

AN ABSTRACT OF THE THESIS OF

BILLY LYNN HARRIS for the DOCTOR OF PHILOSOPHY  
(Name) (Degree)  
in SOIL SCIENCE presented on January 26, 1973  
(Major) (Date)

Title: GENESIS, MINERALOGY, AND PROPERTIES OF PARKDALE  
SOILS, OREGON

Abstract approved: \_\_\_\_\_

Redacted for privacy

\_\_\_\_\_  
M. E. Harward

Prior to the present studies, Parkdale soils were considered to have developed in volcanic ash. They showed many properties typical of soils with high amorphous material content. However, many features of the soils were puzzling. Crystalline clays composed a higher proportion of the total clays and were of a different mineralogy from those of other soils formed in volcanic ash. Parkdale soils seemed to be weathered, but little horizon differentiation had occurred. These and other questions stimulated studies to evaluate genesis, distribution, age, properties, and classification of Parkdale soils. Comparisons were also made between the well drained Parkdale and associated somewhat poorly drained Dee soils.

Parkdale soils mostly occur in the Upper Hood River Valley of Oregon and are distributed throughout the valley floor. Parkdale soil profiles are relatively uniform across the landscape. They are high in amorphous materials and have developed primarily in weathered

basalt, andesite, and dacite. Chemical composition and particle size data show good correlation of Parkdale soils with rocks and unconsolidated materials on the northeastern flanks of Mt. Hood. Scattered throughout the profile of these soils are pebbles and pieces of charcoal which are coated with soil materials. The pebble content generally increases with depth. These soils have moderate amounts of clay and the content varies little with depth. Parkdale soils and an underlying cobble layer are co-extensive over many different materials. The data suggest that parent materials for Parkdale soils were emplaced by mudflow processes between 6890 and 12,270 years B. P. There is a small amount of contamination of surface horizons by volcanic ash and possibly other eolian materials. Parkdale or Parkdale-like soils occur at several locations outside the Upper Hood River Valley, but these areas are consistent with a mudflow origin.

Other researchers had experienced difficulties in laboratory characterization of Parkdale soils. One of these difficulties involved dispersion. Of three methods evaluated, Parkdale soils dispersed best at pH 3.5, next best at pH 10.5, and least in distilled water. Also, clays dispersed at pH 3.5 showed minimal treatment effects when compared to water dispersed clays. Investigation of organic matter removal treatments revealed that  $\text{H}_2\text{O}_2$  has greater effects than NaOCl on amount and composition of clays dispersed. Cation exchange determinations of Parkdale soil clays showed that methods involving

washes with either water or alcohol gave low values when compared to values from a method not involving washes.

Parkdale soils exhibit little genetic development. Horizon differentiation has been largely limited to organic matter accumulation in surface horizons. Higher organic matter contents than in associated soils was attributed to effects of amorphous materials. There are more "shot" and a higher percentage of crystalline clays in the surface than in lower horizons. Allophane dominates the clay-size material. Chloritic intergrades, cristobalite, feldspars, and small amounts of smectite, quartz, mica, and halloysite are also present in the clay fraction. The moderate clay content but lack of profile differentiation suggests 1) weathering of materials before emplacement and 2) limited clay formation since deposition. The minimal development of Parkdale soils was attributed mostly to restricted moisture availability during warm, dry summers.

Dee sola are more poorly drained, deeper, and more mature than Parkdale sola. Dee soils have lower organic carbon and amorphous material contents as compared to Parkdale soils. Halloysite dominates the clay fraction, particularly in upper horizons, of Dee soils, while allophane is dominant in Parkdale soils.

Parkdale soils have <60% vitric pyroclastic materials and bulk densities of >0.85 g/cc, indicating that they should be classified as Andic Xerumbrepts, rather than Umbric Vitrandepts.

Genesis, Mineralogy, and Properties  
of Parkdale Soils, Oregon

by

Billy Lynn Harris

A THESIS

submitted to

Oregon State University

in partial fulfillment of  
the requirements for the  
degree of

Doctor of Philosophy

June 1973

APPROVED:

Redacted for privacy

\_\_\_\_\_  
Professor of Soil Science  
in charge of major

Redacted for privacy

\_\_\_\_\_  
Head of Department of Soil Science

Redacted for privacy

\_\_\_\_\_  
Dean of Graduate School

Date thesis is presented January 26, 1973

Typed by Mary Jo Stratton for Billy Lynn Harris

## ACKNOWLEDGEMENTS

The author wishes to express his deepest gratitude to Dr. M. E. Harward for his counsel, guidance, and encouragement during work toward this thesis. The interest and helpful discussions of Drs. E. G. Knox and R. B. Parsons are also greatly appreciated. Appreciation is also extended to Drs. H. E. Enlows, R. A. Schmitt, and A. P. Appleby for their interest and willingness to serve as program committeemen.

The author gratefully acknowledges financial support from an NDEA Title IV Fellowship and supplemental funds from the AEC grant AT(45-1)-2227-T9 and from the Oregon Agricultural Experiment Station.

Special thanks are expressed to my wife, Janie, for her encouragement and for typing the rough draft. The surprising understanding of my boys, Cord and Jeff, is also deeply appreciated.

## TABLE OF CONTENTS

	<u>Page</u>
I. GENERAL INTRODUCTION TO THE PROBLEM AND STUDY AREA	1
Motivation and Introduction	1
Description of Study Area	4
Geography	4
Climate and Vegetation	6
Geology	7
II. SOURCE AND CORRELATION	13
Introduction	13
Methods	14
Soil Samples	14
Particle Size Analyses	15
Heavy Mineral Separation	15
X-ray Spectroscopy Analyses	17
Petrographic Analyses	18
Radiocarbon Age Determination	19
Results and Discussion	19
Description of Parkdale Soils	19
Variations of Parkdale Soils	23
Occurrence and Distribution of Parkdale Soils	30
Source for Parent Material of Parkdale Soils	48
Age of Parkdale Soils	64
Summary and Conclusions on Source and Correlation	68
III. EFFECTS OF LABORATORY TREATMENTS ON PARKDALE SOILS	71
Introduction	71
Methods	72
Dispersion and Removal of Clays	72
Organic Matter Removal	72
Differential Thermal Analyses	73
X-ray Diffraction Analyses	73
Cation Exchange Capacity Determinations	74
Removal of Free Iron Oxides and Amorphous Components	75

	<u>Page</u>
Electrical Conductivity	75
pH Measurement	75
Results and Discussion	75
Effects on Organic Matter Removal Treatments	76
Effects of Dispersion Methods on Parkdale Soils	81
CEC Determinations of Parkdale Soils by Different Methods	89
Summary and Conclusions on Effects of Laboratory Treatments	91
 IV. MINERALOGY, GENESIS, AND CLASSIFICATION OF PARKDALE SOILS	 94
Introduction	94
Methods	96
Soil Fractionation	96
Cation Exchange Capacity Determinations	96
Soil pH Measurement	96
Organic Carbon Analyses	96
Extractable Cations, Phosphorus, and Base Saturation	97
Differential Thermal Analyses	97
Infra-red Analyses	97
X-ray Diffraction Analyses	98
Chemical Analyses of Clays	98
Test for Allophane	98
Petrographic Analyses	98
Amorphous Material Determination	99
Results	99
Properties of Whole Soils	99
Characteristics of Clays	110
Discussion	129
Soil Genesis	129
Classification	137
Conclusions on Mineralogy, Genesis, and Classification of Parkdale Soils	139
 BIBLIOGRAPHY	 142
 APPENDICES	 150



## LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Particle size distribution of Parkdale soils.	21
2	Sand subfraction ratios of a Parkdale soil.	24
3	Mineral composition of sand size fraction of Parkdale soils.	26
4	Si, Al, and Fe composition of a Parkdale soil.	27
5	Mineral separate analyses of very fine sand fraction of a Parkdale soil.	27
6	Composition of magnetite grains and statistical correlations for a Parkdale soil.	28
7	Sand content, sand subfraction ratios and correlations of Parkdale soils.	29
8	Petrographic analyses of sand fraction of Parkdale soils.	31
9	Sand content, subfraction ratios and correlation of soils east of the Upper Hood River Valley with Parkdale soils.	36
10	Chemical analyses of selected samples from the area surrounding the Upper Hood River Valley.	37
11	Statistical evaluation of magnetite analyses as related to correlation and distribution of Parkdale soils.	39
12	Sand content, subfraction ratios and correlation of soils north of the Upper Hood River Valley with Parkdale soils.	40
13	Petrographic analyses of sands from Parkdale and Parkdale-related soils.	41

<u>Table</u>		<u>Page</u>
14	Sand content, subfraction ratios and correlation of soils west of the Upper Hood River Valley with Parkdale soils.	43
15	Sand content, subfraction ratios and correlation of soils south of the Upper Hood River Valley with Parkdale soils.	47
16	Chemical composition of selected pyroclastic deposits, lava flows, and soil samples.	50
17	Statistical evaluation of magnetite analyses for source correlation.	51
18	Chemical analyses of rocks and deposits from the northeastern side of Mt. Hood (Wise, 1969) compared to Parkdale soils.	61
19	Effect of pH and organic matter removal on clay content, amorphous material content, and CEC.	77
20	Effect of dispersion treatments on clay content and CEC's.	82
21	Properties of solutions before and after stirring a Parkdale soil suspension.	87
22	Cations in solution before and after stirring a Parkdale soil suspension.	88
23	Cation exchange capacities of Parkdale soils and clays by different methods.	90
24	Particle size distribution of a Parkdale and a Dee soil (percent of $\leq 2$ mm).	100
25	Selected properties of a Parkdale and a Dee soil.	102
26	Selected chemical properties of a Parkdale and a Dee soil.	104

<u>Table</u>		<u>Page</u>
27	Chemical composition of a Parkdale and a Dee soil.	106
28	Components of sand fraction from a Parkdale soil.	107
29	Selected properties of Parkdale and Dee soil clays.	111
30	Chemical composition of Parkdale and Dee soil clays.	112
31	Rapid test for allophane for a Parkdale and a Dee soil.	114

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Location of study area.	5
2	Major sample sites and their relationship to Parkdale soils.	16
3	Description of sections of Parkdale soils and underlying materials.	22
4	Major distribution and selected thicknesses of Parkdale soils.	32
5	Generalized profile of Parkdale soils from Mt. Hood to Middle Mountain.	33
6	Differential thermal analyses curves of Parkdale soil clays after various treatments to remove organic matter.	79
7	Differential thermal analyses curves of clays obtained by dispersion in three different media.	84
8	X-ray diffraction patterns for <2 micron clay samples from a Parkdale soil Ap horizon.	116
9	X-ray diffraction patterns for <2 micron clay samples from a Parkdale soil C4 horizon.	117
10	X-ray diffraction patterns for <2 micron clay samples from Parkdale soil C2 and C6 horizons.	118
11	X-ray diffraction patterns for <2 micron clay samples from a Dee soil B21 horizon.	120
12	X-ray diffraction patterns for <2 micron clay samples from a Dee soil C1 horizon.	121
13	Differential thermal analyses curves from total clays for several horizons of a Parkdale soil.	123

<u>Figure</u>		<u>Page</u>
14	Differential thermal analyses curves from total clays for several horizons of a Dee soil.	125
15	Differential thermal analyses curves for crystalline clays from B21 and C1 horizons of a Dee soil.	126
16	Infra-red spectra from Parkdale soil total clays.	128
17	Infra-red spectra from Dee soil total clays.	128
18	Electron micrographs of Parkdale soil total clays.	130

# GENESIS, MINERALOGY, AND PROPERTIES OF PARKDALE SOILS, OREGON

## CHAPTER I

### GENERAL INTRODUCTION TO THE PROBLEM AND STUDY AREA

#### Motivation and Introduction

For years, people have gone to the Upper Hood River Valley in Oregon to observe Parkdale soils. These soils were thought to have developed in volcanic ash. Some suggested that the parent material was accumulated tephra from Mt. Mazama; others disagreed. If these soils developed in ash other than Mazama, then what was the source? A number of possible sources exist. If the valley soils developed in volcanic ash, then there should be accumulations of volcanic ash in appropriate locations in surrounding areas. If that ash could be found, it should be possible to correlate it to a source. However, there seemed to be little siliceous tephra in either upland or valley soils.

Comparison of Parkdale soils with those developed on tephra from Mt. Mazama showed notable contrasts. On the one hand, crystalline clays in the Parkdale soils constitute a higher percentage of the clay fraction and are of different mineralogy than clays from soils developed in Mt. Mazama tephra. On the other hand, some of

the properties of Parkdale soil clays were typical of allophanic constituents. Differences in primary mineral suites were also evident. These and other differences served to further contribute to the enigma of a source for Parkdale soil materials.

One of several problems encountered with Parkdale soil samples in the laboratory was dispersibility. Some samples would disperse; others would not. Occasionally this occurred with subsamples from the same soil horizon. There were also problems of reproducibility of results in chemical studies. These problems tended to distinguish Parkdale soils from others. A detailed study could hopefully answer some of these questions.

Different studies of soils developed in Mt. Mazama tephra were each oriented to a particular question or property. Determinations of porosity and pore size distribution of the pumiceous material, origin of 2:1 type phyllosilicates, distribution and stratigraphy of the soils and tephra, characterization of amorphous materials, and source correlations were done by different people in separate studies. It was hoped that Parkdale soils could be comprehensively studied and avoid similar fragmentation. Therefore, plans were to study several aspects of Parkdale soils including origin, properties, genesis and classification. Such a study would hopefully answer many questions and provide a relatively complete evaluation of Parkdale soils.

The major objectives for this study were:

1. To determine the source or sources of parent material of Parkdale soils;
2. To evaluate the distribution of Parkdale and Parkdale-like soil materials;
3. To determine the age of Parkdale soils;
4. To investigate problems encountered with dispersibility and obtain reproducible physical characterization of Parkdale soils;
5. To investigate effects of a few treatments on Parkdale soils;
6. To determine mineralogy and selected chemical characteristics in order to evaluate genesis of Parkdale soils;
7. To compare and contrast genesis of Parkdale and Dee soils;
8. To utilize results of these studies to classify Parkdale soils.

For convenience, some of these objectives were collected into similar groups and will be discussed together. The first three, numbers 4 and 5, and the last three made logical separations for the text of this dissertation. The following material is organized, therefore, into sections of Description of the Study Area, Source and Correlation, Effects of Laboratory Treatments on Parkdale Soils, and Mineralogy, Genesis, and Classification of Parkdale Soils.



## Description of the Study Area

### Geography

The Hood River Valley lies immediately northeast of Mt. Hood (Figure 1) in the northern Middle Cascade Mountains of the Sierra-Cascade Province described by Fenneman (1931). According to Hodge (1940), this area is at the northern end of the Cascade Plateau Province of Oregon. The Hood River Valley is divided into two almost equal parts by Middle Mountain. The Hood River flows in a generally northerly direction to its confluence with the Columbia River. The southern part, referred to as the Upper Hood River Valley and lying mostly between latitudes  $45^{\circ}26'$  and  $45^{\circ}34'$  and longitudes  $121^{\circ}34'$  and  $121^{\circ}38'$  (T1S and T1N, R10E) is the primary area of this study.

The Upper Hood River Valley is generally level-bottomed with minor relief associated with drainages. There is a gentle slope to the north with a decrease in elevation from about 608 m to 304 m over a distance of approximately 13 km. The valley is about 5-1/2 km wide and is surrounded by mountains. It is incised on the eastern side by the East Fork of the Hood River and bordered on the west by the Middle Fork of the Hood River. A few minor creeks flowing northward drain into the East Fork along the northern part of the valley.

In order to better understand the features and soils of the upper valley, it was necessary to investigate surrounding soils. Studies

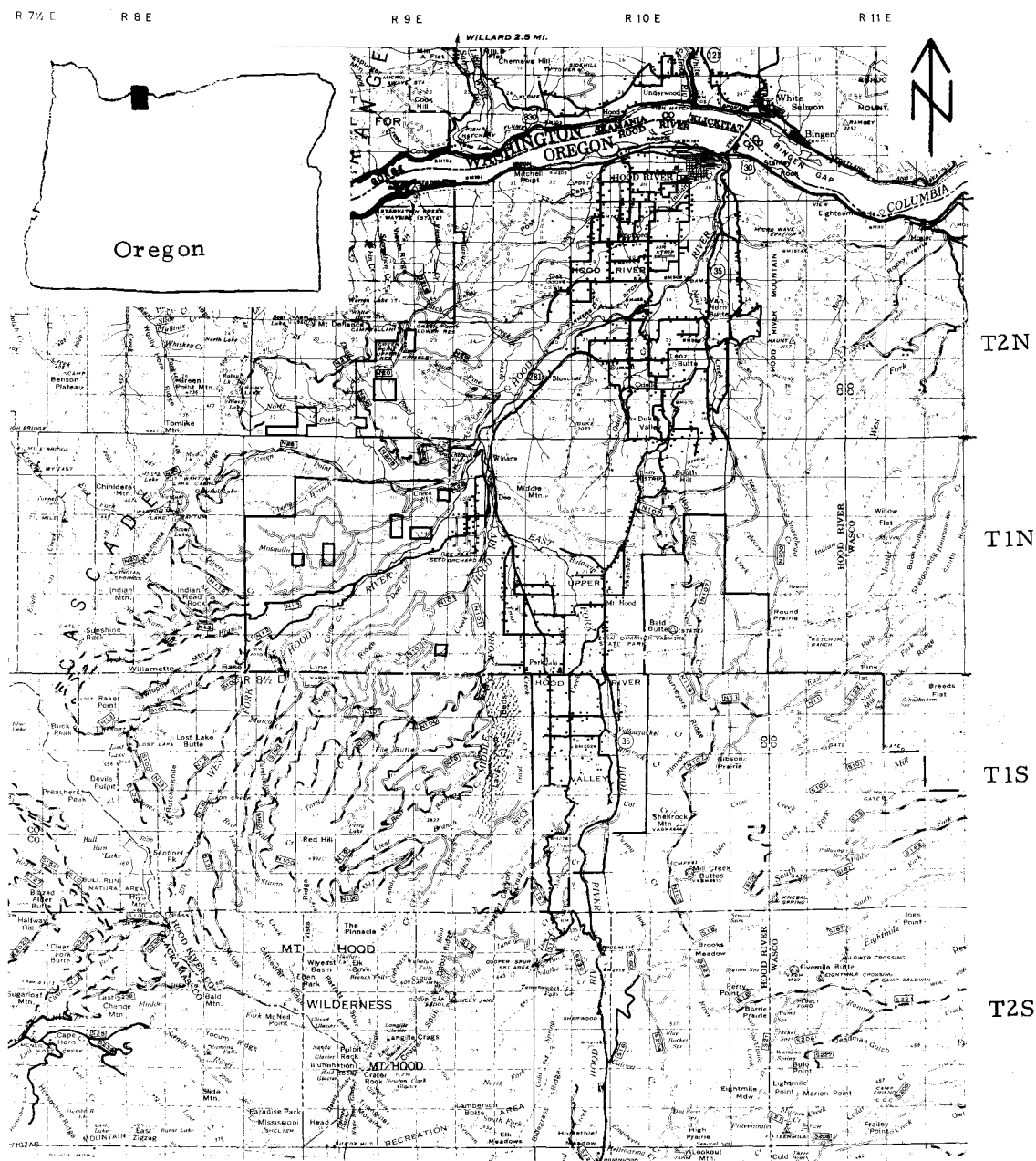


Figure 1. Location of study area (2 cm = approx. 5 km).

were also made in the Lower Hood River Valley, Columbia Plateau, and areas across the Columbia River in Washington.

### Climate and Vegetation

Climate of the Upper Hood River Valley can be briefly described as warm and dry in summers and cold and wet in winters. The mean annual temperature and precipitation are 47.3°F and 116.8 cm, respectively (Appendix IV). Potential evapotranspiration rates far exceed available precipitation during the five warmest months of the year. The reverse is true during the coldest months. Much of the precipitation comes as snowfall. The frost-free (32°F) season is 110 days and for 28°F it is 167 days (Johnsgard, 1963).

Presently the valley is used for intensive agriculture. Pear and apple orchards and strawberries are the major crops.

