM
K1AM	IIC1	138.0	1.92	MEDIUM
K1AM	IIC1	138.0	1.81	MEDIUM
K1BM	B2IR	5.0	.74	MEDIUM

PEDON	HORIZON	DEPTH CM	BULK DENSITY G/CC	AGE GROUP
K1BM	B2IR	5.0	.74	MEDIUM
K1BM	B2IR	5.0	.83	MEDIUM
K1BM	B2IR	15.0	.98	MEDIUM
K1BM	B2IR	15.0	.93	MEDIUM
K1BM	IIA2	30.0	1.56	MEDIUM
K1BM	IIA2	30.0	1.40	MEDIUM
K1BM	IIA&B	45.0	1.59	MEDIUM
K1BM	IIA&B	45.0	1.54	MEDIUM
K1BM	IIC1	140.0	1.85	MEDIUM
K1BM	IIC1	140.0	1.90	MEDIUM
K1AS	B2IR	5.0	.60	MEDIUM
K1AS	B2IR	5.0	.55	MEDIUM
K1AS	B2IR	15.0	.53	MEDIUM
K1AS	B2IR	15.0	.59	MEDIUM
K1AS	IIA2	30.0	1.69	MEDIUM
K1AS	IIA2	30.0	1.48	MEDIUM
K1AS	IIA&B	45.0	1.52	MEDIUM
K1AS	IIA&B	45.0	1.54	MEDIUM
K1AS	IIC1	115.0	1.70	MEDIUM
K1AS	IIC1	115.0	1.69	MEDIUM
K1BS	B2IR	5.0	1.00	MEDIUM
K1BS	B2IR	5.0	.47	MEDIUM
K1BS	B2IR	15.0	.94	MEDIUM
K1BS	B2IR	15.0	.86	MEDIUM
K1BS	IIA2	30.0	1.58	MEDIUM
K1BS	IIA2	30.0	1.46	MEDIUM
K1BS	IIA&B	45.0	1.66	MEDIUM
K1BS	IIA&B	45.0	1.64	MEDIUM
K1BS	IIC1	123.0	1.80	MEDIUM
K1BS	IIC1	123.0	1.77	MEDIUM

APPENDIX XVII

SOIL WATER RETENTION RAW DATA FOR TERTIARY VOLCANIC STUDY SUBSITES

PEDON	HORIZON	DEPTH	% WATER BY WT.			AGE
			.02	.10	.33	GROUP
		CM	BARS	BARS	BARS	
B1AC	A2	15.0	31.63	29.18	18.29	OLD
B1AC	B21T	30.0	59.24	57.27	53.93	OLD
B1AC	B22T	45.0	76.91	75.62	67.24	OLD
B1BC	A2	15.0	42.42	38.28	35.10	OLD
B1BC	A2	30.0	40.39	40.07	39.41	OLD
B1BC	B21T	45.0	46.85	45.31	43.99	OLD
B1AM	A2	15.0	26.38	23.21	22.10	OLD
B1AM	B21T	30.0	16.74	15.49	14.90	OLD
B1AM	B22T	45.0	28.25	25.61	22.69	OLD
B1BM	A2	15.0	33.88	31.64	29.13	OLD
B1BM	B21T	30.0	56.03	52.57	51.33	OLD
B1BM	B22T	45.0	50.57	48.83	46.79	OLD
B1AS	A2	20.0	21.26	18.44	13.60	OLD
B1AS	B21T	30.0	24.31	22.60	13.12	OLD
B1AS	B22T	45.0	32.50	31.37	28.24	OLD
B1BS	A2	15.0	31.97	29.97	28.75	OLD
B1BS	A2	30.0	28.49	25.33	22.88	OLD
B1BS	B21T	45.0	51.17	49.37	48.39	OLD
B2AC	A2	15.0	28.06	26.63	25.92	OLD
B2AC	B21T	30.0	31.20	30.93	30.29	OLD
B2AC	B21T	45.0	42.12	41.48	40.67	OLD
B2BC	A2	15.0	30.52	27.48	17.22	OLD
B2BC	B22T	30.0	47.53	46.07	44.82	OLD
B2BC	IIB22T	45.0	52.60	51.34	44.60	OLD
B2AM	A2	15.0	29.07	28.68	28.41	OLD
B2AM	A2	30.0	25.81	25.31	22.53	OLD
B2AM	B22T	45.0	54.45	53.29	52.34	OLD
B2BM	A2	15.0	35.01	32.28	22.82	OLD
B2BM	B21T	30.0	25.07	23.22	13.15	OLD
B2BM	B22T	45.0	47.49	44.44	43.54	OLD
B2AS	A2	15.0	29.25	27.52	25.16	OLD
B2AS	B21T	30.0	33.90	31.98	31.13	OLD
B2AS	B22T	45.0	40.83	39.56	38.02	OLD
B2BS	A2	15.0	33.58	31.85	23.52	OLD
B2BS	B21T	30.0	49.68	46.98	38.42	OLD
B2BS	B22T	45.0	81.07	78.32	18.36	OLD
B3AC	A2	15.0	30.41	28.45	27.13	YOUNG