Vegetation in uncultivated areas of the upper valley consists of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), ponderosa pine (Pinus ponderosa Laws.), vine maple (Acer circinatum Pursh), wild cherry (Prunus species), golden chinquapin (Castanopsis chrysophylla (Dougl.) A. DC.), dogwood (Cornus nuttalli Aud. ex T. & G.), hazel (Corylus cornuta Marsh. var. californica (DC.) Sharp), snowberry (Symphoricarpos albus (L.) Blake), willow (Salix species), Oregon-grape (Berberis nervosa Pursh), blackberry (Rubus ursinus Cham. & Schlecht.), thimbleberry (Rubus parviflorus Nutt.), rose (Rosa

species), ferns, and other forbs, shrubs, and grasses (Franklin and Dyrness, 1969).

In upland areas surrounding the Upper Hood River Valley, major vegetation components are: Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), grand fir (Abies grandis (Dougl.) Lindl.), noble fir (Abies procera Rehd.), western hemlock (Tsuga heterophylla (Raf.) Sarg.), bigleaf maple (Acer macrophyllum Pursh), dogwood (Cornus nuttalli Aud. ex T. & G.), vine maple (Acer circinatum Pursh), white pine (Pinus monticola Dougl.), hazel (Corylus cornuta Marsh. var. californica (DC.) Sharp), golden chinquapin (Castanopsis chrysophylla (Dougl.) A. DC.), deerbrush (Ceanothus integerrimus H. & A.), snowbrush (Ceanothus velutinus Dougl. ex Hook.), manzanita (Arctostaphylos species), and numerous other shrubs, forbs, and grasses (Franklin and Dyrness, 1969).

### Geology

Northern Oregon Cascades. Fenneman (1931) indicates that the major drainage systems, as well as the elevation of the mountainous areas, are related more to uplift of deformed peneplains than to accumulation of lava. He states that the first mountains in the area were extensively eroded and then inundated by Columbia River Basalt during the Miocene time. Subsequent to this (Pliocene), some areas began sinking while others were uplifted as a series of blocks and folds.

During the remainder of Pliocene time, erosion erased the relief to produce a peneplain. Following further uplift and dissection of the peneplain, volcanic cones were constructed on the surface, giving present structural features.

Callaghan (1933), Hodge (1940), Peck et al. (1964), Wise (1969), and others disagree in part with Fenneman. They believe that the present Cascade Range began forming explosively during Pliocene time. Vast quantities of volcanic rocks and ash were erupted, blanketing the landscape. These materials buried river valleys as the streams had to carry increasing volumes of debris. This resulted in water deposition of large amounts of volcanic materials, covering low lying hills in the former drainage systems. Many streams became blocked and had to change their courses. Hodge (1940) mentions that Pliocene volcanism continued into the Pleistocene but changed from an explosive character to one of quiet flows. The lavas were mostly andesites, but also include basalts, dacites, and trachytes.

Mt. Hood Area. Wise (1964, 1966, 1969) has done extensive work on the geology of a 777 square km area which includes Mt. Hood. He states that Mt. Hood formed on a surface of Yakima Basalt (described by Waters, 1961) which is late Miocene. During Miocene, after the Columbia River Basalt was deposited, volcanic activity in the area was relatively mild. However, volcanoclastic debris and interbedded flows accumulated locally to thicknesses as much as 425 m (Wise, 1969).

The Dalles Formation outcrops on a ridge to the east of the upper part of the Hood River Valley (Wise, 1969). This formation is composed mostly of conglomerate and breccias with two interbedded flows near the top of exposures in that area. The rocks and clasts contained in the formation are primarily hornblende andesites and pyroxene andesites. This formation probably extends across the valley and underlies the older lavas on Blue Ridge, which lies to the west of the Upper Hood River Valley. Wise (1969) believes that the Dalles Formation developed from mild, sporadic vulcanism during late Miocene. He mentions that it is composed primarily of debris fans that arose from a center of vulcanism close to Hood River Meadows which is on the southeastern flanks of Mt. Hood. The source cone was probably covered by subsequent flows from Mt. Hood.

During the Pliocene, volcanic activity was intense. Hundreds of meters of olivine and pyroxene andesite lavas accumulated. A few basalt flows preceded the andesite lavas (Wise, 1969). During late Pliocene time, approximately 42 cubic kilometers of lavas, ranging from olivine basalts to hornblende dacites, were erupted. About 20% of these were basalts and the remainder andesites. Large flows of olivine basalt and olivine andesite occurred on what is now the north side of Mt. Hood.

Quaternary volcanoes in the Mt. Hood area erupted lavas that range in composition from olivine basalts to pyroxene andesites

(Wise, 1969). The cones and flows are young enough to be reflected in present landforms. Blue Ridge volcanoes, during this period, ejected about 1.25 cubic km of olivine basalts, olivine andesites, and aphanitic andesites from eight separate vents along the ridge (Wise, 1969).

In the area of Lost Lake Butte, significant flows of olivine andesite formed a sizable cone in the valley of what is now called the Lost Branch of the Hood River. The cone has a volume of about 31 cubic km (Wise, 1969).

Wise (1969), in discussing the formation of the Mt. Hood Volcano, states that the cone is composed of about 70% lava flows. The volcano covers an area of 238 square km. The composite cone of nearly 117 cubic km is composed primarily of olivine andesite, pyroxene andesite, and hornblende dacite flows and pyroclastic debris.

All the andesites from Mt. Hood are porphyritic. The olivine andesites contain phenocrysts of olivine, augite, andesine, and hypersthene. The pyroxene andesites are similar in composition, but lack olivine. The hornblende dacites contain mostly oxyhornblende, hypersthene, and andesine. In the nearly holocrystalline groundmass, plagioclase, hypersthene, magnetite, augite, biotite, K-feldspar, cristobalite, and hematite occur (Wise, 1969).

On the northern and northeastern flanks of Mt. Hood, large olivine andesite and olivine basalt flows were ejected during Holocene

(Wise, 1969). These came after the major cone building process. Several of these flows originated in the area around Cloud Cap; others came from The Pinnacle (a cinder cone). Another Holocene olivine andesite flow in the valley of the Middle Fork of the Hood River just west of Parkdale occurred with no significant accumulation of cinders.

One of the last eruptive sequences from Mt. Hood occurred about 2000 years ago. The material erupted was primarily of hornblende dacite composition (Wise, 1969). This eruption started after a long period of quiescence during which glaciation of the cone had occurred. Characterizing this eruption were explosions, contact of hot lava with snow, hot avalanches, mud flows, and slurry floods. The debris flows are seen primarily on the southwestern slope of the cone (Wise, 1969).

Lawrence (1948) stated that Mt. Hood erupted about the year 1800 leaving a deposit of fine grained tephra 15 cm thick at Tilly Jane and 11 cm thick at Hood River Meadows. He further stated that at least 500 years passed between the eruption of 1800 and the preceding eruption. Wise (1969) does not mention activity that recent on Mt. Hood.

Dissection has not been great even though the entire cone was covered with ice during Fraser Glaciation (Wise, 1968). This glaciation left extensive debris on the lower slopes.

Glaciation. Contemporaneous with mountain building processes, glaciation occurred. Hodge (1940) indicated that there were three major glacial advances in the Hood River Valley during which ice



moved the entire distance from Mt. Hood to the Columbia River at least once. Subsequently, there have been one and possibly two less extensive glaciations. Fraser Glaciation, which was one of the more recent ice ages, was primarily mountain glaciation (Armstrong, 1956). Handewith (1959) and Mason (1954) interpret present increases in the volume of ice on the north side of Mt. Hood to be indicative of an ice wave at higher elevations.

Wise (1968) shows the extent of ice movement on Mt. Hood during the last major glacial advance and indicates that the ice sheets never left the flanks of the mountain. He referred to this ice age as Fraser Glaciation occurring 15,000 years ago. There seems to be some confusion about either the age or the name of this glaciation. Armstrong (1956) states that Fraser Glaciation occurred less than 11,300 years ago. Crandell et al. (1958) indicate that Vashon Glaciation occurred 15,000 years ago in the Puget Sound area of Washington. Apparently, Wise (1968) either incorrectly labeled the glaciation or the age he chose to describe the glaciation is somewhat too old. For purposes of the studies here, the important point is that, whether called Fraser or Vashon, glaciation occurred on Mt. Hood about 15,000 years ago.

Climate was milder between the ice stages. Remnants of a rain forest remain on Mt. Hood above 2888 m elevation (Hodge, 1931). The present timberline is at about 1824 m elevation. This indicates that the climate was once much warmer than it is at present.

## CHAPTER II

### SOURCE AND CORRELATION

#### Introduction

Parkdale soils occur in the Upper Hood River Valley. An initial phase of investigation sought to determine their characteristics, distribution and why they occupy present positions on the landscapes.

Another objective was to determine the source or sources of the parent materials of Parkdale soils. These soils were considered to be typical of those formed in volcanic ash. Borchardt (1970) expressed the generally held view that these soils formed primarily in tephra from Mt. Mazama. He hypothesized that differences in appearance and chemistry of Parkdale soils, relative to soils formed in Mt. Mazama tephra, were due to weathering. Others expressed doubts that Mt. Mazama was the source and suggested other possibilities. There are numerous volcanoes and countless events during which pyroclastic materials were ejected.

Wilcox (1965) summarized many studies and gave chronology of many of the tephra layers in the Pacific Northwest. Borchardt (1970) and Mullineaux et al. (1972) further expanded correlation of widespread tephra deposits; Mullineaux et al. (1972) documented several tephra strata from Mt. St. Helens. Almost all areas of the Pacific

Northwest have been affected to some degree by tephra. However, amounts of tephra present vary widely from place to place.

Possibilities of materials other than ash were also indicated. The preponderance of silt-sized particles immediately suggested the question of Parkdale soils having been developed in loess. If the soils in the valley were of aeolian origin, they could be related to either the large body of loess on the Columbia River Plateau or to loess from more local sources. The possibility of Parkdale soils being developed on other types of deposits, including glacial till, alluvium and mudflow, was also considered. Origin of the material needed to be established before other studies were completely meaningful.

Age of the soils should also be determined since, if the age were known, correlation with tephra layers would be more efficient. Correlations with major periods of instability or loess deposition would also be easier. Age determination would be necessary if weathering rates in genetic processes were to be studied. Therefore, age determination of Parkdale soils by either relative or absolute means was also an objective of this phase of the study.

### Methods

#### Soil Samples

Sample sites for Parkdale soils were located to be individually

typical of a given area and together to represent the areal extent of the soils (Figure 2 and Appendix I). Two of the sites (134 and 138) selected for detailed studies have been used by soil scientists with the Soil Conservation Service to obtain samples for laboratory analyses. One of these, site 138, is the type location for the Parkdale series.

Soils in the mountainous areas surrounding the valley were sampled with no attempt to completely describe each profile. Samples were taken of soil horizons and rarely by combining similar horizons. Loess and tephra deposits outside the area were similarly sampled.

#### Particle Size Analyses

Air dried soil samples were sieved with a 2 mm sieve. The >2 mm fraction was then wet sieved with a minimum amount of crushing. This procedure removed material that was classified as stable aggregates.

Particle size distribution analyses of the <2 mm fraction were done by the pipette method of Kilmer and Alexander (1949).

#### Heavy Mineral Separation

Density separation of heavy minerals from the very fine sand fraction was accomplished by the method described by Allen (1959). Magnetic heavy minerals were separated with a hand magnet and their percentage of the total heavy mineral fraction calculated by weight comparisons.

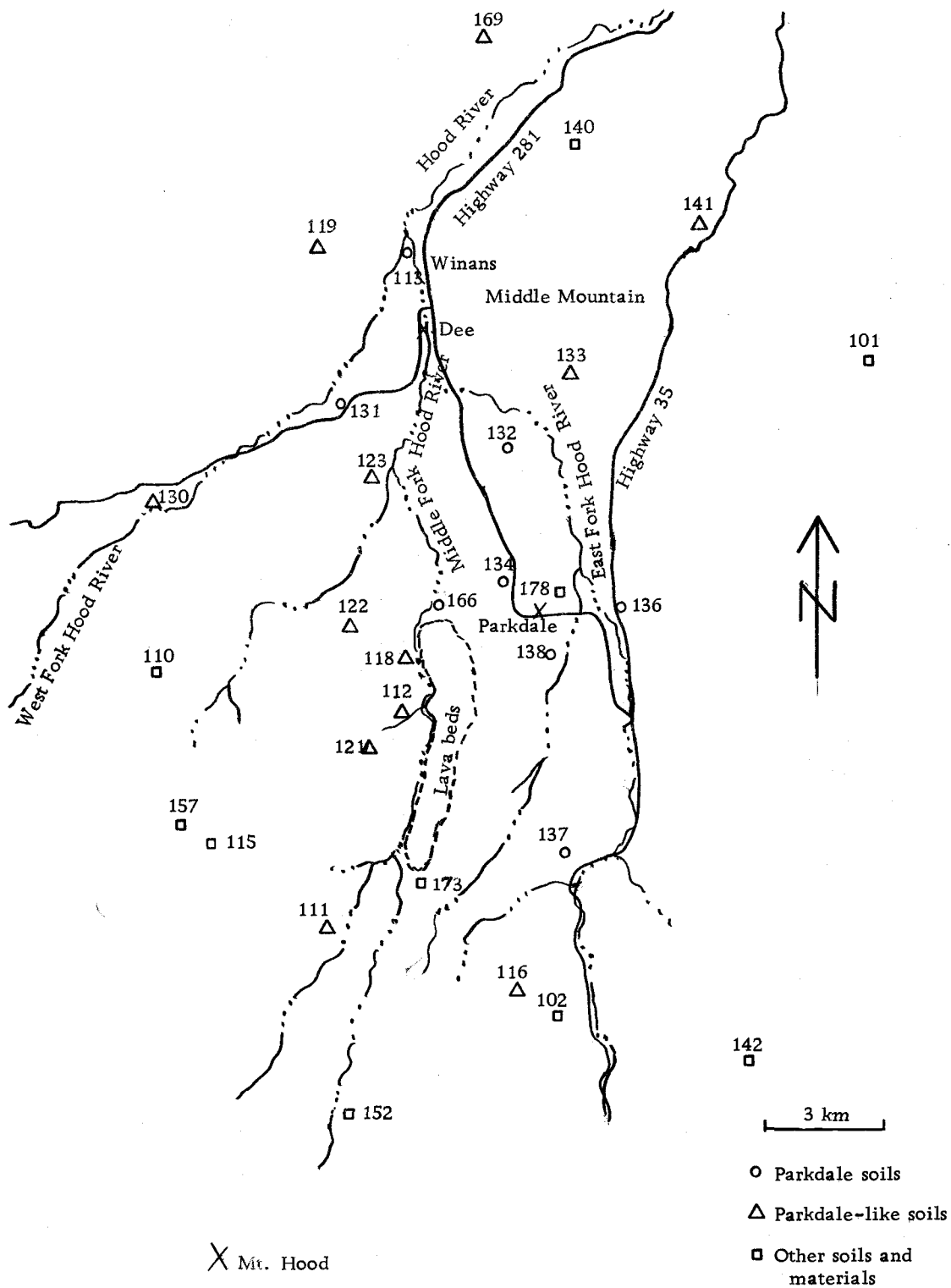


Figure 2. Major sample sites and their relationship to Parkdale soils.

### X-ray Spectroscopy Analyses

X-ray spectroscopy was used for quantitative determinations of Si, Al, Fe, Zr, Ti, Ca, and K on <2 mm samples and Ti, Fe, and Mn on magnetite separates (Kohn, 1970). Magnetite grains were separated with a magnet and also by hand picking. The grains were cleaned with a Bronwill Biosonik<sup>®</sup> BP-III ultrasonic system. All the samples were ground to <53 microns ( $\mu$ ) prior to the analyses.

Basically the method of Baird (1961) as modified by Borchardt and Theisen (1971) was used for X-ray spectrographic analysis. It was noticed that surfaces of samples high in amorphous materials cracked after the die assembly was cooled and the pressure released. The modifications by Borchardt and Theisen (1971) failed to prevent this cracking. Therefore, the method was modified further. The pressure was maintained above  $141 \text{ kg/cm}^2$  throughout the heating procedure and released only after the die assembly had cooled to less than  $40^\circ\text{C}$ . This eliminated the necessity of spraying the sample surface with a clear acrylic resin. The samples were stored in dessicators.

Specimens were analyzed using a Phillips Norelco Universal Vacuum X-ray Spectrograph. Chromium or tungsten radiation was used in combination with a LiF crystal-scintillation counter or EDDT crystal-flow proportional counter assembly coupled to a pulse height

analyzer. Summary of the methods used for each element determined is given in Appendix II.

U. S. Geological Survey standard rocks G-2, GSP-1, BCR-1, PCC-1, AGV-1, and DTS-1 (Flanagan, 1967); W-1 (Fairbairn et al., 1951; Fleischer and Stevens, 1962); and U. S. Bureau of Standards NBS-91, NBS-97, and NBS-98 (U. S. Bureau of Standards, 1931a, b, c) were used to obtain standard curves. Hopefully, use of these rock materials as standards reduces errors which arise from matrix effects. The unknown samples are compared directly with the rock standards which have similar overall chemical compositions and calculations of composition are made accordingly.

### Petrographic Analyses

Thin sections were made by impregnating selected sand separates with a Laminac<sup>®</sup>-acetone mixture and allowing them to dry. A billet was then cut to fit a standard petrographic slide (27 x 46 mm). The side to be mounted onto the slide was sanded smooth using sandpaper. Lakeside<sup>®</sup> was used to mount the billet onto the slide. The billet was cut as close to the slide as possible. The section was then sanded to a thickness of 30  $\mu$  and a cover glass secured with Permunt<sup>®</sup>.

Approximately 300-400 point counts (Krumbein and Pettijohn, 1938) were made on each slide and the results reported as percentage of individual species in the total sample.

### Radiocarbon Age Determination

Charcoal samples for radiocarbon age determination were analyzed by Teledyne Isotopes, Westwood Laboratories, 50 Van Buren Avenue, Westwood, New Jersey 07675.

### Results and Discussion

This portion of the study of Parkdale soils is concerned with description of ranges in morphological characteristics and properties, parent material source, distribution and correlation of materials, and age.

#### Description of Parkdale Soils

Parkdale soils have sola about 50 cm thick (Ames and Ness, 1971). They have a thick, dark surface horizon with <50% base saturation (umbric epipedon) and a weakly developed subsoil horizon (cambic horizon). The granular or fine subangular-blocky structure of these soils is also weakly developed. However, the nature of the structure, matrix material and porosity provides no physical restrictions to plant roots. Parkdale soils have moderate permeability and are well drained. They are dark brown (7.5 YR 3/2, moist) in the A horizons and increase in value and chroma to 7.5 YR 4/4 (moist) with depth. The soil is not sticky and only very slightly plastic. Between



5 and 10% "shot," 1 to 7 mm in diameter, occur in the surface horizon and these increase in size and decrease in amount with depth.

Parkdale soils are generally described as loams or silt loams in the field, but are difficult to characterize in the laboratory due to dispersion problems. Particle size distributions (Table 1) show that Parkdale soils, as represented by modal pedon site 134, are mostly silt loams. Dominant grain sizes are silt, very fine sand, and fine sand. Clay content is apparently about 10%, although some variation is noted with depth. Uncertainties in these measurements will be discussed further in Chapter III.

Parkdale soils and associated parent materials have no bedding planes, heavy mineral layers, organic matter rich layers (except for the present soil surface), tephra layers, or any other evidences of cyclic deposition. Geologic materials underlying Parkdale soil materials do show stratification at some locations. Descriptions of sections (Figure 3) show that below a layer of cobbles, which ubiquitously underlie Parkdale soil materials, glacial till, stream-bedload cobbles, and fine alluvium or mudflow deposits have been observed.

Pieces of charcoal, mostly smaller than 1/2 cm, are scattered almost homogeneously throughout Parkdale soils. This charcoal is not related to burning of vegetation in place on the soils, since the pieces are separate and do not occur in old root channels or krotovinas.

Table 1. Particle size distribution of Parkdale soils (percent < 2 mm).

Sample <sup>a</sup>	Depth (cm)	> 2 mm	Sand (mm)						Silt (mm)		Clay (mm)		
			Very coarse 2-.1	Coarse .1-.5	Medium .5-.25	Fine .25-.1	Very fine .1-.05	Total sand 2-.05	Coarse 0.05-0.02	Fine 0.02-0.002	Total silt 0.05-0.002	Total clay < 0.002	Textural class
134-1	0-23	9.5	1.7	3.4	7.1	12.5	11.7	36.4	21.6	31.7	53.3	10.3	sil
134-2	23-46	9.5	1.8	3.8	7.3	12.4	11.3	36.7	22.2	33.9	56.1	7.2	sil
134-3	61-91	4.4	0.6	3.3	6.7	11.1	10.2	31.9	22.1	36.6	58.7	9.4	sil
134-4	91-152	3.6	0.8	4.3	9.0	9.8	12.6	36.3	17.5	35.1	52.6	11.0	sil
134-5	152-213	8.1	0.6	4.1	8.5	13.5	10.6	37.4	15.2	35.9	51.2	11.5	sil
134-6	213-274	8.8	1.0	3.6	6.2	10.9	11.5	33.3	16.8	38.0	54.8	11.9	sil
134-7	274-335	13.2	1.2	3.7	5.4	12.8	12.3	35.5	14.7	38.5	53.2	11.3	sil
134-8	335-371	22.2	4.0	5.1	6.7	13.7	13.2	42.7	13.1	34.4	47.5	9.7	1

<sup>a</sup>Sample site location given in Figure 2 and Appendix I.

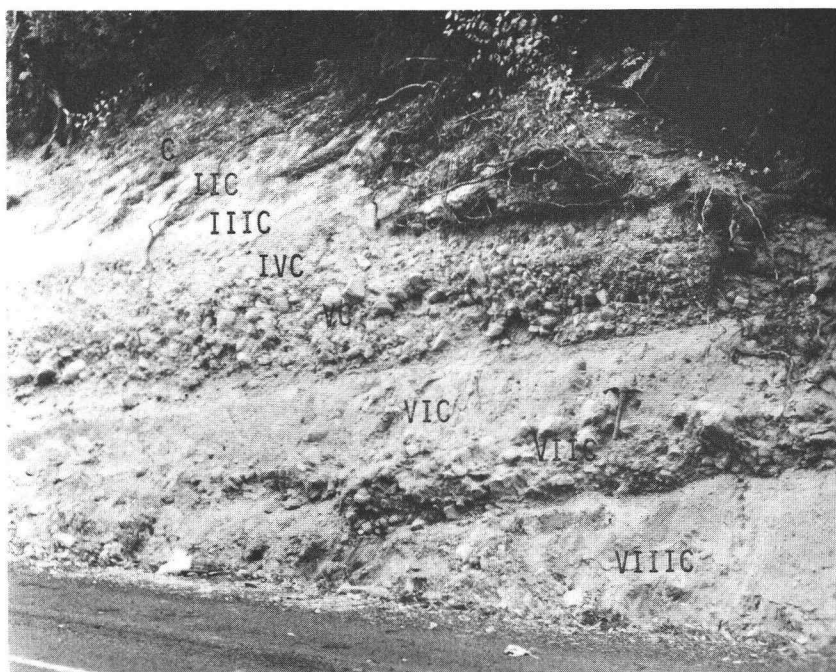


Plate of section at SE1/4 SW1/4 Sec. 34, T1N, R10E corresponding to log on facing page.

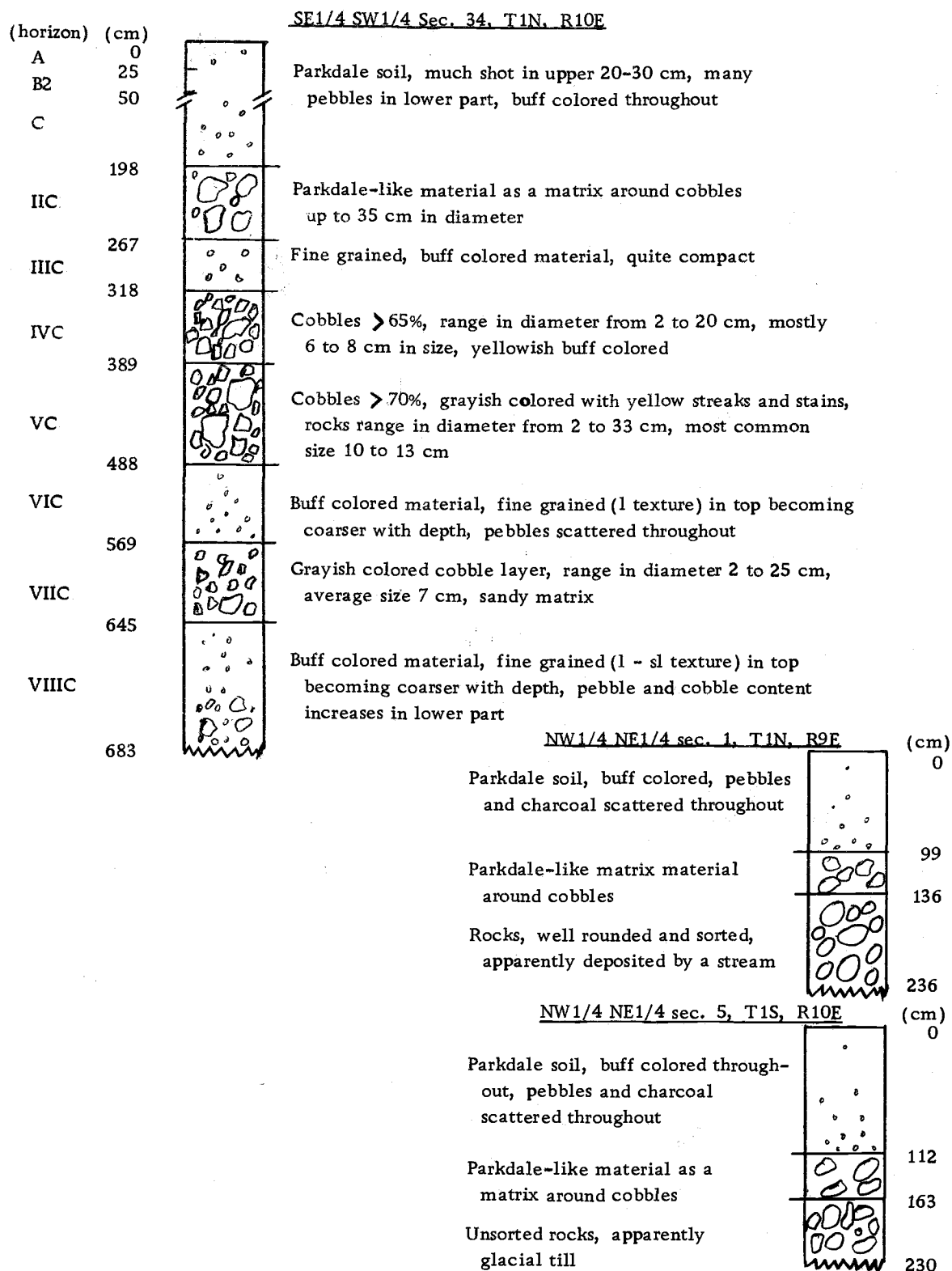


Figure 3. Log of sections of Parkdale soils and underlying materials (depths in cm).

Many, if not most, of these charcoal fragments are surrounded by concentrically layered soil material.

Pebbles, which have a smooth rounded appearance, are also scattered throughout the soils in small amounts. Occurrence of these pebbles, which are of varying lithologies, is not related to krotovinas.

The soil material appears to be reasonably well weathered to depths of almost 4 m, but there is very little horizon differentiation.

#### Variations of Parkdale Soils

Variations both within and among Parkdale soil profiles occur and need to be discussed before distribution and relationships to other soils can be meaningfully approached.

Variations Within Parkdale Soils. Sand content of the <2 mm fraction of a Parkdale soil varies within a profile from about 32 to 43% (Table 1). Not considering the extremes, variation is from 33 to 36%. This range illustrates minor deviations. Some variation may be attributed to differential breakdown of concretionary or aggregated materials during the analyses. This breakdown also affected the silt and clay measurements. Silt content varies from 48 to 59% but on the average is about 54% (Table 1). Clay averages about 10% but varies from 7 to 12% (Table 1).

Content of material >2 mm is higher in surface and bottom horizons relative to middle horizons (Table 1). Below 91 cm there is

increasing content of >2 mm material with depth. Observations revealed that the relatively large amount of >2 mm material in surface horizons is due to the presence of "shot" or concretions. Below these upper horizons "shot" is still present but pebbles or rock fragments increasingly become the predominant >2 mm material. This suggests that "shot" content decreases and pebble content increases with depth in these soils. Therefore, discounting the "shot" content of >2 mm rock fragments increases with depth from the surface.

Sand subfraction analyses (Table 2) further indicate homogeneity with depth within Parkdale soils. Greatest variation is in medium to coarse sand (ms/cs) ratios and is probably due, at least in part, to sampling errors arising because of the very low content of these fractions in the whole soil.

Table 2. Sand subfraction ratios of a Parkdale soil.

Sample <sup>a</sup>	Depth (cm)	vfs/fs <sup>b</sup>	fs/ms <sup>b</sup>	ms/cs <sup>b</sup>
134-1	0-23	0.9	1.8	1.9
134-3	61-91	0.9	1.6	1.8
134-4	91-152	0.7	1.5	2.4
134-5	152-213	0.7	1.5	2.2
134-6	213-274	0.8	1.9	1.7
134-7	274-335	0.8	2.1	1.3
134-8	335-371	0.8	1.9	1.3

<sup>a</sup> Sample site location in Figure 2 and Appendix I.

<sup>b</sup> vfs = very fine sand; fs = fine sand; ms = medium sand; and cs = coarse sand.

There is some variation in mineralogy of sands within a Parkdale soil profile (Table 3). The upper two horizons appear somewhat different from the lower horizons. Content of feldspars, fine grained volcanics, weathering products, and pumice and glass show most variation. This indicates that some material, unlike the original material, was likely mixed into surface horizons.

Chemical analyses of Parkdale soil reveal general uniformity in  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{Fe}_2\text{O}_3$  contents (Table 4). However, some variations are evident.  $\text{SiO}_2$  content tends to decrease with depth, whereas  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$  tend to increase.

Magnetic /non-magnetic mineral ratios and to some extent light/heavy mineral ratios (Table 5) also illustrate relative homogeneity within Parkdale soils.

Analyses of magnetite samples from site 134 (Table 6) further suggest uniformity of materials within Parkdale soils. There is very little variation from the soil surface down to a depth of almost 4 m.

Variations Among Parkdale Soils. Typical profiles were selected to represent the known and obvious occurrence of Parkdale soils. These sites were all in the Upper Hood River Valley. Sand contents (Table 7 and Appendix V-a) of these profiles show comparatively little variation and no consistent trends with distance in any direction. Sand subfraction ratios (Table 7 and Appendix V-b) indicate

Table 3. Mineral composition of sand size fraction of Parkdale soils (percent).

Sample <sup>a</sup>	Depth (cm)	Horn-			Mag- netite	Fine-grained volcanics	Pumice and glass	Weathering <sup>b</sup>	
		Pryoxene	blende	Feldspars				products	Other
138-1	0-25	4.0	4.2	45.5	1.3	36.2	3.2	4.8	0.9
138-2	25-46	6.4	3.2	46.9	3.8	22.0	7.0	8.3	2.3
138-4	96-152	4.0	4.0	40.2	1.3	17.5	1.3	30.2	1.3
138-5	152-213	5.6	4.4	34.2	0.9	13.7	1.5	36.3	3.5
138-6	213-274	4.4	1.7	30.3	1.7	21.6	1.4	38.0	0.9
138-7	274-330	7.8	1.3	26.2	2.9	17.7	0.8	42.3	1.1

<sup>a</sup>Sample site location given in Figure 2 and Appendix I.

<sup>b</sup>This does not include clays and silts removed prior to analyses nor materials removed with "shot".



Table 4. Si, Al, and Fe composition of a Parkdale soil (also see Appendix VII).

Sample <sup>a</sup>	Depth (cm)	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)
134-1	0-23	53.2	19.3	7.5
134-2	23-46	53.7	20.9	8.2
134-3	61-91	53.2	21.4	8.2
134-4	91-152	50.6	23.1	8.5
134-5	152-213	49.0	24.1	9.0
134-6	213-274	49.0	24.3	9.3
134-7	274-335	47.9	24.6	9.2
134-8	335-371	48.5	24.4	9.4

<sup>a</sup> Sample site location given in Figure 2 and Appendix I.

Table 5. Mineral separate analysis of very fine sand fraction of a Parkdale soil.

Sample <sup>a</sup>	Depth (cm)	<u>light</u> heavy	<u>magnetic</u> non-magnetic
134-1	0-23	7.8	0.20
134-3	61-91	6.2	0.22
134-8	335-371	7.9	0.17

Table 6. Composition of magnetite grains and statistical correlations for a Parkdale soil

Sample <sup>a</sup>	Depth (cm)	Ti/Mn		Fe/Ti		Fe/Mn	
		ratio	within <sup>b</sup> 95% CI	ratio	within <sup>c</sup> 95% CI	ratio	within <sup>d</sup> 95% CI
134-1	0-23	2.1	yes	1.8	yes	3.7	yes
134-2	23-46	1.9	yes	1.8	yes	3.4	yes
134-5	152-213	2.3	yes	1.8	yes	4.1	yes
134-8	335-371	1.9	yes	1.9	yes	3.6	yes

<sup>a</sup>Sample site location given in Figure 2 and Appendix I.

<sup>b</sup>95% confidence interval around mean of values from modal Parkdale soil ( $2.05 \pm 0.60$ ).

<sup>c</sup>95% confidence interval around mean of values from modal Parkdale soil ( $1.83 \pm 0.16$ ).

<sup>d</sup>95% confidence interval around mean of values from modal Parkdale soil ( $3.70 \pm 0.94$ ).

Table 7. Sand content, sand subfraction ratios and correlation of Parkdale soils.

Sample <sup>a</sup>	Depth (cm)	Sand (%)	vfs/fs <sup>e</sup>		fs/ms <sup>e</sup>		ms/cs <sup>e</sup>	
			ratio	within <sup>b</sup> 95% CI	ratio	within <sup>c</sup> 95% CI	ratio	within <sup>d</sup> 95% CI
113-3	51-91	36.8	0.9	yes	2.0	yes	1.3	yes
131-3	51-122	33.2	0.7	yes	1.6	yes	2.0	yes
132-3	61-91	35.3	0.8	yes	1.4	yes	2.0	yes
134-3	61-91	32.6	0.9	yes	1.6	yes	1.8	yes
136-3	61-84	32.8	0.9	yes	2.0	yes	1.7	yes
137-2	25-61	41.0	1.2	no	2.2	yes	1.7	yes
138-3	71-96	38.7	0.8	yes	1.7	yes	2.3	yes

<sup>a</sup> Sample site locations given in Figure 2 and Appendix I.

<sup>b</sup> 95% confidence interval around mean of values from modal Parkdale soils ( $0.81 \pm 0.23$ ).

<sup>c</sup> 95% confidence interval around mean of values from modal Parkdale soils ( $1.75 \pm 0.45$ ).

<sup>d</sup> 95% confidence interval around mean of values from modal Parkdale soils ( $1.89 \pm 0.83$ ).

<sup>e</sup> vfs = very fine sand, fs = fine sand, ms = medium sand, cs = coarse sand.

good correlation between all sites. The only exception is the vfs/fs ratio from sample 137-2; however, even that value is very close to those from Parkdale soils.

Heavy mineral analyses also indicate little variation between Parkdale soils. Analyses of minerals from sample 138-3 gave a light/heavy ratio of 7.8 and a magnetic/non-magnetic ratio of 0.19. These data, when compared to data in Table 5 from another profile, show very close agreement.

Petrographic analyses of sands (Table 8) from selected sample sites indicate variations between Parkdale soil profiles. Most of the variations are in content of feldspars and fine grained volcanics. Overall, the variations are not great. Some of these variations could be due to problems of obtaining representative sand samples.

The thickness of Parkdale soil materials also varies between locations (Figures 4 and 5). The soils terminate very quickly with increasing elevation in all directions from the valley floor except southwest. The southern distribution of Parkdale soils extends upon the flanks of Mt. Hood. Greatest thickness of the soil material is found in the southwestern part of the valley (Figure 5).

#### Occurrence and Distribution of Parkdale Soils

Having assessed variations both within and among Parkdale soils,

Table 8. Petrographic analyses of sand fraction of Parkdale soils (percent).

Sample <sup>a</sup>	Depth (cm)	Pyroxene	Horn- blende	Feldspars	Mag- netite	Fine- grained volcanics	Pumice and glass	Devitrified glass	Weathering <sup>b</sup> products	Other
113-2	15-51	6.4	4.3	52.7	3.6	18.5	3.9	2.5	7.1	1.0
131-2	23-51	3.6	6.6	55.6	2.6	22.7	1.3	1.0	6.3	0.3
132-2	30-61	5.1	4.2	48.8	2.4	25.1	3.6	1.2	8.1	1.5
134-2	23-46	2.3	4.6	46.9	2.0	30.2	3.3	1.0	8.2	1.6
137-2	25-61	3.5	2.9	31.7	2.9	37.8	7.3	3.8	9.5	0.6
138-2	25-46	6.4	3.2	46.9	3.8	22.0	7.0	1.0	8.3	1.0

<sup>a</sup>Sample site locations given in Appendix I.

<sup>b</sup>Weathering products not including clays and silts removed prior to these analyses nor materials removed as "shot".

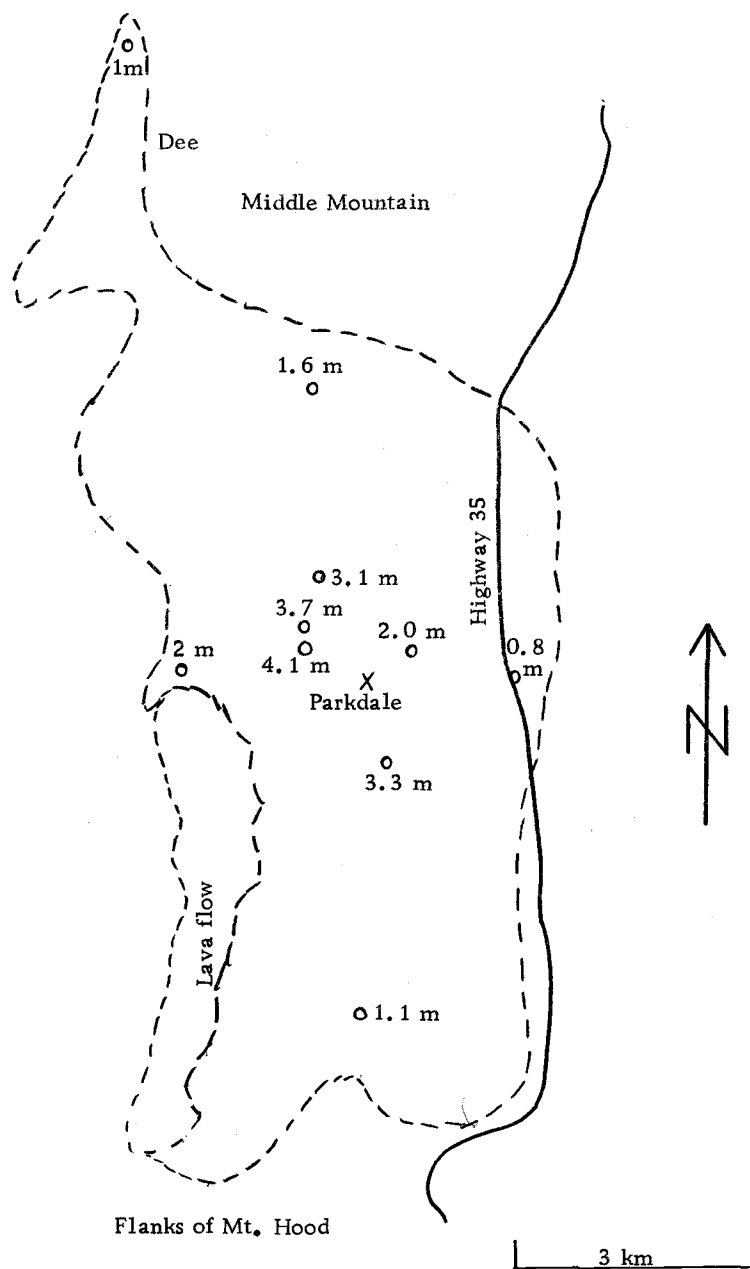


Figure 4. Primary occurrence and thicknesses of Parkdale soils.