PEDON	HORIZON	DEPTH	% WATER BY WT.			AGE GROUP
			.02	.10	.33	
		CM	BARS	BARS	BARS	
B3AC	A2	15.0	30.41	28.45	27.15	YOUNG
B3AC	B21T	30.0	30.61	29.54	28.40	YOUNG
B3AC	B21T	45.0	29.22	28.10	26.99	YOUNG
B3AC	IIA&B	105.0	41.14	38.67	34.86	YOUNG
B3BC	A2	15.0	27.93	25.74	15.59	YOUNG
B3BC	B21T	30.0	42.86	42.60	42.19	YOUNG
B3BC	B22T	45.0	42.65	42.19	41.92	YOUNG
B3BC	B22T	45.0	52.48	51.43	50.11	YOUNG
B3AM	A2	15.0	27.97	26.00	14.23	YOUNG
B3AM	A2	30.0	26.28	24.23	14.37	YOUNG
B3AM	B21T	45.0	36.00	35.92	35.71	YOUNG
B3BM	A2	15.0	20.89	19.12	11.80	YOUNG
B3BM	B22T	30.0	38.52	38.09	37.25	YOUNG
B3BM	B22T	45.0	32.91	32.47	26.08	YOUNG
B3AS	A2	15.0	25.48	23.95	16.26	YOUNG
B3AS	B21T	30.0	21.05	20.73	20.32	YOUNG
B3AS	B22T	45.0	22.00	21.60	21.27	YOUNG
B3BS	A2	15.0	24.44	22.31	14.49	YOUNG
B3BS	B21T	30.0	53.82	51.90	49.38	YOUNG
B3BS	B21T	45.0	39.23	38.66	38.23	YOUNG

APPENDIX XVIII

SOIL WATER RETENTION RAW DATA FOR

LIMESTONE DOMINATED GLACIAL TILL STUDY SUBSITES

PEDON	HORIZON	DEPTH	% WATER BY WT.			AGE
			.02	.10	.33	GROUP
		CM	BARS	BARS	BARS	
F1AC	B2IR	5.0	34.72	33.97	33.45	OLD
F1AC	B2IR	15.0	30.63	21.00	17.48	OLD
F1AC	IIA2	30.0	34.08	31.42	29.60	OLD
F1AC	IIA&B	45.0	35.23	31.96	29.39	OLD
F1AC	IIB&A	71.0	35.28	28.87	28.79	OLD
F1AC	IIB21T	88.0	39.37	34.80	32.37	OLD
F1BC	B2IR	15.0	1.98	94.94	93.88	OLD
F1BC	IIA2	30.0	31.82	30.56	28.50	OLD
F1BC	IIA2	45.0	32.10	30.59	28.22	OLD
F1BC	IIA&B	65.0	35.36	32.37	29.21	OLD
F1BC	IIB&A	82.0	34.68	32.78	32.20	OLD
F1BC	IIB22T	148.0	37.83	35.12	33.66	OLD
F1AM	B2IR	15.0	89.93	82.90	82.09	OLD
F1AM	IIA2	30.0	33.04	31.77	31.13	OLD
F1AM	IIA&B	45.0	41.25	40.41	39.25	OLD
F1AM	IIB21T	105.0	20.76	20.16	19.73	OLD
F1BM	B2IR	15.0	74.00	70.68	68.77	OLD
F1BM	IIA2	30.0	15.65	13.65	13.15	OLD
F1BM	IIA&B	45.0	41.18	39.83	39.56	OLD
F1BM	IIB21T	85.0	34.12	33.26	32.24	OLD
F1AS	B2IR	15.0	40.10	30.69	30.06	OLD
F1AS	IIA&B	30.0	38.35	35.60	34.89	OLD
F1AS	IIA&B	45.0	35.64	32.20	32.07	OLD
F1AS	IIA&B	54.0	26.46	25.30	24.51	OLD
F1AS	IIB21T	97.0	28.18	27.15	26.34	OLD
F1BS	IIA2	15.0	20.53	19.68	19.21	OLD
F1BS	IIA2	30.0	33.04	31.77	31.13	OLD
F1BS	IIA2	45.0	22.79	21.79	20.75	OLD
F1BS	IIA&B	54.0	26.52	25.30	24.51	OLD
F1BS	IIB21T	110.0	35.31	32.63	29.97	OLD
K2AC	B2IR	15.0	86.53	85.77	78.66	MEDIUM
K2AC	IIA2	30.0	25.68	23.44	22.61	MEDIUM
K2AC	IIA&B	45.0	31.41	30.35	28.91	MEDIUM
K2AC	IIB&A	67.0	37.89	31.01	29.15	MEDIUM
K2AC	IIB2T	80.0	39.86	36.75	33.49	MEDIUM
K2AC	IIC1	100.0	34.92	30.74	29.14	MEDIUM
K2BC	B2IR	15.0	71.17	68.04	57.33	MEDIUM