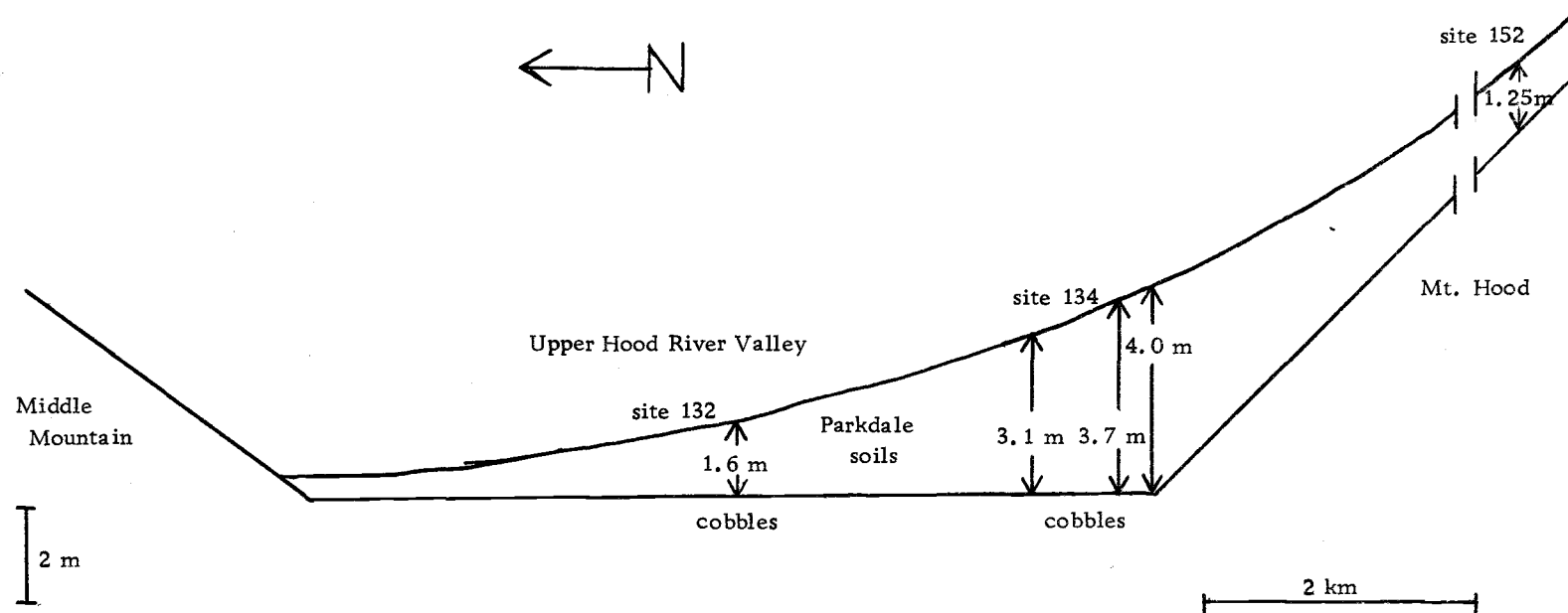


Figure 5. Generalized profile of Parkdale soils from Mt. Hood to Middle Mountain.

it then becomes meaningful to investigate their occurrence and distribution. Parkdale soils occur mainly on the floor of the Upper Hood River Valley (Figure 4). Considerable reconnaissance and study was done to determine if Parkdale soils occur elsewhere.

The most recent soil survey for the area was published in 1914 (Strahorn and Watson, 1914). That survey was of too small scale to be useful in this study in determining detailed soil distributions. More recent soil surveying had been done, but that was incomplete.

The study to determine distribution of Parkdale soils and Parkdale-like soil materials involved both field work and laboratory work. All major deposits surrounding the Upper Hood River Valley were sampled (Figure 2 and Appendix I).

The area surrounding the Upper Hood River Valley was conceptually divided according to the cardinal directions to facilitate discussion. This should aid the reader to keep oriented while at the same time provide for shorter and less confusing presentation of data. The data shown in tables along with the discussion are only a portion of that collected. Other data are shown in appendices.

Area East of Upper Hood River Valley. Immediately east and bordering the Upper Hood River Valley is a rather large ridge system. Along the ridge top, there are several relatively broad flat areas. In the southern part of that ridge a few prominent cones rise to heights as much as 1976 m. In some cases, relatively deep soils occur on the



north slopes of these cones. Those sites both on the flats and on the slopes that had significant accumulations of soil materials were studied. In all cases, those materials, even though lying close to the valley, were statistically dissimilar to Parkdale soils (Table 9 and Appendix V-a and b). Many samples showed comparatively different total sand contents. The only sample (144-3, Appendix I) that appeared similar to Parkdale soils was from approximately 21 km south-southeast of the upper part of the valley. It lies in the White River watershed rather than the Hood River. It does not represent a major deposit; distribution and thickness are both very limited.

Chemical analyses of whole samples (Table 10 and Appendix VII) and magnetite separates (Table 11) of two of the major deposits on the eastern ridge system further point out dissimilarities when compared to Parkdale soils.

Both particle size data and chemical analyses show that the soils east of the valley are not like those in the valley. This, therefore precludes occurrence of Parkdale soils in that area.

Area North of Upper Hood River Valley. North of the upper valley is Middle Mountain which separates the upper and lower Hood River Valleys. One of the first questions to be investigated was the occurrence of Parkdale soils in the lower valley where the Hood soil is the major series. Although texturally very similar, Parkdale and Hood soils are mineralogically different. They are greatly different

Table 9. Sand content, subfraction ratios and correlation of soils east of the Upper Hood River Valley with Parkdale soils.

Sample <sup>a</sup>	Depth (cm)	Sand (%)	vfs/fs <sup>e</sup>		fs/ms <sup>e</sup>		ms/cs <sup>e</sup>	
			ratio	within <sup>b</sup> 95% CI	ratio	within <sup>c</sup> 95% CI	ratio	within <sup>d</sup> 95% CI
103-1	5-9	50.6	2.0	no	3.6	no	1.6	yes
103-2	10-30	53.7	1.3	no	3.0	no	1.0	yes
108-1	3-7	44.6	4.1	no	2.1	yes	1.6	yes
108-2	12-30	47.7	1.3	no	3.1	no	1.0	yes
142-1	10-25	27.3	1.1	no	2.5	no	3.7	no
142-2	25-38	32.6	2.0	no	5.2	no	2.1	yes
142-3	38-46	44.5	1.3	no	2.6	no	2.0	yes
142-4	46-53	29.4	1.2	no	3.1	no	3.9	no
142-5	53-64	33.7	0.9	yes	3.3	no	3.0	no
142-6	64-76	59.2	1.3	no	2.6	no	2.5	yes
143-1	0-15	30.7	1.8	no	4.2	no	2.9	no
143-2	15-23	34.8	2.4	no	3.6	no	2.1	yes
143-3	23-56	30.4	2.0	no	4.7	no	2.4	yes
143-4	56-86	36.3	1.4	no	3.4	no	2.5	yes
143-5	86-94	37.5	1.2	no	3.5	no	2.7	yes
144-2	13-38	29.6	1.8	no	4.6	no	1.7	yes
144-3	38-51	32.2	0.8	yes	2.2	yes	2.4	yes
144-5	52-61	14.6	0.8	yes	3.0	no	2.8	no

<sup>a</sup>Sample site locations in Figure 2 and Appendix I. <sup>b</sup>95% confidence interval around mean of values from modal Parkdale soils (0.81±0.23). <sup>c</sup>95% confidence interval around mean of values from modal Parkdale soils (1.75±0.45). <sup>d</sup>95% confidence interval around mean of values from modal Parkdale soils (1.89±0.83). <sup>e</sup>vfs = very fine sand, fs = fine sand, ms = medium sand, cs = coarse sand.

Table 10. Chemical analyses of selected samples from the area surrounding the Upper Hood River Valley.

Sample <sup>a</sup>	Depth (cm)	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)
<u>Parkdale soil (avg.)</u>				
134	-	50.0	23.0	8.5
<u>East</u>				
142-2	25-38	66.9	15.8	3.4
143-3	23-56	61.7	16.2	4.5
<u>West</u>				
110-1	1-15	54.8	18.9	5.3
110-2	15-23	44.3	27.8	6.4
110-3	23-38	44.3	23.7	14.6
110-4	38-51	41.6	24.0	16.4
110-5	51-76	43.2	26.8	13.9
110-6	76-140	44.3	26.2	14.1
<u>South</u>				
152-1	6-10	64.3	17.1	4.6
152-2	16-36	58.0	16.4	5.2
152-3	36-40	64.3	15.6	4.8
152-4	40-43	63.1	16.3	4.4
152-5	44-49	59.5	17.9	5.9
152-6	53-56	60.6	17.6	5.6
152-7	56-75	53.2	20.5	7.4
173	-	59.0	18.9	6.3
<u>North</u>				
133-3	66-102	49.5	21.7	12.5
169-2	107-175	54.3	22.2	9.4
170	28-43	65.3	16.3	6.3

<sup>a</sup> Samples arranged according to direction from upper Hood River Valley. Site locations given in Figure 2 and Appendix I.

chemically (compare sample 134 with 170, Table 10). Mineral analyses further reveal dissimilarities. Analyses of mineral separates for Hood soils (sample site 170) gave a light/heavy ratio of 16.7 and a magnetic/non-magnetic ratio of 0.14. These data show large differences from those of a modal Parkdale soil (Table 5). Both field and laboratory studies demonstrate that Parkdale and Hood soils are different.

Sample sites 140 and 141 are in the southern upper reaches of the lower valley. Sample site 169 is located to the west, well above the lower valley floor on a bench-like position. Data from these three sites reveal interesting similarities. Magnetite analyses show that sites 141 and 169 correlate well with Parkdale soils (Table 11). Total sand content and sand subfraction analyses (Table 12) of sites 140 and 141 show good correlation with Parkdale soils. Petrographic studies (Table 13) show site 141 to be like the modal Parkdale soils. Chemical analyses (Table 10) and mineral separate analyses also indicate good correlation of site 169 to Parkdale soils. Chemical analyses show that samples from site 169 have a slightly higher  $\text{SiO}_2$  content but almost identical  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$  contents as Parkdale soils. Mineral separate analyses gave a light/heavy ratio of 9.4 and a magnetic/non-magnetic ratio of 0.26. These ratios are both very close to those of Parkdale soils (Table 5). These results show that Parkdale and Parkdale-like soils in the Lower Hood River Valley

Table 11. Statistical evaluation of magnetite analyses as related to correlation and distribution of Parkdale soils.

Sample <sup>a</sup> and area	Depth (cm)	Ti/Mn		Fe/Ti		Fe/Mn	
		ratio	within <sup>b</sup> 95% CI	ratio	within <sup>c</sup> 95% CI	ratio	within <sup>d</sup> 95% CI
<u>East</u>							
142-2	25-38	1.9	yes	1.3	no	2.5	no
142-5	53-64	5.1	no	0.7	no	3.6	yes
143-3	23-56	1.3	no	2.2	no	2.9	yes
<u>North</u>							
133-2	18-66	2.5	yes	1.6	no	4.0	yes
141-1	0-25	1.9	yes	1.9	yes	3.6	yes
169-2	107-175	2.3	yes	1.8	yes	4.1	yes
<u>South</u>							
152-2	42-91	1.1	no	2.6	no	2.9	yes
152-7	141-191	1.9	yes	2.0	yes	3.8	yes

<sup>a</sup> Cardinal directions refer to areas in relation to the Upper Hood River Valley. Sample site locations given in Figure 2 and Appendix I.

<sup>b</sup> 95% confidence interval around mean of values from modal Parkdale soil ( $2.05 \pm 0.60$ ).

<sup>c</sup> 95% confidence interval around mean of values from modal Parkdale soil ( $1.83 \pm 0.16$ ).

<sup>d</sup> 95% confidence interval around mean of values from modal Parkdale soil ( $3.70 \pm 0.94$ ).

Table 12. Sand content, subfraction ratios and correlation of soils north of the Upper Hood River Valley with Parkdale soils.

Sample <sup>a</sup>	Depth (cm)	Sand (%)	vfs/fs <sup>e</sup>		fs/ms <sup>e</sup>		ms/cs <sup>e</sup>	
			ratio	within <sup>b</sup> 95% CI	ratio	within <sup>c</sup> 95% CI	ratio	within <sup>d</sup> 95% CI
133-1	0-18	38.7	0.8	yes	1.5	yes	2.0	yes
133-3	66-102	34.8	1.0	yes	1.6	yes	1.6	yes
140-1	0-23	38.0	0.7	yes	1.4	yes	1.8	yes
140-2	23-46	34.1	0.7	yes	1.5	yes	1.7	yes
141-1	0-25	30.7	0.8	yes	1.4	yes	1.9	yes
141-2	25-51	29.5	0.8	yes	1.5	yes	2.2	yes
141-3	76-102	33.1	0.8	yes	1.6	yes	2.1	yes

<sup>a</sup> Sample site locations in Figure 2 and Appendix I.

<sup>b</sup> 95% confidence interval around mean of values from modal Parkdale soils ( $0.81 \pm 0.23$ ).

<sup>c</sup> 95% confidence interval around mean of values from modal Parkdale soils ( $1.75 \pm 0.45$ ).

<sup>d</sup> 95% confidence interval around mean of values from modal Parkdale soils ( $1.89 \pm 0.83$ ).

<sup>e</sup> vfs = very fine sand, fs = fine sand, ms = medium sand, cs = coarse sand.

Table 13. Petrographic analyses of sands from Parkdale and Parkdale related soils (percent).

Sample <sup>a</sup>	Depth (cm)	Pyroxene	Horn- blende	Feldspars	Mag- netite	Fine- grained volcanics	Pumice and glass	Devitrified glass	Weathering <sup>b</sup> products	Other
<u>Parkdale Soil</u>										
134-2	23-46	2.3	4.6	46.9	2.0	30.2	3.3	1.0	8.2	1.6
<u>Parkdale Related Soils</u>										
112-2	23-81	8.9	2.8	35.4	4.3	28.3	8.0	3.1	8.6	0.6
130-2	25-56	5.7	7.1	44.7	2.4	17.6	4.1	5.8	11.2	1.3
133-2	18-66	3.6	5.0	37.7	4.6	13.6	7.6	12.7	14.6	0.5
141-2	25-51	3.7	3.7	49.2	2.0	23.1	6.4	3.0	8.4	0.7

<sup>a</sup>Sample site locations given in Figure 2 and Appendix I.

<sup>b</sup>Weathering products not including clays and silts removed prior to these analyses nor materials removed as "shot".

are limited to the upper slopes and level areas at higher elevations rather than in the present valley floor.

A relatively level area on top of Middle Mountain was selected for sampling (site 133). Soils at this site are morphologically similar to Parkdale soils. Analyses indicate that total sand content and subfraction ratios are similar to Parkdale soils (Table 12). However, chemical analyses (Table 10) and magnetite analyses (Table 11) show definite differences. Petrographic studies (Table 13) show that that soil on Middle Mountain (site 133) does not appear at all similar to Parkdale soils. Apparently Parkdale soils do not occur on top of Middle Mountain.

Area West of the Upper Hood River Valley. West of the Upper Hood River Valley is a mountainous area known as Blue Ridge. This ridge system lies directly north of Mt. Hood. Sample sites in that area were divided into two groups. The first group consists of those sites close to the upper valley. Actually these sites are at higher elevations on east-facing slopes that lead into the valley. The second group consists of sites further away from the valley. They are scattered throughout the Blue Ridge area. An effort was made to sample all materials morphologically similar to Parkdale soils.

The group of samples close to the valley (sample sites 112, 118, 121, 122, and 123, Figure 3) are listed first in Table 14. With only one exception, their sand contents and subfraction ratios



Table 14. Sand content, subfraction ratios and correlation of soils west of the Upper Hood River Valley with Parkdale soils.

Sample <sup>a</sup>	Depth (cm)	Sand (%)	vfs/fs <sup>b</sup>		fs/ms <sup>b</sup>		ms/cs <sup>b</sup>	
			ratio	within 95% CI <sup>c</sup>	ratio	within 95% CI <sup>d</sup>	ratio	within 95% CI <sup>e</sup>
112-1	0-23	43.0	1.0	yes	1.9	yes	1.4	yes
112-3	81-114	34.5	1.0	yes	2.0	yes	1.3	yes
112-5	259-300	38.4	0.8	yes	1.9	yes	1.4	yes
118-1	0-23	31.7	1.1	no	3.9	no	1.1	yes
118-2	23-69	32.0	2.2	no	1.5	yes	1.2	yes
121	2-41	56.8	0.9	yes	2.0	yes	1.0	yes
122	13-36	43.2	0.8	yes	1.7	yes	1.6	yes
123	25-36	42.5	0.8	yes	2.3	no	1.3	yes
110-3	23-38	23.8	0.4	no	1.2	no	0.6	no
110-4	38-51	38.6	0.5	no	1.3	yes	0.6	no
110-6	76-140	30.0	0.7	yes	1.6	yes	1.0	yes
111-1	2-20	46.7	1.2	no	1.9	yes	1.4	yes
111-2	20-46	56.6	1.0	yes	2.2	yes	1.1	yes
119-1	0-20	39.0	0.8	yes	1.5	yes	2.0	yes
119-2	61-76	33.0	0.8	yes	1.6	yes	1.7	yes
119-3	200-220	25.7	1.0	yes	2.5	no	1.0	yes

(Continued on next page)

Table 14. (Continued)

Sample	Depth (cm)	Sand (%)	vfs / fs		fs / ms		ms / cs	
			ratio	within 95% CI	ratio	within 95% CI	ratio	within 95% CI
130-1	2-25	49.7	0.7	yes	1.7	yes	2.3	yes
130-3	56-70	48.9	0.8	yes	2.0	yes	2.6	yes
157-2	7-15	37.5	0.7	yes	1.7	yes	5.7	no
157-3	15-17	22.8	2.3	no	3.6	no	2.4	yes
157-5	18-28	38.5	0.4	no	1.5	yes	3.4	no
157-6	28-38	26.3	0.4	no	2.6	no	3.9	no

<sup>a</sup>Sample site locations in Figure 2 and Appendix I.

<sup>b</sup>vfs = very fine sand; fs = fine sand; ms = medium sand; cs = coarse sand.

<sup>c</sup>95% confidence interval around mean of values from modal Parkdale soils ( $0.81 \pm 0.23$ ).

<sup>d</sup>95% confidence interval around mean of values from modal Parkdale soils ( $1.75 \pm 0.45$ ).

<sup>e</sup>95% confidence interval around mean of values from modal Parkdale soils ( $1.89 \pm 0.83$ ).

correlate very well with Parkdale soils. The lone exception is sample 118-1 which apparently represents an over-burden of material not found at the other sites. Petrographic studies (Table 13) indicate that 112-2 is like Parkdale soil material. These data indicate that Parkdale-like material occurs to at least an elevation of 730 m in this area.

Two other sample sites showing good correlation with Parkdale materials are 119 and 130 (Table 14). Sample site 119 is about 1.6 km west of the constriction between the upper and lower valleys (Figure 2). The site is at about 486 m elevation on a slope above a small creek. This deposit is over 2 m thick at some places and is texturally similar, but somewhat redder, than Parkdale soils. Sample site 130 is similar and is located about 8 km up the West Fork of the Hood River from the town of Dee (Figure 2). The overall thickness of this material is less than at sample site 119, but is still over 1 m in some places. Mineralogically, these materials are similar to Parkdale soils even though they have a lower content of fine-grained volcanics and a higher content of pumice and glass (Table 13). Both site 119 and site 130 appear to be similar to Parkdale soils.

Sample site 111 (Figure 2) is of particular interest since it is on the flank of Mt. Hood at about 1094 m elevation. It correlates surprisingly well to Parkdale soils and will be discussed later.

Other sites in the western area do not correlate well with Parkdale soils. Particle size analyses indicate that 110-6 is similar to Parkdale soils (Table 12); however, chemical analyses reveal that the two materials are different (Table 10).

In summary, distribution of Parkdale soils and like materials west of the Upper Hood River Valley is restricted to the slopes into the valley to an elevation of 730 m, slopes west of Dee, and the northeastern flanks of Mt. Hood.

Area South of the Upper Hood River Valley. South of the Upper Hood River Valley is Bluegrass Ridge and the eastern flanks of Mt. Hood. Sand analyses (Table 15) revealed that none of the samples from the eastern flanks of Mt. Hood (sites 102, 117, and 152), Hood River Meadows (site 150), or Horsethief Meadows (site 151) correlate well with Parkdale soils. However, magnetite analyses (Table 11) and chemical analyses (Table 10) indicated that 152-7 correlated well with Parkdale soil materials. Other samples from the same site were mostly different from Parkdale soils.

Therefore, the area south of the valley, in general, does not contain Parkdale soils nor large amounts of Parkdale-like materials. There are some interesting similarities, however, of the materials on the flanks of Mt. Hood to those in the valley. These will be discussed later.

Table 15. Sand content, subfraction ratios and correlation of soils south of the Upper Hood River Valley with Parkdale soils.

Sample <sup>a</sup>	Depth (cm)	Sand (%)	vfs/fs <sup>e</sup>		fs/ms <sup>e</sup>		ms/cs <sup>e</sup>	
			ratio	within <sup>b</sup> 95% CI	ratio	within <sup>c</sup> 95% CI	ratio	within <sup>d</sup> 95% CI
102-1	5-10	59.6	2.5	no	1.6	yes	1.3	yes
102-2	11-20	54.4	1.4	no	2.7	no	1.0	yes
117-1	8-38	56.4	1.4	no	3.7	no	0.9	no
117-2	38-76	61.4	1.3	no	2.1	yes	0.9	no
150-1	60-102	23.7	7.6	no	9.0	no	1.5	yes
151-2	27-51	36.4	1.9	no	3.3	no	1.2	yes
151-3	60-67	49.0	1.4	no	4.2	no	0.8	no
151-4	72-84	68.2	0.9	yes	2.8	no	1.4	yes
152-1	6-10	35.7	1.6	no	2.8	no	1.4	yes
152-2	16-36	30.4	2.8	no	7.5	no	2.5	yes
152-3	36-40	31.9	2.5	no	6.4	no	1.6	yes
152-4	40-43	42.9	1.6	no	4.1	no	1.5	yes
152-5	44-49	67.7	0.8	yes	1.4	yes	0.8	no
152-6	53-56	39.5	1.6	no	3.3	no	1.7	yes
152-7	56-75	71.9	0.9	yes	2.7	no	1.8	yes
152-8	75-110	69.1	0.9	yes	2.5	no	1.4	yes

<sup>a</sup>Sample site locations given in Figure 2 and Appendix I.

<sup>b</sup>95% confidence interval around mean of values from modal Parkdale soils ( $0.81 \pm 0.23$ ).

<sup>c</sup>95% confidence interval around mean of values from modal Parkdale soils ( $1.75 \pm 0.45$ ).

<sup>d</sup>95% confidence interval around mean of values from modal Parkdale soils ( $1.89 \pm 0.83$ ).

<sup>e</sup>vfs = very fine sand, fs = fine sand, ms = medium sand, cs = coarse sand.

### Source of Parent Material of Parkdale Soils

Many possibilities existed both for the source and method of emplacement of the materials in the Upper Hood River Valley.

Loess, volcanic ash, alluvium, glacial till, and debris from flows were considered.

Volcanic Ash. The prevailing idea has been that Parkdale soils formed in vitric volcanic ash. If the parent material were initial air-fall ash, then there should be significant deposits in protected areas in the mountains surrounding the Upper Hood River Valley. Further, if the material were not initial air-fall ash but still derived from ash deposits and emplaced in the Upper Hood River Valley by some other process, then there still should be at least remnants of ash deposits somewhere in the surrounding uplands. Assuming that the ash was derived from such distant sources as Mt. Mazama, Mt. St. Helens, or cones immediately across the Columbia River in Washington, study of the nature and distribution of soil materials in the uplands should lend credence to one, all, or none of these sources. To pursue these ideas, extensive searching was done for vitric ash.

To facilitate comparisons, reference samples of tephra deposits from Mt. St. Helens and Mt. Mazama were obtained. At the same time, an effort was made to trace tephra layers particularly those from St. Helens, to the Hood River Valley. An effort to follow

layers on the ground was unsuccessful. Therefore, samples of the various tephra deposits were taken close to their source with the hope that little variation in chemistry and mineralogy occurred throughout their distribution. Chemical analyses of these materials (Table 16) revealed much variation between tephra layers. Compared with Parkdale soils, some of the Mt. St. Helens tephra are similar in Si and Al contents but are not similar in Fe content. Magnetite analyses (Table 17) show poor correlation of Parkdale soil materials with all the Mt. Mazama and Mt. St. Helens tephra samples except Mt. St. Helens M (upper) (layer described by Mullineaux et al., 1972). However, this layer is not chemically similar to Parkdale soils (Table 16).

One sample site southwest of Mt. St. Helens (sample site 168) indicates distribution of tephra from Mt. St. Helens in a general direction that might deposit ash in the Hood River Valley. However, this material is chemically unlike Parkdale soils (Table 16).

Another sample of pumiceous material was taken on the Warm Springs Indian Reservation south of Mt. Hood (site 160). This site sampled with the assistance of C. T. Youngberg (Oregon State University), represents a significant tephra deposit of unknown source. This material is chemically similar to Parkdale soils (Table 16), but shows poor correlation by magnetite analyses (Table 17).

Much searching was done for tephra in the area around the

Table 16. Chemical composition of selected pyroclastic deposits, lava flows, and soil samples.

Sample <sup>a</sup>	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)
Parkdale soil average	50.0	23.0	8.5
62-19 (Mt. Mazama)	67.4	16.1	2.3
180 (Mt. Hood)	60.6	20.1	5.1
129 (Parkdale lava flow)	52.7	19.6	8.5
St. Helens J <sup>b</sup>	52.7	24.1	4.8
St. Helens M (upper) <sup>b</sup>	60.6	20.5	3.5
St. Helens M (lower) <sup>b</sup>	52.7	24.3	5.8
St. Helens unnamed <sup>b</sup>	50.6	27.2	4.6
160-2 (Warm Springs)	54.3	22.6	6.3
168-6 (Fargher Lake)	60.1	22.0	1.6
179-2 (Walla Walla)	65.3	15.6	6.1

<sup>a</sup>Sample site locations given in Appendix I.

<sup>b</sup>Sample names after Mullineaux et al. (1972).



Table 17. Statistical evaluation of magnetite analyses for source correlation.

Sample <sup>a</sup>	Depth (cm)	Ti/Mn		Fe/Ti		Fe/Mn	
		ratio	within 95% CI <sup>b</sup>	ratio	within 95% CI <sup>c</sup>	ratio	within 95% CI <sup>d</sup>
<u>Volcanic ash</u>							
101	-	1.3	no	2.9	no	3.7	yes
115-2	39-46	1.7	yes	2.3	no	3.9	yes
160-2	60-175	1.1	no	3.4	no	3.7	yes
62-19	183-193	1.2	no	3.0	no	3.6	yes
St. Helens W <sup>e</sup>	-	0.8	no	3.6	no	2.9	yes
St. Helens Z <sup>e</sup>	-	1.0	no	3.7	no	3.7	yes
St. Helens J <sup>e</sup>	-	1.0	no	3.6	no	3.6	yes
St. Helens M <sup>e</sup> upper	-	2.5	yes	1.7	yes	4.3	yes
St. Helens <sup>e</sup> unnamed	-	1.7	yes	2.6	no	4.4	yes
<u>Loess</u>							
179-1	13-30	1.5	yes	2.5	no	3.7	yes
<u>Mudflow</u>							
152-2	42-91	1.1	no	2.6	no	2.9	yes
152-7	141-191	1.9	yes	2.0	yes	3.8	yes

<sup>a</sup> Sample site locations given in Appendix I.

<sup>b</sup> 95% confidence interval around mean of values from modal Parkdale soil ( $2.05 \pm 0.60$ ).

<sup>c</sup> 95% confidence interval around mean of values from modal Parkdale soil ( $1.83 \pm 0.16$ ).

<sup>d</sup> 95% confidence interval around mean of values from modal Parkdale soil ( $3.70 \pm 0.94$ ).

<sup>e</sup> Sample names after Mullineaux et al. (1972).

Upper Hood River Valley. Several poorly drained upland areas were found that contained traces of vitric tephra, but no large deposits were located. (For future reference, sample sites 115, 124, 125, 144, 156, 157, and 167 [Appendix I] are poorly drained areas with limited thicknesses of vitric tephra.)

At one place, site 101 (Figure 2), pumiceous material had accumulated in a concavity on a slope. This site is in the southeastern extremity of the Lower Hood River Valley. The deposit was protected by an overburden of colluvial debris. There are no extensive deposits of this type in the Upper Hood River Valley.

This layers of fine-grained silicic tephra may be seen at many locations to the east and southeast of Mt. Hood. A controversial ash deposit supposedly from Mt. Hood was mentioned by Lawrence (1948); however, Wise (1969) makes no mention of such activity from Mt. Hood. Lawrence (1948) described the ash as being several centimeters thick at Cloud Cap on the flanks of Mt. Hood and extending across the gorge of the East Fork of the Hood River to the eastern ridge. On this ridge he recognized only 1 to 2 cm thicknesses. This suggests limited distribution and volume of material. This material could represent either initial or reworked tephra from other sources. Samples from this area (sample site 152, Appendix III-c) reveal some ash layers in the upper part of the profile but mostly non-ash material below 15 cm.

In general, vitric ash is present in most soils surrounding the valley, but no thick ash deposits are evident. Much of the ash has apparently been mixed with other materials. Morphological and petrographic studies show that Parkdale soils do contain recognizable vitric ash but in limited amounts (Table 8). There is more vitric ash in upper horizons than deeper in the soils. This suggests that some volcanic ash was added after emplacement. The large amounts of weathering products in Parkdale soils could have been weathered, at least in part, from volcanic ash. The weathering would have had to have taken place before the soil materials were emplaced in the valley (see Chapter IV). If this occurred, the contribution of vitric ash to Parkdale soils could be underestimated by looking only for recognizable remnants of ash in parent materials. However, the general lack of glass shards, pumice, and vitric tephra in Parkdale and parent materials tends to discount the theory of these soils having developed predominantly in either initial airfall or reworked ash from Mt. Mazama or Mt. St. Helens unless the material was almost completely altered prior to deposition.

Loess. Loess was considered to be a possible parent material for Parkdale soils since the soil particles are predominantly silt and very fine sand sized. The proximity of a large body of loess about 30 km east of the Hood River Valley further suggested this possibility. Total soil chemical analyses (Table 16) and magnetite

grain analyses (Table 17) of samples of the loess east of the valley (Walla Walla soil, site 179) show that the loess is not similar to Parkdale soils. Additional data from other sample sites in the loess area show further differences. Sand content and sand subfraction analyses of sites 105, 106, and 109 (Appendix V-a and b) show that these soils are different from Parkdale soils. Petrographic studies reveal that the loess contains much muscovite, whereas Parkdale soils contain little if any. All these data indicate that Parkdale soils formed in mineralogically, chemically, and physically different material than the loess east of the Hood River Valley.

The occurrence of pebbles and charcoal pieces > 2 mm scattered throughout the Parkdale soil also suggest a source other than loess. These observations and the absence of an adequate local source suggest that Parkdale soils are not formed in loess.

Glacial Till. Glacial till was considered to be a possible source of parent materials due to the position of the upper valley with respect to Mt. Hood. There are tills on the flanks of Mt. Hood and under the material in which Parkdale soils have developed (Figure 3). These tills consist of unsorted materials of many sizes and do not resemble Parkdale soils. Also, Wise (1968) shows that glaciers never left the flanks of Mt. Hood during Fraser Glaciation (15,000 years ago), the last major ice period. Radiocarbon age dating (to be discussed later) shows that Parkdale soils are younger than

15,000 years and since there have been no major periods of glaciation since that time, glacial till was discounted as a possible source for the Parkdale soil materials.

Alluvium. Alluvium was hypothesized as a possible parent material since the particle size of the materials is consistent with those easily suspended and carried by moving water. The most likely type of alluvium to represent Parkdale soil material is an alluvial fan. Alluvium typically shows stratification due to cyclic sedimentation of dissimilar sized or chemically or mineralogically different materials. Parkdale soils are not stratified. If the material in the Upper Hood River Valley were alluvium, much variation would be expected due to the steep slopes and stream gradients into the valley. These gradients would probably produce coarse deposits such as those associated with present drainages. This assumes similar gradients during the time of deposition of Parkdale materials as now. Parkdale soil materials are uniform in particle size throughout the entire valley. Alluvial fans become finer with distance from the point of emergence from higher land masses; this type of variation does not occur in Parkdale soils. These data and the general appearance of the materials indicate that alluvium is not the best possibility for the source of Parkdale soil materials.

Mudflow. Many observations have been made both in the field and the laboratory that are consistent with deposition of the Parkdale

soil materials by mudflow. The graded particle size distribution of > 2 mm materials (Table 1) is characteristic for mudflows according to Crandell and Waldron (1956). Occurrence of pebbles, charcoal, and "shot" throughout the soil materials is also consistent with mudflow deposition. The coatings around many of the pebbles and charcoal pieces suggest the possibility of their formation during transportation in a mudflow. Occurrence of the charcoal as small discrete pieces, rather than as remnants of roots, limbs, or logs, suggests destruction and scattering during transportation. Occurrence of the soil-coated cobbles that underlie Parkdale soil materials could be attributed to mudflow processes. Observations that these cobbles and overlying finer materials are co-extensive over many different materials (Figure 3), and have the same matrix materials, indicate that they are of the same depositional unit. Mudflow transportation and deposition would be consistent with these observations. Occurrence and distribution of Parkdale soils on the landscape (Figures 4 and 5) are also characteristic of mudflow deposition. Observations that these soils are composed of various kinds of rocks and minerals occurring side by side in both weathered and fresh conditions, suggests weathering of some components prior to deposition. Mudflow processes could account for the mixing of these with unaltered materials.

Deepest deposits of Parkdale soil materials are found where

the slope breaks from the relatively steep slopes of Mt. Hood to the more level valley floor (Figure 5).

Thickness of the soil decreases in all directions from that point. Parkdale-like soil materials also thin very quickly on increasing elevations in all directions from the valley except to the southwest, which is also consistent with mudflow deposition. A likely source for the mudflow is available. Mt. Hood rises steeply to the southwest of the valley. A canyon on the flanks of Mt. Hood debouches into the upper part of the valley.

Numerous observations throughout Oregon and southern Washington show that there is a tendency for windblown materials to accumulate on the north and northeastern sides of mountains. In addition, glacial flour may also have accumulated on the flanks of Mt. Hood during Fraser Glaciation. There are numerous possibilities for induced instability to occur in tectonically active areas, which Mt. Hood apparently was during the not too distant past (Wise, 1969).

Debris may be shaken down slopes by earthquakes, volcanic eruptions, or other phenomena associated with volcanoes and volcanic activity. To investigate the possibility of remnants of materials on the flanks of Mt. Hood that are similar to those that would have given rise to mudflows, study was made of a section close to Cloud Cap which is at about 1824 m elevation (sample site 152, Figure 2 and Appendix III-c). This site is very near the canyon

from which a mudflow could have originated and should contain similar material to that composing the mudflow. The section at site 152 has many layers as indicated in the description (Appendix III-c). Previous discussions of samples from site 152 (page 46) pointed out that total soil chemical analyses (Table 10) and also magnetite analyses (Table 17) indicated similarities of the layers between 55 and 110 cm to Parkdale soils. These similarities stimulated some calculations to further assess likenesses. The upper 16-1/2 cm are layers of alternation zones of vitric ash and organic matter. The shortage of vitric ash in Parkdale soils (previously discussed) indicates that if a mudflow occurred, it is likely to have been prior to accumulation of these relatively unweathered vitric ash layers. In these calculations, an attempt was made to mathematically duplicate mudflow processes. The calculations allow a view of the character of resultant material from a mixture of all the horizons at the Cloud Cap location (sample site 152) below 16-1/2 cm. Calculations for average content of materials > 2 mm in the modal Parkdale soil, based on content of > 2 mm material in relation to thickness of each horizon results in an estimate average of 12%. The same calculation for sample site 152 gives 19%. Actually, samples from the lower layers at site 152 contain many rocks that are larger than those in the upper part of Parkdale soils. The cobble layer underlying the finer materials at both site 152 and Parkdale soils was not



considered in these calculations. If the larger rocks in the samples from site 152 are discounted in the calculations, then a value much closer to 12% is obtained. This assumption is not unreasonable since larger rocks could settle out of a relatively fluid mudflow. These calculations, although somewhat crude, tend to support the mudflow theory.

Calculations were also made for material  $< 2$  mm from sample sites 134 and 152. These calculations were based on the data shown in Appendix V-a. Considering all  $< 2$  mm material below 16-1/2 cm at sample site 152 mixed together, a weighted average was calculated for each sand subfraction. Content of each subfraction and thicknesses of horizons were allowed for. Values for vcs, cs, ms, fs, and vfs were 2.9, 5.2, 7.4, 20.0, and 22.0%, respectively, for the resultant mixture. Ratios of vfs/fs, fs/ms, and ms/cs are 1.1, 2.7, and 1.4, respectively. These correlate reasonably well with the modal Parkdale soils which gave  $0.81 \pm 0.23$ ,  $1.75 \pm 0.45$ , and  $1.89 \pm 0.83$  for the same ratios. These calculations illustrate the possibility that a mudflow, originating in material like the lower layers at sample site 152, could result in a material texturally very similar to that in which Parkdale soils formed. It appears certain that the layers below 55 cm would have been included in the mudflow, and the layers above 16-1/2 cm would not. However, there is some uncertainty about the likelihood of contributions of the intermediate layers

to the mudflow. Materials below 55 cm contain some weathered volcanic ash.

If a mudflow came from Mt. Hood, there should be other soils like Parkdale at relatively high elevations in the source area. In order to investigate the possibility that Parkdale soils occur in the canyon on the northeastern side of Mt. Hood, samples from site 111 at about 1094 m elevation were studied. This site is well above the 604 m elevation of the southern part of the upper valley. These materials, as previously shown, correlate well with Parkdale soil materials (Table 14). This soil may not represent the elevation limit for occurrence of Parkdale-like materials on the northeastern flank of Mt. Hood. However, it does indicate their occurrence at higher elevations in this than in other geographic areas.

To investigate chemical correlations of material from the northeastern flanks of Mt. Hood, a random sample of stream bottom sand was collected from Eliot Branch of the Middle Fork of the Hood River (site 173, Figure 2). This stream drains Eliot glacier and cuts the northeastern flank of Mt. Hood. These sands probably represent a fair cross-section of the rock types of the area. Analyses of these sands show a surprisingly close correlation to Parkdale soils (Table 10). Also, Wise (1969) analyzed rocks and deposits from the north, northeast, and eastern sides of Mt. Hood (Table 18). Those basalts, olivine andesites, and pyroxene andesites, in general,

Table 18. Chemical analyses of rocks and deposits from the north-eastern side of Mt. Hood (Wise, 1969) compared to Parkdale soils.

Sample <sup>a</sup>	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	TiO <sub>2</sub> (%)	CaO (%)	K <sub>2</sub> O (%)
<u>Mt. Hood</u>						
142	55.6	18.2	8.4	1.1	7.2	0.9
143	54.7	17.9	8.6	1.2	7.4	0.9
144	56.3	18.4	7.8	1.1	7.2	0.9
145	55.0	18.4	8.3	1.1	7.8	0.9
146	55.0	19.1	8.3	1.2	7.6	0.8
147	55.3	19.1	8.2	1.2	7.6	0.8
148	55.0	19.3	8.2	1.2	7.6	0.8
149	53.7	16.9	9.3	1.3	8.3	1.2
150	54.2	19.6	8.1	1.1	7.0	1.0
151	56.0	18.5	8.6	1.2	7.1	0.7
152	56.6	18.2	7.8	1.0	6.8	1.0
153	57.3	17.6	7.8	1.1	7.4	1.3
154	59.1	17.9	6.9	0.9	6.4	1.1
155	59.1	17.8	7.2	0.9	6.8	1.1
156	49.7	18.3	9.5	1.3	10.2	0.8
157	54.7	17.5	8.1	1.2	8.6	1.0
158	54.8	17.4	8.3	1.2	8.4	1.0
116	55.6	18.0	7.3	1.1	8.9	0.7
117	57.0	17.9	7.2	0.8	7.6	1.0
118	58.7	17.7	7.4	1.0	7.1	1.2
<u>Parkdale Soil</u>						
134-2	53.7	20.9	8.2	1.1	3.2	1.2
134-7	47.9	24.6	9.2	1.2	2.4	0.7

<sup>a</sup> Numbers of samples from Mt. Hood are according to Wise (1969). Sample location of Parkdale soil given in Appendix I.

correlate quite well with materials in the Upper Hood River Valley. In fact, with the exception of Ca content, the chemical composition of the rocks is almost identical to those for Parkdale soils (Table 18). These data and those from sample site 111 indicate that both soils and bedrock on the northeastern flanks of Mt. Hood correlate well with Parkdale soils.