PEDON	HORIZON	DEPTH	% WATER BY WT.			AGE
			.02	.10	.33	GROUP
		CM	BARS	BARS	BARS	
K2BC	B2IR	15.0	71.17	68.04	57.33	MEDIUM
K2BC	IIA2	30.0	28.40	24.32	21.40	MEDIUM
K2BC	IIA2	45.0	24.87	22.23	20.78	MEDIUM
K2BC	IIA&B	58.0	28.45	25.37	23.71	MEDIUM
K2BC	IIB2T	73.0	38.93	36.66	35.62	MEDIUM
K2BC	IIC1	100.0	37.23	32.11	29.75	MEDIUM
K2AM	B2IR	15.0	55.43	53.96	47.70	MEDIUM
K2AM	IIA2	30.0	24.04	23.14	22.38	MEDIUM
K2AM	IIA&B	37.0	25.48	24.42	23.16	MEDIUM
K2AM	IIB21T	45.0	32.65	31.01	30.00	MEDIUM
K2AM	IIC2	155.0	35.25	31.44	30.51	MEDIUM
K2BM	B2IR	15.0	36.54	35.40	32.30	MEDIUM
K2BM	IIA2	30.0	27.61	25.70	24.70	MEDIUM
K2BM	IIA&B	45.0	29.67	26.08	24.29	MEDIUM
K2BM	IIB2T	69.0	42.06	38.33	34.98	MEDIUM
K2BM	IIC2	160.0	32.00	28.52	27.25	MEDIUM
K2AS	B2IR	15.0	55.42	52.84	52.20	MEDIUM
K2AS	IIA2	30.0	30.46	28.93	27.92	MEDIUM
K2AS	IIA&B	45.0	37.12	34.45	32.33	MEDIUM
K2AS	IIB2T	54.0	30.35	27.77	24.13	MEDIUM
K2AS	IIC2	101.0	34.34	31.35	29.07	MEDIUM
K2BS	IIA2	15.0	29.59	25.37	23.52	MEDIUM
K2BS	IIA&B	30.0	40.71	39.07	37.65	MEDIUM
K2BS	IIB2T	45.0	38.27	35.20	31.11	MEDIUM
K2BS	IIC2	148.0	28.14	26.83	25.25	MEDIUM
K3AC	B2IR	15.0	73.01	71.73	67.83	YOUNG
K3AC	IIA2	30.0	30.07	28.00	26.54	YOUNG
K3AC	IIA2	45.0	27.60	25.73	22.47	YOUNG
K3AC	IIA&B	62.0	74.36	72.06	68.23	YOUNG
K3AC	IIB2T	69.0	35.16	32.76	31.13	YOUNG
K3AC	IIC1	113.0	24.58	23.37	22.45	YOUNG
K3BC	B2IR	15.0	82.00	72.35	69.20	YOUNG
K3BC	IIA2	30.0	27.96	25.45	23.57	YOUNG
K3BC	IIA&B	45.0	26.63	25.13	23.32	YOUNG
K3BC	IIB2T	73.0	37.04	34.96	31.92	YOUNG
K3BC	IIC1	100.0	36.83	33.18	29.69	YOUNG
K3AM	B2IR	15.0	59.57	56.94	50.15	YOUNG