The mudflow deposit in the Upper Hood River Valley is very large. However, mudflows of the size required for such a deposit have been recorded. Crandell and Waldron (1956) describe a mudflow that originated on the northeast side of Mt. Rainier and flowed for 73 km down the valley of the White River and spread out on the Puget Sound lowland as a lobe 32 km long and 5 to 16 km wide. Thickness of the flow ranged from about a meter to over 106 m. The Parkdale mudflow would not need to be nearly as large as the one from Rainier to account for the materials in the Hood River Valley. However, the fact that such a large flow has occurred lends credence to the other data that a large mudflow could originate from Mt. Hood.

Mudflow deposition can also explain the distribution of Parkdale-like materials that are outside the Upper Hood River Valley. A natural constriction exists between the upper and lower Hood River valleys in the Winans area (Figure 2). When the mudflow reached this constriction, an accumulation of "backwater" could have occurred much the same as Crandell and Waldron (1956) reported for the

mudflow at Mt. Rainier. Therefore, material could have been backed up the valley of the West Fork of the Hood River with resultant deposition in that valley at Dee Flat and at the locations of sample sites 131 and 130. This "backwater" would also have resulted in deposition of material high on the west-facing slopes in the immediate area of the valley constriction. At the same time, material could have spilled over the gap between Middle Mountain and the ridge east of the Hood River Valley, depositing material in the upper part of the lower valley. The mudflow could also have deposited material in the Lower Hood River Valley floor on top of Hood soils, which seem to be older than the mudflow. Similarities in morphology, coarse grain mineralogy, and development of Hood soils compared to Woodburn and Willamette soils, which are associated with late Pleistocene surfaces in the Willamette Valley (Parsons, 1972), suggest similar ages. These soils are older than indicated ages for the mudflow (discussed later). A rise in the local base levels of the Columbia River or flooding of the Hood River could have removed the mudflow deposit off the Hood soils in the lower valley. However, it is difficult to conceive of erosion sufficiently uniform to remove all vestiges of the mudflow material while allowing the underlying Hood soils to remain relatively undisturbed (Parsons, 1972).

Alternatively, the constriction in the valley at Winans may have prevented the mudflow from spreading over the lower valley

floor and funneled it down the channel of the Hood River, so that soils in the lower valley would not have been covered by the mudflow. In this case, the Hood soils could be older and yet not be covered by Parkdale-like material.

Occurrence of Parkdale-like material at relatively high elevations in the lower valley was considered further. These deposits were hypothesized to be due to "sloshing over" of the relatively fluid material comprising the mudflow as it reached the valley constriction. Another alternative is for the material to have been deposited by mudflows of local origin. The main problem with this hypothesis is that the materials which represent these deposits correlate so well with materials in the Upper Hood River Valley. To have several small mudflows with virtually the same physical, chemical, and mineralogical characters certainly would not be impossible, but is improbable.

#### Age of Parkdale Soils

Several possibilities existed for obtaining a relative or an absolute age for Parkdale soils. Potentially, there were many layers of tephra from various cones in the Pacific Northwest that could be present. These, if found and correlated with dated deposits, could provide a relative age. This avenue was abandoned when no well defined tephra layers could be found that had a direct relationship

to Parkdale soils.

Radiocarbon dating seemed possible, since the Parkdale soils contain pieces of charcoal. This charcoal, as previously mentioned, is scattered throughout the soil and occurs as small discrete pieces. Enough of this charcoal was carefully selected for an age determination. The sample site is in the NW1/4 SE1/4 SW1/4 of sec. 31, T1N, R10E. This site is an exposure in a deep road cut on the south side of an east-west paved road. The sampling was done with the help of C. E. Silvernale. Samples were taken from a zone 1.7 to 2.1 m from the soil surface. The method of sampling consisted of sieving the soil material through a 1 mm sieve and selecting the charcoal remaining on the screen. Samples were carefully handled and transported in precleaned glass containers to minimize contamination. During the sampling, care was exercised to avoid krotovinas, old root channels, and charred roots. An age of  $12,270 \pm 190$  years B. P. was obtained for the charcoal (Teledyne Isotopes, Westwood, New Jersey). This gives the earliest probable date for the deposition of the "Parkdale" material in the Upper Hood River Valley. It is not known how long the charcoal may have been in place at its original site prior to being transported into the valley. If the charcoal were quite young at the original site, then the age could closely represent the length of time the materials have been in place in the Hood River Valley; in other words, it would give a valid date for

deposition of the materials. This assumes that charcoal does not persist on the ground surface for great periods of time. On the other hand, if the charcoal were buried at the original site, it could have persisted for a long time prior to the mudflow. Therefore, the age of the charcoal provides a maximum age for the Parkdale soils but certainly not for the component rock fragments and mineral grains in these soils. Much of the material comprising the Parkdale mudflow could have been exposed to weathering for thousands of years prior to the mudflow. Stated differently, this charcoal age gives the maximum age for emplacement of the mudflow, not an absolute age of constituent inorganic materials.

Since this age dating gave a maximum age for the mudflow, there was need to determine a minimum age. This would give an age bracket in which Parkdale soils would fit.

It was observed that the Parkdale soil materials underlie the Parkdale Lava Flow. The lava flow lies within the valley down which the mudflow would have had to travel. Following suggestions of E. M. Taylor, a location was found where charcoal could be obtained from beneath the lava flow and above the Parkdale-like soil material. The site for this sampling is in the SW1/4 SE1/4 NE1/4 of sec. 2, T1S, R9E. At this location the Middle Fork of the Hood River has undercut the lava flow, exposing the soil-lava flow contact. Apparently the hot lava flow, while overriding the surface, charred the



soil organic materials. The charring resulted in a layer, 1 cm and less in thickness, just below the rocks of the lava flow and just above the mineral soil. M. E. Harward, Oregon State University, and P. E. Hammond, Portland State University, assisted in sampling this charcoal. Samples were collected from the contact zone and transported in metal cans. Analyses of this charcoal gave an age of  $6890 \pm 130$  years B. P. (Teledyne Isotopes, Westwood, New Jersey) and probably represents a close estimate of the age of the lava flow. Therefore, Parkdale soils are older than 6890 years.

The  $^{14}\text{C}$  data indicates that the mudflow occurred between 6890 and 12,270 years ago. These ages correlate with events in other areas, since they correspond to the age of the Winkle surface in the Willamette Valley (Balster and Parsons, 1968; Parsons, Balster and Ness, 1970). This was a period of instability in the Willamette Valley during which streams were downcutting on higher gradients than at present. This suggests that the period of instability in the Mt. Hood area, that gave rise to the Parkdale mudflow, existed contemporaneously with one in the Willamette Valley and has regional implications as a likely time for landslides and mudflows. On a broader scale, the age of 12,270 years correlates with the Carey II ages that Ruhe and Scholtes (1956) obtained in the Midwest. This age would be considered to be Recent (Ruhe, 1969).

## Summary and Conclusions on Source and Correlation

### Description of Parkdale Soils

Parkdale soils are about 50 cm thick. They are dark brown to brown and are silt loam to loam in texture. They are not sticky but are slightly plastic. They have weak structure and weakly developed horizonation and contain intermixed pebbles and charcoal. The parent materials are reasonably well weathered and are underlain immediately by a cobble layer. Below this cobble layer, various materials occur, including glacial till, coarse or fine alluvium, and mudflow materials.

### Variations of Parkdale Soils

Within Parkdale soils, materials are uniform in particle size distribution of the  $< 2$  mm fraction. Content of non-pedogenic  $> 2$  mm materials tends to increase with depth. Analyses of various mineral separates and sand subfractions revealed uniformity within profiles. Mineralogical and chemical analyses suggest some contamination of upper horizons by siliceous tephra but reasonable uniformity otherwise. Particle size distributions, sand subfraction ratios, and mineral separate analyses reveal few variations among Parkdale soils. However, petrographic analyses and thickness measurements

do suggest differences. Variations in sand mineralogy are not great and, in general, indications are that Parkdale soils vary little throughout the valley except for thickness.

#### Occurrence and Distribution of Parkdale Soils

This investigation showed that, except for a few locations, Parkdale soils and like materials occur mostly within the Upper Hood River Valley. They cover almost the entire valley floor and are deepest toward the southwest side of the valley. The locations of occurrence outside the upper valley are: the upper reaches of the lower valley on the southeastern and southwestern sides, the east-facing slopes west of Winans and the upper valley, and the northeastern flanks of Mt. Hood.

#### Source for Parent Material of Parkdale Soils

After investigating several possibilities, mudflow processes were suggested to be the most probable method of emplacement for the parent material of Parkdale soils. Deposition as a mudflow best explains morphological, chemical, physical, and distribution features of Parkdale soil materials. Mt. Hood is the likely source for the mudflow. There are presently materials on the northeastern flanks of Mt. Hood that, if mixed, would result in a deposit much like

Parkdale soil material. Chemical analyses of sands and rocks from the northeastern flanks of Mt. Hood correlate well with Parkdale materials. A mudflow that occurred on Mt. Rainier (Crandell and Waldron, 1956) demonstrates that the size of mudflow required for the Parkdale deposit is not unreasonable. The Mt. Rainier mudflow had many of the same features as the one in the Upper Hood River Valley.

#### Age of Parkdale Soils

Radiocarbon determinations yielded an age of  $12,270 \pm 190$  years B. P. for charcoal sampled from a depth of about 2 m in Parkdale soil materials and an age of  $6890 \pm 130$  years B. P. for charcoal sampled from between Parkdale soils and an overlying lava flow. These dates suggest that the Parkdale materials were emplaced between 6890 and 12,270 years ago. They correlate with a period of regional instability at the end of the Pleistocene.

### CHAPTER III

## EFFECTS OF LABORATORY TREATMENTS ON PARKDALE SOILS

### Introduction

Problems had been encountered in prior laboratory studies of Parkdale soils. There was also need to establish the best methods to use in subsequent studies of chemical and mineralogical properties. More information was needed to adequately explain why duplicate samples reacted differently to dispersion techniques. A reproducible method for dispersing clays, so that they could be removed for further analyses, was also sought.

Numerous researchers have worked to perfect methodology for organic matter removal from soil samples. The more common methods involve the use of either  $\text{H}_2\text{O}_2$  or  $\text{NaOCl}$ . Lavkulich and Wiens (1970) criticize the use of  $\text{H}_2\text{O}_2$  because of its apparent destructiveness on soil materials. This destructive effect should be pronounced for highly amorphous systems like those present in Parkdale soils. Therefore, study was made to allow comparison of effects of both chemicals on Parkdale soils.

Cation exchange capacity (CEC) is another soil property frequently measured. Hydrolysis effects, pH dependent charge, salt

trapping, and other problems tend to complicate CEC measurements for soils high in amorphous materials. Recognition of possible misinterpretations of CEC data led to an investigation of variations in results between methods for measurement.

## Methods

### Dispersion and Removal of Clays

Clays were dispersed in distilled water or distilled water with HCl or NaOH added to give a solution of pH 3.5 or 10.5 respectively. Suspension was achieved with a mechanical stirrer. After dispersion, the suspended clays were removed by centrifugation. In all cases, the procedure was continued until a clear supernatant was obtained, indicating virtually all clay had been extracted.

### Organic Matter Removal

Organic matter was removed by use of either  $\text{H}_2\text{O}_2$  or NaOCl. The NaOAc buffered  $\text{H}_2\text{O}_2$  procedure (Jackson, 1956), involving digestion at  $65^\circ\text{C}$ , was one procedure used.

The NaOCl procedure for removal of organic matter is that proposed by Anderson (1963).

### Differential Thermal Analyses

Differential thermal analyses (DTA) were made with a Dupont model 900 Differential Thermal Analyzer equipped with a high temperature cell. All samples were  $\text{Mg}^{++}$  saturated and equilibrated over saturated  $\text{Mg}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$  (relative humidity (RH) 54%) prior to analyses. Prior to and during analyses the sample chamber was continually flushed with  $\text{N}_2$  gas (2 SCFH).

### X-ray Diffraction Analysis

X-ray diffraction (XRD) procedures used in this study have been partially described elsewhere (Harward *et al.*, 1969). Basically, the procedure involves preparation of oriented specimens on slides of  $\text{Mg}^{++}$  and  $\text{K}^+$  saturated clays by the paste method of Theisen and Harward (1962). Three  $\text{Mg}^{++}$  saturated clay specimens were analyzed. One was equilibrated over  $\text{Mg}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$  (54% RH), one was solvated by condensation of glycerol vapor (Brown and Farrow, 1956), and one was solvated by condensation of ethylene glycol vapor (Kunze, 1955). X-ray analyses were made of all three treatments in an atmosphere controlled at 54% RH.

A  $\text{K}^+$  saturated clay specimen, that had been previously dried at  $105^\circ\text{C}$ , was equilibrated over  $\text{Mg}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$  (54% RH) and analyzed at room temperature in a 54% RH atmosphere. Other  $\text{K}^+$  saturated samples were analyzed at room temperature in dry air

after heat treatments of 105°, 300°, and 500° C.

X-ray diffraction patterns were obtained with a Philips Norelco X-ray diffractometer equipped with a focusing monochromater and a Geiger-Mueller tube. Cu K $\alpha$  radiation was used in the analyses.

#### Cation Exchange Capacity Determinations

Cation exchange capacity (CEC) determinations were made by three methods. Methods I and II involved saturating with Na<sup>+</sup> (N NaCl) and displacement of the Na<sup>+</sup> with Mg<sup>++</sup> (N MgCl<sub>2</sub>). Displaced Na<sup>+</sup> was determined with a Perkin-Elmer Model 306 Atomic Absorption Spectrophotometer. Method I involved washing the sample three times with water to remove excess salts after Na<sup>+</sup> saturation. In Method II, three washings with 99% methanol were substituted for the water washings.

Method III is the procedure proposed by Wada and Ataka (1958). This procedure requires saturation of the exchange complex with NH<sub>4</sub><sup>+</sup>, then weighing to determine the excess liquid of the N NH<sub>4</sub>Cl solution remaining in the sample. The NH<sub>4</sub><sup>+</sup> is displaced with K<sup>+</sup> and then determined. CEC is calculated after subtraction of the excess NH<sub>4</sub><sup>+</sup> in the liquid phase.



### Removal of Free Iron Oxides and Amorphous Components

The procedure used for dissolution and removal of free iron oxides and amorphous components was that recommended by Dudas and Harward (1971). This method involves the use of ammonium oxalate at pH 3 for iron oxide removal and KOH for dissolution of amorphous silica, alumina, and alumino-silicates.

### Electrical Conductivity

Electrical conductivity measurements were made with an Industrial Instruments model RC 16B1 conductivity bridge equipped with a Barnstead model B-1 conductivity cell.

### pH Measurement

Measurements of pH were made with a Beckman model 76 Expanded Scale pH Meter.

## Results and Discussion

Results of these studies have been divided into three treatment groups to facilitate discussion. The three groups are concerned with organic matter removal, dispersion, and CEC measurement.

### Effects of Organic Matter Removal Treatments

Anderson (1963) and Lavkulich and Wiens (1970) criticize organic matter removal methods involving the use of  $H_2O_2$  due to potential destruction of inorganic soil materials. Apparently this problem is greatest for soils highest in amorphous materials. Parkdale soils have a relatively large content of amorphous materials; therefore, the potential effect of organic matter removal treatments is also large. To study these effects, samples were given one of two treatments or no treatment for organic matter removal and then dispersed at one of two pH's. The clays were then separated and analyzed. Amounts of organic materials removed were not investigated; effects on inorganic materials were evaluated.

Samples pretreated with  $H_2O_2$  resulted in greatest clay yields at both pH 3.5 and 10.5; samples pretreated with NaOCl were intermediate; those not treated for organic matter removal yielded lowest amounts of clay (Sample 1 vs 4 vs 11 and Sample 3 vs 6 vs 12, Table 19). These data are consistent with results of Anderson (1963). Clay yields obtained from samples with no organic matter removed were only 1/3 to 1/4 as large as those with removal treatments. Therefore, organic matter must be destroyed for studies requiring maximum clay separation from Parkdale soils.

Table 19. Effect of pH and organic matter removal on clay content, amorphous material content, and CEC.

Sample <sup>a</sup>	pH for dispersion	o. m. removal treatment <sup>b</sup>	Clay <sup>c</sup> (%)	Amorphous <sup>d</sup> (%)	CEC <sup>e</sup> (meq/100g)
1	3.5	H <sub>2</sub> O <sub>2</sub>	19.5	67.9	35.2
3	10.5	H <sub>2</sub> O <sub>2</sub>	16.2	59.2	49.8
4	3.5	NaOCl	16.4	78.9	43.8
6	10.5	NaOCl	14.4	71.5	59.8
11	3.5	none	5.0	N. D.	53.1
12	10.5	none	4.2	N. D.	N. D.

<sup>a</sup> All samples are subsamples of total < 2mm sample from 137-7 (Appendix I).

<sup>b</sup> o. m. = organic matter

<sup>c</sup> Determined by differences in dry weights by subtracting sands and silts from initial weight.

<sup>d</sup> Weight loss of clay fraction after dissolution of amorphous materials with KOH and treatments for Fe-removal.

<sup>e</sup> Method III - NH<sub>4</sub><sup>+</sup> saturation, no washes, NH<sub>4</sub><sup>+</sup> displaced by K<sup>+</sup> and determined.

N. D. = not determined.

Various analyses were performed to study the nature of the clays obtained from samples after the treatments for organic matter removal. Analyses included amorphous material content, CEC, DTA, and XRD analyses of the clay separates.

Results show that amorphous material content of clay fractions is about 11% less after  $\text{H}_2\text{O}_2$  treatments than after NaOCl treatments (Sample 1 vs 4 and Sample 3 vs 6, Table 19). These data follow trends discussed by Lavkulich and Wiens (1970).

Cation exchange information shows that NaOCl treated samples have 20 to 25% higher CEC's than  $\text{H}_2\text{O}_2$  treated samples (Table 19). Compared to untreated samples, both  $\text{H}_2\text{O}_2$  and NaOCl pretreated samples have lower CEC's. However, this comparison probably reflects the CEC of organic matter in the untreated samples.

Differential thermal analyses (DTA) of clays were done to further investigate differences that had appeared due to the organic matter removal methods (Figure 6). Baselines were adjusted for the patterns to correct for instrumental drift. There are essentially no differences between the patterns for clays after either  $\text{H}_2\text{O}_2$  or NaOCl treatments. Also, compared to clays from samples with no organic matter removed, the treated samples show few differences. The low temperature endotherm tends to be less intense, have more of a shoulder, and occur at a somewhat higher temperature for those clays with organic matter removed.

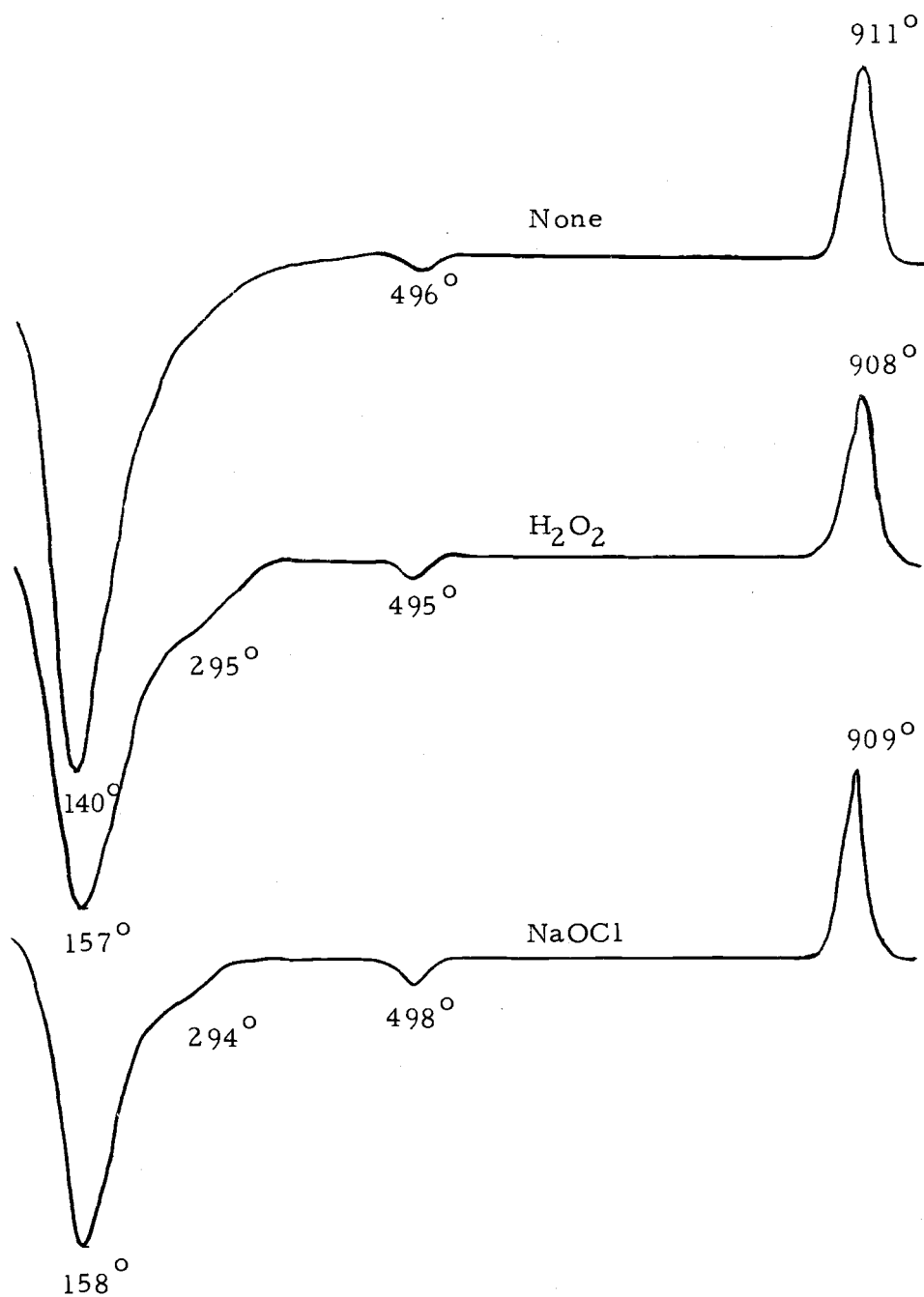


Figure 6. Differential thermal analyses curves of Parkdale soil clays after various treatments to remove organic matter. (temperatures in °C; baselines adjusted)

Campbell et al. (1968) reported that  $\text{H}_2\text{O}_2$  treatment of samples caused great reduction in the exothermic peak for allophane. They suggest that if allophane is to be studied,  $\text{H}_2\text{O}_2$  treatments should be avoided. Data in Figure 6 indicate that this is not the case for samples analyzed in this study. Neither  $\text{H}_2\text{O}_2$  nor  $\text{NaOCl}$  had distracting effects on interpretations.

Clays obtained from samples after treatment with various organic matter removal procedures were analyzed by XRD. These analyses (data not presented) also showed no differences resulting from either  $\text{H}_2\text{O}_2$  or  $\text{NaOCl}$  treatments compared with each other and against untreated samples.

Anderson (1963) noticed distinct differences in XRD patterns for clays that were obtained from  $\text{H}_2\text{O}_2$  and  $\text{NaOCl}$  treated soil samples. The primary differences he found were reduced intensities for peaks from crystalline clay minerals. If these differences do exist, the trends would be difficult to establish for Parkdale soils. This is because the dominant clay material is amorphous. To evaluate effects on crystalline clays, the amorphous material must be removed. The methods for amorphous material removal are potentially much more destructive than the organic matter removal treatments. This necessarily complicates interpretations of organic matter removal treatment effects. Amorphous materials were removed, however, and XRD analyses revealed no detectable

differences in the samples that could be attributed to organic matter removal methods.

To summarize this study on organic matter removal, many interpretations are possible. Organic matter removal clearly is necessary for maximum clay yields. However, there are still unanswered questions about effects of  $H_2O_2$  and NaOCl. It could be that NaOCl is more destructive of crystalline clays than  $H_2O_2$  and, thereby, induces formation of more amorphous materials. Alternatively, NaOCl may be more effective in dispersion of amorphous materials than is  $H_2O_2$ . However, the most plausible interpretation is that  $H_2O_2$  is more destructive of amorphous materials than is NaOCl.

#### Effects of Dispersion Methods on Parkdale Soils

Dispersion of Parkdale soil samples at pH 3.5 released 15 to 20% more clay than dispersion at pH 10.5 (Sample 1 vs 3, Sample 4 vs 6, and Sample 11 vs 12, Table 19). From another study, dispersion at pH 3.5 released more clay than dispersion in distilled water and both of these methods estimate more clay than conventional pipette analyses (Table 20). Sodium hexametaphosphate was used as a dispersant in pipette analyses. Although dispersion in acid media consistently gave higher yields of clay relative to more basic media,

Table 20. Effect of dispersion treatments on clay content and CEC's

Sample	Depth (cm)	pH 3.5 <sup>a</sup>			H <sub>2</sub> O <sup>a</sup>			Pipette analysis Clay (%)
		Clay (%)	Number <sup>b</sup> washings	CEC meq/100g	Clay (%)	Number <sup>b</sup> washings	CEC meq/100g	
134-1	0-23	11.0	58	48.8	10.3	36	48.3	10.3
134-2	23-46	14.2	47		13.7	81		7.2
134-3	61-91	17.9	47	43.5	12.8	77	39.9	9.4
134-4	91-152	21.2	47		5.1	51		11.0
134-5	152-213	24.5	49	52.4	13.5	43	39.8	11.5
134-6	213-274	26.8	45		18.8	39		11.9
134-7	274-335	24.0	48	53.1	22.2	35	55.5	11.3
134-8	335-371	20.9	48		16.9	40		9.8

<sup>a</sup> Solution used to disperse samples - HCl in H<sub>2</sub>O or H<sub>2</sub>O alone; Total clay removed by repeated centrifugation; then freeze dried and weighed (all samples pretreated with H<sub>2</sub>O<sub>2</sub> for organic matter removal).

<sup>b</sup> Number of 200 ml washings required to remove all clay.



the differences reported in Table 20 are probably too great to attribute to effects of pH alone. The data in Table 20 may indicate ease of dispersion more than potential dispersibility. If this is true, then repeated extraction ad infinitum at any pH, by any method, would result in the same estimate for clay content for Parkdale soils.

In regard to qualitative differences in the clays dispersed, the amorphous content of materials obtained at pH 3.5 was 10 to 15% higher than those from pH 10.5 (Sample 1 vs 3 and Sample 4 vs 6, Table 19). CEC's for clays dispersed in acid media were lower than those for clays dispersed in basic media (Sample 1 vs 3 and Sample 4 vs 6, Table 19). Comparison of CEC's for clays obtained from dispersion at pH 3.5 with those from dispersion in distilled water (Table 20) reveals few differences. Differences that do occur are not consistent with either method of dispersion or depth of sampling.

Comparisons of data from DTA for clays dispersed in distilled water with those dispersed in either a pH 3.5 solution or a pH 10.5 solution reveal essentially no differences (Figure 7). The acid dispersed clays tended to give high temperature exotherms at somewhat lower temperatures than clays dispersed in either water or basic solution. From a mineralogical standpoint, no major differences between dispersion methods are evident for dominant components of the clay fraction. XRD analyses (not shown) also revealed no differences between clays obtained by dispersion in solutions of pH 3.5,

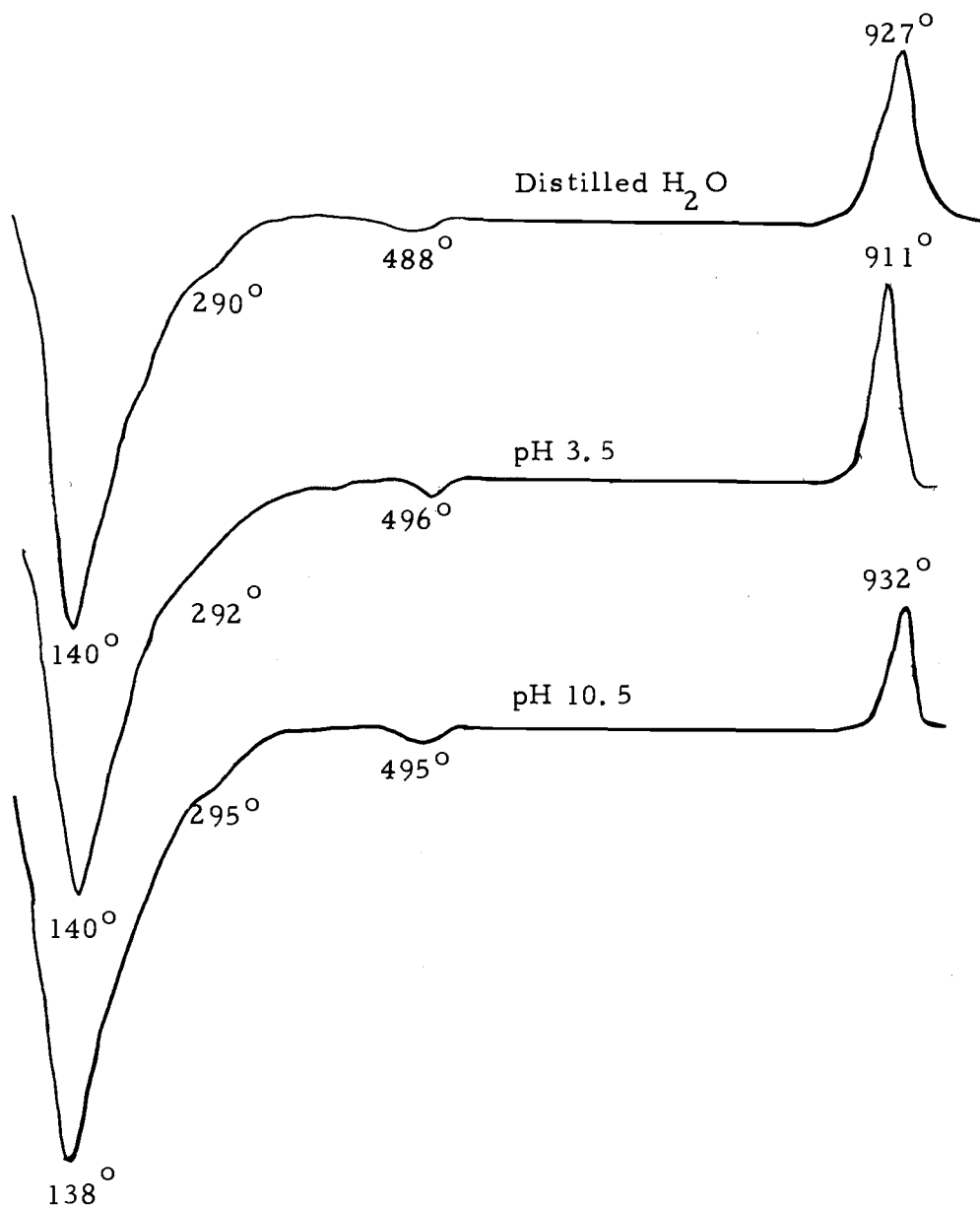


Figure 7. Differential thermal analyses curves of clays obtained by dispersion in three different media (no organic matter removed, temperatures in °C; baselines adjusted).

pH 10.5 and distilled water. However, information on total clays by XRD was restricted due to the preponderance of amorphous materials.

To briefly summarize effects of dispersion methods, dispersion at pH 3.5 maximizes clay yields compared to dispersion in other media. Differences in quantity of clays dispersed may more accurately represent ease of dispersion than potential dispersibility. The pH 10.5 solution apparently destroyed more amorphous material than the other methods. Few differences were evident between clays dispersed at pH 3.5 and those dispersed in distilled H<sub>2</sub>O. Mineralogical interpretations were the same, whether the clays were dispersed in distilled water or in either a pH 3.5 or pH 10.5 solution. Dispersion in a pH 3.5 solution may be a preferred procedure for Parkdale soil clays, since it gives maximum clay yields while minimizing effects on the clays compared to those from water dispersion.

A problem involving dispersion and flocculation was encountered. Parkdale soil samples (20 g) were first pretreated with NaOAc buffered H<sub>2</sub>O<sub>2</sub> for organic matter removal; then they were washed three times with the NaOAc buffer solution. Next, they were washed four times with distilled water to remove excess salts, and extraction procedures for clay removal were begun with dispersion in distilled water. At first, when distilled water was added to the

sample, flocculation immediately occurred. After the samples had been extracted 14 times with distilled water (200 ml/extraction), it was noticed that dispersion occurred when the water was poured into the container with the soil. However, after the soil material was thoroughly mixed with a mechanical stirrer, having only a smooth rubber tip on the stirring shaft, flocculation occurred. After the 14 extractions, analyses were made to evaluate causes for the flocculation.

Three to five washes are normally considered sufficient to remove excess salts from samples. However, the samples in this study had been washed with water, counting the extractions, a total of 18 times. It was, therefore, assumed that sufficient water washes had been used to remove all excess salts.

Electrical conductivity increased in all the suspensions after stirring (Table 21). pH values also tended to increase. Changes in concentration of Ca, Mg, and Mn in the solutions were minimal (Table 22). However,  $\text{Na}^+$  concentration showed a marked increase after stirring. The soils were initially  $\text{Na}^+$  saturated because of the NaOAc used in the organic matter removal treatment.

Rich (1962) has shown that soils high in amorphous and poorly crystalline sesquioxides can effectively trap salts which are then slowly released in washing solutions. It is suspected that the amorphous materials in Parkdale soils may react similarly to those

Table 21. Properties of solutions before and after stirring a Parkdale soil suspension.

Sample	Depth (cm)	Before		After	
		EC <sup>a</sup>	pH	EC <sup>a</sup>	pH
134-1	0-23	23	8.2	31	8.7
134-2	23-46	38		67	
134-3	61-91	30		39	
134-4	91-152	43	8.2	79	8.2
134-5	152-213	30		42	
134-6	213-274	37	8.9	62	9.0
134-7	274-335	28		42	
134-8	335-371	35	9.0	48	9.0

<sup>a</sup>EC = electrical conductivity (micromhos/cm).

Table 22. Cations in solution before and after stirring a Parkdale soil suspension.

Sample	Depth (cm)	Ca (ppm)		Mg (ppm)		Na (ppm)		Mn (ppm)	
		Before	After	Before	After	Before	After	Before	After
134-1	0-23	0.01	0.01	0.01	0.03	0.8	2.2	0.02	0.01
134-4	91-152	0.00	0.00	0.00	0.01	1.6	6.4	0.02	0.02
134-6	213-274	0.00	0.00	0.01	0.01	2.0	5.3	0.01	0.00
134-8	335-371	0.00	0.00	0.01	0.03	2.2	4.7	0.02	0.01

discussed by Rich. If this is true, salt trapping with slow cation release to washing solutions could cause flocculation.

Davies (1933), after experiencing similar problems of flocculation of samples, concluded that sesquioxide phases released by the stirring were responsible for the flocculation.

#### CEC Determinations of Parkdale Soils by Different Methods

This study included three different methods for measurement of CEC's. Methods I and II include washings to remove excess salts subsequent to cation saturation and prior to cation displacement for determination; Method III does not involve washings. Water was used as a washing solution in Method I, whereas alcohol was used in Method II. Both Methods I and II involved saturation with  $\text{Na}^+$  and displacement with  $\text{Mg}^{++}$ . Method III involved saturation with  $\text{NH}_4^+$  and displacement with  $\text{K}^+$ .

Values from Methods I and II are similar to one another and different from values from Method III (Table 23). Method I gave the lowest values of the three methods, presumably due to hydrolysis and consequent removal of saturating cations by the water washes. Effect of the alcohol in Method II was not as great. The values obtained by Methods I and II were low in comparison to values in the literature for amorphous materials (Wada and Ataka, 1958) and also

Table 23. Cation exchange capacities of Parkdale soils and clays by different methods.

Sample	Depth (cm)	Method I <sup>a</sup>	Method II <sup>b</sup>	Method III <sup>c</sup>
		meq/100 g		
<u>Total soil (&lt; 2 mm)</u>				
134-1	0-23	6.8	8.5	18.8
134-2	23-46	2.6	3.6	
134-3	61-91	3.2	3.9	11.7
134-4	91-152	3.2	3.8	
134-5	152-213	3.2	3.9	
134-6	213-274	3.0	4.1	
134-7	274-335	3.0	4.1	14.9
134-8	335-371	5.0	5.2	
<u>Total clay (&lt; 2 <math>\mu</math>)</u>				
134-1	0-23	4.1	9.2	48.8
134-2	23-46	1.3	7.2	
134-3	61-91	1.3	10.1	43.5
134-4	91-152	0.8	5.4	
134-5	152-213	2.0	11.5	52.4
134-6	213-274	3.2	8.2	
134-7	274-335	1.3	6.7	53.1
134-8	335-371	1.6	6.5	

<sup>a</sup> Method I -  $\text{Na}^+$  saturation; 3 water washes;  $\text{Na}^+$  displaced by  $\text{Mg}^{++}$  and determined.

<sup>b</sup> Method II - Like Method I, except 99% alcohol used instead of water for washes.

<sup>c</sup> Method III -  $\text{NH}_4^+$  saturation; no washes;  $\text{NH}_4^+$  displaced by  $\text{K}^+$  and determined.



in relation to values obtained by Method III. These large differences, caused by the higher estimates of CEC by Method III, were not expected and are somewhat puzzling. These differences were more evident for the clays than for whole soils. Method III gave values similar to those obtained for amorphous materials by Wada and Ataka (1958) and Birrell and Gradwell (1956). The decision to use  $\text{NH}_4^+$  and  $\text{K}^+$  may have been unfortunate due to problems of "fixation" by vermiculite (Barshad, 1954). It will be shown in Chapter IV that vermiculite occurs in these samples. Interactions between  $\text{NH}_4^+$  and  $\text{K}^+$  complicate the interpretations. However, since Method III involves displacement and determination of  $\text{NH}_4^+$  in the extracting solution, errors are minimized. Amorphous materials tend to coat the crystalline clays, restricting expression of their properties (Briner and Jackson, 1969). It is believed, therefore, that the differences are mostly due to removal of ions during washing of samples in Methods I and II.

### Summary and Conclusions on Effects of Laboratory Treatments

#### Organic Matter Removal Treatments

To summarize effects of organic matter destruction treatments on Parkdale soils and clays, it has been shown that: (a) pretreatment of soil samples with  $\text{H}_2\text{O}_2$  resulted in greatest clay yields

compared to NaOCl treated and untreated samples; (b)  $\text{H}_2\text{O}_2$  treated samples had clays with about 11% less amorphous material than the samples treated with NaOCl; (c) CEC's of  $\text{H}_2\text{O}_2$  pretreated clays were lower than CEC's from NaOCl pretreatments; (d) mineralogical interpretations of DTA and XRD data were the same for both  $\text{H}_2\text{O}_2$  and NaOCl pretreated clays.

There are many interpretations from these results.  $\text{H}_2\text{O}_2$  may initiate dispersion of a relatively large amount of clay while at the same time causing dissolution of some of the amorphous components. NaOCl undoubtedly has similar effects but not to the extent of  $\text{H}_2\text{O}_2$ . Indications are that either method of organic matter removal can be used successfully in studies involving DTA and XRD analyses. A 20-25% differential in CEC exists between  $\text{H}_2\text{O}_2$  and NaOCl treated samples. Depending on the type of analyses to be done and the purpose of the study, further investigation of the effects of these two chemicals may be necessary. NaOCl, as also shown by other studies (Anderson, 1963; Lavkulich and Wiens, 1970), has less severe effects on samples and should be preferred over  $\text{H}_2\text{O}_2$  for most studies. However, to eliminate concern over treatment effects, for routine analyses organic matter probably does not need to be removed, so that neither  $\text{H}_2\text{O}_2$  nor NaOCl need be used.

### Dispersion Treatments

Study of dispersion treatment methods showed that: (a) dispersion of Parkdale soil samples at pH 3.5 released 15 to 20% more clay than dispersion at pH 10.5 and 10 to 40% more clay than dispersion in distilled water; (b) amorphous material content of clays dispersed at pH 3.5 was 10 to 15% higher than those from pH 10.5 dispersion; (c) CEC's for clays dispersed at pH 3.5 were about 40% lower than those for clays dispersed at pH 10.5; (d) CEC's for clays dispersed in distilled water were essentially the same as those for clays dispersed at pH 3.5; (e) acid dispersed clays yielded equivalent mineralogical interpretations to those dispersed in basic media or in water.