PEDON	HORIZON	DEPTH	% WATER BY WT.			AGE GROUP
			.02	.10	.33	
		CM	BARS	BARS	BARS	
K3AM	B2IR	15.0	59.57	56.94	50.15	YOUNG
K3AM	IIA2	30.0	31.99	30.41	29.24	YOUNG
K3AM	IIA&B	45.0	39.38	37.44	34.61	YOUNG
K3AM	IIB2T	78.0	38.60	36.18	33.80	YOUNG
K3AM	IIC1	110.0	29.50	27.46	25.57	YOUNG
K3BM	B2IR	15.0	76.08	72.33	70.90	YOUNG
K3BM	IIA2	30.0	29.98	27.50	25.62	YOUNG
K3BM	IIA2	45.0	26.10	24.10	22.86	YOUNG
K3BM	IIA&B	71.0	32.54	30.65	29.18	YOUNG
K3BM	IIB2T	105.0	28.33	26.68	25.27	YOUNG
K3BM	IIC1	142.0	28.22	26.85	25.41	YOUNG
K3AS	B2IR	15.0	70.41	66.25	63.36	YOUNG
K3AS	IIA2	30.0	30.38	28.69	26.91	YOUNG
K3AS	IIA2	45.0	30.67	29.43	28.18	YOUNG
K3AS	IIA&B	68.0	39.84	35.60	33.54	YOUNG
K3AS	IIB2T	95.0	32.80	31.20	29.97	YOUNG
K3AS	IIC1	125.0	28.40	26.35	24.71	YOUNG
K3BS	B21R	15.0	73.09	71.36	69.90	YOUNG
K3BS	IIA2	30.0	22.09	20.21	18.29	YOUNG
K3BS	IIA&B	45.0	35.87	32.70	31.48	YOUNG
K3BS	IIB2T	70.0	35.73	32.31	30.49	YOUNG
K3BS	IIC2	125.0	24.94	23.54	22.11	YOUNG

APPENDIX XIX

SOIL WATER RETENTION RAW DATA FOR

QUARTZITE DOMINATED GLACIAL TILL STUDY SUBSITES

PEDON	HORIZON	DEPTH	% WATER BY WT.			AGE
			.02	.10	.33	GROUP
		CM	BARS	BARS	BARS	
F2AC	B2IR	15.0	43.21	33.79	33.17	MEDIUM
F2AC	IIA2	30.0	26.84	25.86	25.16	MEDIUM
F2AC	IIA2	45.0	24.64	23.59	22.48	MEDIUM
F2AC	IIA&B	80.0	24.83	23.06	21.45	MEDIUM
F2AC	IIC1	120.0	22.84	20.37	19.01	MEDIUM
F2BC	B2IR	15.0	61.34	51.81	49.30	MEDIUM
F2BC	IIA2	45.0	25.76	24.29	22.08	MEDIUM
F2BC	IIA&B	80.0	16.09	15.44	15.12	MEDIUM
F2BC	IIC1	120.0	20.64	16.70	15.65	MEDIUM
F2AM	B2IR	15.0	6.24	3.92	3.11	MEDIUM
F2AM	IIA2	30.0	38.70	36.90	35.34	MEDIUM
F2AM	IIA2	45.0	40.29	39.43	38.30	MEDIUM
F2AM	IIA&B	90.0	42.35	41.25	40.17	MEDIUM
F2AM	IIC1	130.0	26.66	22.75	21.23	MEDIUM
F2BM	B2IR	15.0	59.13	53.02	52.05	MEDIUM
F2BM	IIA2	30.0	36.70	35.77	34.48	MEDIUM
F2BM	IIA2	45.0	22.79	21.75	20.75	MEDIUM
F2BM	IIA&B	90.0	31.71	30.39	29.05	MEDIUM
F2BM	IIC1	130.0	21.62	18.64	17.39	MEDIUM
F2AS	B2IR	15.0	15.17	8.55	4.21	MEDIUM
F2AS	IIA2	30.0	22.12	20.69	18.71	MEDIUM
F2AS	IIA&B	100.0	20.41	18.77	17.47	MEDIUM
F2AS	IIC1	145.0	25.05	20.06	18.53	MEDIUM
F2BS	IIA2	30.0	18.41	17.62	14.46	MEDIUM
F2BS	IIA2	45.0	21.44	20.67	19.82	MEDIUM
F2BS	IIA&B	90.0	21.81	20.67	19.66	MEDIUM
F2BS	IIC1	130.0	21.45	19.16	17.79	MEDIUM
F3AC	B2IR	15.0	36.03	34.72	33.57	YOUNG
F3AC	IIA2	30.0	29.65	28.62	27.38	YOUNG
F3AC	IIA2	45.0	57.91	54.49	49.55	YOUNG
F3AC	IIC1	165.0	57.16	39.70	36.52	YOUNG
F3BC	B2IR	15.0	60.55	45.27	37.04	YOUNG
F3BC	IIA2	30.0	25.02	24.42	23.51	YOUNG
F3BC	IIA2	45.0	21.20	20.61	19.74	YOUNG
F3BC	IIA&B	75.0	45.52	43.41	41.55	YOUNG
F3BC	IIC1	120.0	51.58	40.85	37.40	YOUNG
F3AM	B2IR	15.0	35.88	18.93	7.77	YOUNG

PEDON	HORIZON	DEPTH CM	% WATER BY WT. .02 BARS	.10 BARS	.33 BARS	AGE GROUP
F3AM	B2IR	15.0	35.88	18.96	7.77	YOUNG
F3AM	IIA2	45.0	36.89	35.36	31.78	YOUNG
F3AM	IIA&B	90.0	28.97	26.97	23.63	YOUNG
F3AM	IIC1	150.0	33.32	30.57	25.71	YOUNG
F3BM	B2IR	15.0	75.24	[illegible]	59.75	YOUNG
F3BM	IIA2	30.0	25.68	24.66	22.50	YOUNG
F3BM	IIA2	45.0	26.11	24.71	23.46	YOUNG
F3BM	IIA&B	100.0	43.40	40.56	29.78	YOUNG
F3BM	IIC1	150.0	59.27	49.29	44.42	YOUNG
F3AS	B2IR	15.0	38.24	33.16	27.19	YOUNG
F3AS	IIA2	30.0	24.43	23.16	21.70	YOUNG
F3AS	IIA2	45.0	27.91	26.05	23.86	YOUNG
F3AS	IIA&B	110.0	28.11	27.07	26.45	YOUNG
F3AS	IIC1	175.0	31.32	25.79	23.97	MEDIUM
F3BS	B2IR	15.0	57.71	56.07	40.06	YOUNG
F3BS	IIA2	30.0	24.82	23.44	21.72	YOUNG
F3BS	IIA2	45.0	40.64	37.92	33.95	YOUNG
F3BS	IIA&B	87.0	25.54	24.76	23.80	YOUNG
F3BS	IIC1	148.0	61.18	36.86	31.21	YOUNG
K1AC	B2IR	15.0	86.99	83.29	78.07	MEDIUM
K1AC	IIA2	30.0	18.92	18.39	16.96	MEDIUM
K1AC	IIA2	45.0	23.30	22.56	20.76	MEDIUM
K1AC	IIA&B	78.0	35.71	34.80	32.11	MEDIUM
K1AC	IIC1	129.0	25.58	22.23	20.86	MEDIUM
K1BC	B2IR	15.0	57.80	56.83	55.49	MEDIUM
K1BC	IIA2	30.0	24.23	23.28	21.37	MEDIUM
K1BC	IIA&B	45.0	26.36	25.77	24.62	MEDIUM
K1BC	IIA&B	105.0	34.10	33.86	32.99	MEDIUM
K1BC	IIC1	145.0	29.35	25.9[illegible]	24.78	MEDIUM
K1AM	B2IR	15.0	48.78	48.58	46.37	MEDIUM
K1AM	IIA2	30.0	28.32	27.65	25.62	MEDIUM
K1AM	IIA2	45.0	22.00	21.62	19.51	MEDIUM
K1AM	IIA&B	90.0	30.07	29.47	28.64	MEDIUM
K1AM	IIC1	138.0	23.84	20.26	19.26	MEDIUM
K1BM	B2IR	15.0	33.10	32.10	31.63	MEDIUM
K1BM	IIA2	30.0	27.83	27.17	25.80	MEDIUM
K1BM	IIA&B	45.0	25.22	24.39	23.15	MEDIUM

PEDON	HORIZON	DEPTH	% WATER BY WT.			AGE
			.02	.10	.33	GROUP
		CM	BARS	BARS	BARS	
K1BM	IIA&B	45.0	25.22	24.39	23.15	MEDIUM
K1BM	IIC1	140.0	34.43	31.55	29.81	MEDIUM
K1AS	B2IR	15.0	71.23	66.89	65.32	MEDIUM
K1AS	IIA2	30.0	26.54	25.64	24.04	MEDIUM
K1AS	IIA&B	45.0	31.05	30.15	27.84	MEDIUM
K1AS	IIC1	115.0	22.82	19.92	18.97	MEDIUM
K1BS	B2IR	15.0	32.73	28.49	15.56	MEDIUM
K1BS	IIA2	30.0	25.36	22.54	20.62	MEDIUM
K1BS	IIA&B	45.0	27.59	26.85	25.86	MEDIUM
K1BS	IIC1	123.0	38.45	35.46	34.47	MEDIUM