### CEC Determination Treatments

Summary of effects of different methods on CEC determinations of Parkdale soils shows that: (a) CEC values from methods involving either water or alcohol washes are similar, and both of these methods gave values that were much lower than values from the method involving no washes; (b) CEC values estimated by the three methods show comparatively greater differences for clays than for total soils; (c) Method III gave results similar to those other researchers have obtained for similar materials.

## CHAPTER IV

### MINERALOGY, GENESIS, AND CLASSIFICATION OF PARKDALE SOILS

#### Introduction

The Parkdale soil series was established in 1912 (Strahorn and Watson, 1914). Since that time, the basic concepts have been continually revised to keep pace with expanding information about the soil and changes in criteria for classification. The purpose of the present study was to further expand the information on Parkdale soils. A better understanding of this series should aid in projecting information to other soils with high amorphous material content. Chapter III has shown several examples of unusual reactions and soil characteristics that can be attributed to the amorphous materials in the Parkdale soils. Skipper (1970) found that Parkdale "allophanic" colloids reacted quite differently in reactions involving chemical hydrolysis of herbicides than did montmorillonites and other soil clays. A study of the mineralogy and properties should provide clues to explain why Parkdale soils react as they do.

Simonson (1959), in his "Outline of a Generalized Theory of Soil Genesis," suggested that soil genesis basically consists of two steps: (a) accumulation of parent materials and (b) horizon

differentiation. In Chapter II the parent material was considered. Soils with appreciable quantities of amorphous materials are often formed from volcanic ash. However, studies have shown that soils high in amorphous materials and allophane may also form from volcanic materials other than ash (Tan, 1965; Briner and Jackson, 1970; Franklin, 1970; Wright as interpreted by Franklin, 1970). Such appears to be the case with Parkdale soils. It was concluded in Chapter II that Parkdale soils did not form dominantly from vitric volcanic ash, but formed in a mudflow deposit from Mt. Hood of rocks of various lithologies. Discussion of authigenic clay formation in Parkdale soils is made difficult because they formed in such a mixed system. In this chapter horizon differentiation will be considered.

Dudas (1973), in a study of soils formed in Mt. Mazama tephra, found different clay mineral suites in well drained sites versus poorly drained sites. Parkdale soils and the associated somewhat poorly drained Dee soils allow similar comparisons.

This study should also provide a basis for classification of soils in the Upper Hood River Valley. In this way, practical application of research efforts can be more quickly realized.

Several of the analyses which were made are inter-related and have a bearing on points to be considered. Therefore, the results will be presented first and the bulk of discussion will follow.

## Methods

### Soil Fractionation

Samples of < 2 mm air dry soils were dispersed in distilled water and the clays separated by centrifugation. Silts and sands were fractionated by dry sieving. Percentages were calculated from gravimetric data.

### Cation Exchange Capacity Determinations

Cation exchange capacities (CEC) were determined by the method of Wada and Ataka (1958) previously discussed (Chapter III). Measurements of CEC were made on < 2 mm soil fractions and on clays both before and after treatments for removal of amorphous material and free iron oxide (removal treatments discussed in Chapter III).

### Soil pH Measurement

Soil pH was determined with a Beckman Expandomatic pH meter on 1:2, soil to solution ratio using distilled water and N KCl.

### Organic Carbon Analyses

A Leco carbon analyzer (model WR12) was used to determine

organic carbon contents of duplicate, 80 mg subsamples of < 2 mm soil fractions ground to pass a 60 mesh screen.

#### Extractable Cations, Phosphorus, and Base Saturation

Extractable cations and phosphorus were determined on the < 2 mm soil fraction by the Soil Testing Laboratory at Oregon State University. Extractable cations were determined after extraction with ammonium acetate (Peech et al., 1947). Phosphorus was determined in dilute acid-fluoride solution (Bray and Kurtz, 1945). Base saturation was determined by comparison of sum of  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$ ,  $\text{Na}^+$ , and  $\text{K}^+$  contents to CEC values.

#### Differential Thermal Analyses

Differential thermal analyses (DTA) were made on  $\text{Mg}^{++}$  saturated clays that had been equilibrated over saturated  $\text{Mg}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$ . Details are given in Chapter III.

#### Infra-red Analyses

A Nujol mull technique was used for infra-red analyses. The mull was sandwiched between Irtran II (ZnS) disks. A Baird Atomic Infra-red Recording Spectrophotometer, Model KM-1, double beam instrument was used for the analyses.

### X-ray Diffraction Analyses

X-ray diffraction (XRD) procedures used in this study involved the use of oriented specimens and analyses with Cu K  $\alpha$  radiation. More detailed description is given in Chapter III.

### Chemical Analyses of Clays

Chemical analyses of clays by X-ray fluorescence were done by essentially the same procedure as that given by Baird (1961) as modified by Borchardt and Theisen (1971). The only difference in their procedure and the one used here was in the pressure used in making the pellets (Chapter II). The pellets used in these analyses were made using Mg<sup>++</sup> saturated clays.

### Test for Allophane

A test for allophane was made using the procedure of Fields and Perrott (1966). This method involves addition of N NaF to whole soil samples and noting pH changes with time.

### Petrographic Analyses

Thin sections were prepared by the method described in Chapter II. Approximately 300-400 point counts (Krumbein and Pettijohn, 1938) were made for each slide and the results reported as



percentage of individual species in the total sample.

### Amorphous Material Determination

Amorphous materials were determined by weight loss after dissolution with KOH and free iron oxide removal (Chapter III).

## Results

### Properties of Whole Soils

Particle Size Distribution. These analyses have already been discussed to some extent in Chapter II, but are repeated here to allow development of concepts relevant to soil genesis. Measurements by pipette procedures showed that sand varies from 32 to 43%, silt varies from 48 to 59%, and clay varies from 7 to 12% within a Parkdale soil (Table 24). Fine and very fine sands dominate the sand subfractions and fine silts exceed coarse silts. The sum of fine sands, very fine sands, and total silts composes 75 to 80% of the organic matter free, < 2 mm Parkdale soil. Data for two other profiles indicate similar particle size distributions at other locations (Appendix V-c).

The Dee soil is somewhat less sandy and more clayey (Table 24). Within the Dee soil, sand varies from 22 to 34%, silt varies from 42 to 57%, and clay varies from 10 to 32%. As with the

Table 24. Particle size distribution of a Parkdale and a Dee soil (percent of  $\leq 2$  mm).

Sample	Horizon	Depth (cm)	Sand (mm)					Silt (mm)			Clay (mm)	Textural class	
			Very coarse  2-1	Coarse  1- 0.5	Medium  0.5- 0.25	Fine  0.25- 0.1	Very fine  0.1- 0.05	Total sand  2- 0.05	Coarse  0.05- 0.02	Fine  0.02- 0.002	Total silt  0.05- 0.002		Total clay  < 0.002
<u>Parkdale</u>													
134-1	Ap	0-23	1.7	3.4	7.1	12.5	11.7	36.4	21.6	31.7	53.3	10.3	sil
134-2	B2	23-46	1.8	3.8	7.3	12.4	11.3	36.7	22.2	33.9	56.1	7.2	sil
134-3	C2	61-91	0.6	3.3	6.7	11.1	10.2	31.9	22.1	36.6	58.7	9.4	sil
134-4	C3	91-152	0.8	4.3	9.0	9.8	12.6	36.3	17.5	35.1	52.6	11.0	sil
134-5	C4	152-213	0.6	4.1	8.5	13.5	10.6	37.4	15.2	35.9	51.2	11.5	sil
134-6	C5	213-274	1.0	3.6	6.2	10.9	11.5	33.3	16.8	38.0	54.8	11.9	sil
134-7	C6	274-335	1.2	3.7	5.4	12.8	12.3	35.5	14.7	38.5	53.2	11.3	sil
134-8	C7	335-371	4.0	5.1	6.7	13.7	13.2	42.7	13.1	34.4	47.5	9.7	l
<u>Dee</u>													
178-1	Ap	0-20	1.2	3.3	5.9	10.2	9.7	30.4	21.5	35.3	56.7	12.9	sil
178-2	B1	20-48	1.1	3.5	5.7	10.3	10.0	30.5	21.7	33.7	55.4	14.1	sil
178-3	B21	48-86	0.4	2.7	5.5	8.6	8.3	25.5	21.7	35.1	56.8	17.7	sil
178-4	B22	86-114	0.9	4.6	8.9	10.8	9.2	34.3	15.9	31.8	47.7	18.0	l
178-5	C1	114-183	1.3	4.1	8.3	12.3	8.3	34.2	13.6	28.8	42.4	23.4	l
178-6	C2	191-203	1.8	2.4	3.1	7.0	7.7	22.0	14.6	31.3	45.9	32.1	cl

Parkdale soil, fine and very fine sands dominate the sand subfractions and fine silts are more prevalent than coarse silts.

Soil Organic Carbon. Organic carbon content of Parkdale soils (Table 25) is about 3% in the surface but decreases with depth to 152 cm. Below this level, organic carbon averages about 0.35%.

Parkdale soil is relatively high in organic carbon compared to other soils in Hood River County (U. S. Department of Agriculture, Soil Conservation Service, Soil Survey Laboratory Staff, 1965).

The Dee soil has less organic carbon than the Parkdale soil, especially in upper horizons (Table 25). Decreasing organic carbon with depth is evident. The low content in upper horizons is somewhat anomalous, since the Dee soil is more poorly drained than the Parkdale soil. In usual situations, organic carbon tends to accumulate more in poorly drained soils than in well drained soils, since the microorganisms that decompose organic compounds are primarily aerobic.

Soil pH. Both the Parkdale and Dee soils have pH values between 6.2 and 6.5 when measured in  $H_2O$  suspensions (Table 25). With KCl solution, pH values of Parkdale and Dee soils decrease from those measured in  $H_2O$  by about 1 and 1.8 units, respectively (Table 25). The pH decrease for Dee soils was somewhat more than expected.

Total Soil Amorphous Content. The Parkdale soil has

Table 25. Selected properties of a Parkdale and a Dee soil.

Sample	Horizon	Depth (cm)	Organic carbon (%)	pH <sup>a</sup>		Amorphous <sup>b</sup> content (%)
				water	<u>N</u> KCl	
<u>Parkdale</u>						
134-1	Ap	0-23	2.90	6.4	5.3	32.1
134-2	B2	23-46	0.97	6.2	5.2	
134-3	C2	61-91	0.55	6.3	5.3	42.7
134-4	C3	91-152	0.36	6.5	5.5	
134-5	C4	152-213	0.34	6.5	5.5	48.0
134-6	C5	213-274	0.35	6.4	5.4	
134-7	C6	274-335	0.40	6.2	5.2	49.4
134-8	C7	335-371	0.36	6.3	5.3	
<u>Dee</u>						
178-1	Ap	0-20	0.91	6.5	5.3	
178-2	B1	20-48	0.34	6.5	4.8	
178-3	B21	48-86	0.33	6.3	4.4	
178-4	B22	86-114	0.25	6.3	4.4	
178-5	C1	114-183	0.28	6.2	4.4	
178-6	C2	191-203	0.43	6.2	4.5	

<sup>a</sup> pH measurements in a 1:2, soil-solution ratio. <sup>b</sup> Based on weight loss after amorphous material and free iron oxide removal.

increasing amounts of amorphous material with depth (Table 25).

The largest increase is between the Ap and C2 horizon. There is little difference between amounts in the C4 and C6 horizons.

Total Soil CEC. CEC's of whole soil are highest for the A horizon in the Parkdale soil (Table 26). CEC's for the Dee soil are relatively constant throughout the solum (Table 26) and are from 12 to 30% lower than those from Parkdale soils which may be attributed to the lower organic matter content in the Dee soil. Greatest differences between the two soils are evident for surface horizons.

Extractable Cations and Phosphorus. Compared to the Dee soil, the Parkdale soil has lower contents of extractable cations throughout (Table 26). Ca and K contents are not too different between the soils, but Mg and Na contents are considerably higher in the Dee soil. Dee soils have two to five times more Mg than the Parkdale soil. The Parkdale soil has an average Ca/Mg ratio of about 5, whereas the Dee soil has an average of about 2. In the Dee soil, Na content shows a marked increase below 86 cm and Ca, Mg, and K increase below 191 cm.

Base Saturation. In both the Parkdale and the Dee soil, base saturation was highest in the surface and decreased with depth (Table 26); however, the level of saturation was considerably higher in the Dee soil.

Total Soil Chemical Composition. Chemical analyses of the

Table 26. Selected chemical properties of a Parkdale and a Dee soil.

Sample	Horizon	Depth (cm)	CEC <sup>a</sup> (meq/100 g)	Extractable cations (meq/100 g)				P (ppm)	Base saturation (%)
				Ca	Mg	K	Na		
<u>Parkdale</u>									
134-1	Ap	0-23	18.8	6.2	1.3	0.4	0.1	4	42.6
134-2	B2	23-46		2.6	0.4	0.3	0.1	2	
134-3	C2	61-91	11.7	3.1	0.6	0.2	0.1	2	34.2
134-4	C3	91-152		3.6	0.5	0.2	0.1	2	
134-5	C4	152-213		3.0	0.9	0.2	0.2	2	
134-6	C5	213-274		2.8	0.9	0.2	0.1	1	
134-7	C6	274-335	14.9	2.4	0.8	0.3	0.2	1	24.8
134-8	C7	335-371		2.8	1.1	0.5	0.2	2	
<u>Dee</u>									
178-1	Ap	0-20	12.3	7.1	2.3	0.5	0.1	28	81.3
178-2	B1	20-48		4.2	2.0	0.5	0.2	14	
178-3	B21	48-86	10.3	4.3	2.5	0.3	0.2	7	70.9
178-4	B22	86-114		3.8	2.1	0.3	0.9	7	
178-5	C1	114-183	12.3	3.8	2.3	0.3	1.0	7	60.2
178-6	C2	191-203		6.4	3.3	0.6	1.1	5	

<sup>a</sup> Measured by Method III as described in Chapter III.

Parkdale soil (Table 27) indicates that  $\text{SiO}_2$ ,  $\text{CaO}$ , and  $\text{K}_2\text{O}$  decrease with depth, while  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{TiO}_2$  increase with depth.  $\text{ZrO}_2$  remains constant throughout the solum. Molar  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratios range from 2.7 in the surface to 2.0 at depth.

Analyses of the < 2 mm fraction of Dee soil (Table 27) indicate the same elemental variations as those for the Parkdale soil. The Dee soil is higher in Si and lower in Al than the Parkdale soil. Molar  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratios tend to decrease with depth from 6.1 in the surface to 4.7 at depth for the Dee soil.

Sand Mineralogy. Feldspars, fine-grained volcanic rock fragments, and weathering products dominate the sand fraction of Parkdale soils (Table 28). These three components comprise from 77 to 89% of the total sands. Pyroxene, hornblende, magnetite, biotite, quartz, cummingtonite, pumice, and glass were also detected.

The feldspars present were apparently of varying composition. The more common plagioclase feldspars have an  $A_b$  content of approximately 46 to 48, indicating that they are andesine. Almost all were zoned. Some appeared quite fresh and untarnished, while others were covered with weathering products. The individual grains ranged in size from < 0.002 mm to > 1 mm. Overall, feldspar content decreased with depth.

Predominantly, the fine-grained volcanic rock fragments are

Table 27. Chemical composition of a Parkdale and a Dee soil (percent).

Sample	Horizon	Depth (cm)	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	ZrO <sub>2</sub>	TiO <sub>2</sub>	CaO	K <sub>2</sub> O
<u>Parkdale</u>									
134-1	Ap	0-23	53.22	19.33	7.49	0.028	1.00	3.76	1.22
134-2	B2	23-46	53.73	20.90	8.19	0.030	1.08	3.20	1.20
134-3	C2	61-91	53.22	21.41	8.24	0.031	1.12	2.98	1.17
134-4	C3	91-152	50.59	23.06	8.51	0.030	1.10	3.16	0.92
134-5	C4	152-213	49.00	24.12	9.02	0.030	1.17	2.78	0.77
134-6	C5	213-274	49.00	24.25	9.34	0.026	1.20	2.46	0.82
134-7	C6	274-335	47.94	24.55	9.21	0.028	1.22	2.42	0.72
134-8	C7	335-371	48.47	24.40	9.38	0.031	1.27	2.52	0.76
<u>Dee</u>									
178-1	Ap	0-20	62.69	17.56	6.48	0.031	0.98	3.58	1.32
178-2	B1	20-48	62.69	17.41	7.22	0.028	1.03	3.37	1.32
178-3	B21	48-86	62.69	17.41	7.45	0.030	1.08	2.95	1.20
178-4	B22	86-114	61.11	18.16	7.72	0.028	1.03	3.26	0.86
178-5	C1	114-183	57.69	19.35	9.30	0.030	1.10	2.84	0.77
178-6	C2	191-203	56.36	20.39	9.38	0.026	1.13	2.14	0.83



Table 28. Components of sand fraction from a Parkdale soil (percent).

Sample <sup>a</sup>	Horizon	Depth (cm)	Pyroxene	Horn- blende	Feld- spars	Mag- netite	Fine-grained volcanics	Pumice and glass	Weathering <sup>b</sup> products	Other
138-1	Ap	0-25	4.0	4.2	45.5	1.3	36.2	3.2	4.8	0.9
138-2	B2	25-46	6.4	3.2	46.9	3.8	22.0	7.0	8.3	2.3
138-4	C3	96-152	4.0	4.0	40.2	1.3	17.5	1.3	30.2	1.3
138-5	C4	152-213	5.6	4.4	34.2	0.9	13.7	1.5	36.3	3.5
138-6	C5	213-274	4.4	1.7	30.3	1.7	21.6	1.4	38.0	0.9
138-7	C6	274-330	7.8	1.3	26.2	2.9	17.7	0.8	42.3	1.1

<sup>a</sup> Sample site location given in Table 2 and Appendix I.

<sup>b</sup> Weathering products not including clays and silts removed prior to analyses nor materials removed as "shot".

from basalts, dacites, and andesites. Many of the rock fragments were highly weathered, with matrices exhibiting iron staining and devitrification. In many cases, there was difficulty distinguishing between rock material and weathering products. Except for the Ap and C4 horizons, the overall content of the fine-grained rock fragments was very similar for all horizons.

Weathering products, as used in this phase of the study, are materials which are inorganic and are not individual mineral or rock grains. It does not include the clays and silts removed prior to these analyses nor those materials removed with "shot". These weathering products are apparently silts, clays, and sands cemented together by iron and aluminum compounds. These products mostly occur as individual aggregates and as rims or rinds around mineral and rock grains. However, some weathering products occurred within mineral and rock grains. The matrix of these weathering products was mostly fine grained, iron stained, and apparently cemented to varying degrees. The Ap and B2 horizons contained far less weathering products than the lower parts of the soil. These differences may be in part due to concentration of weathering products in upper horizons into "shot" or concretionary forms which were largely removed prior to these analyses. Surficial contamination by unweathered materials also tends to dilute weathering products in upper horizons.

The predominant pyroxene was hypersthene, although there was some augite. Some pyroxene grains were fresh and others weathered. The total content was relatively constant through the profile.

Amphiboles of various compositions were present, including lamprobolite, hornblende, and cummingtonite. Uralitic hornblende was also present. The amphiboles, like other minerals, showed various stages of weathering. However, the overall content was relatively uniform throughout the profile. The presence of cummingtonite, if it is not contained in the country rock, may suggest that Parkdale soils have developed, at least in part, from tephra from Mt. St. Helens since several of those tephra deposits contain this relatively rare mineral.

Pumice and glass were greater in upper horizons than in lower horizons. As previously mentioned, this suggests contamination of upper horizons by volcanic ash. The glass in the lower horizons was less vesicular. A few fragments of the glass were reddish-brown and apparently basaltic. Some of the glass occurred as coatings on other mineral grains. The 1.0-0.5 mm fraction of A1 horizons had more pumiceous glass than any other subfraction of that horizon or any other horizon. Some of the tephra studied looked similar to that from Mt. Mazama in such features as color, crystal content, and shapes of vesicles. However, some of the pumice resembled that from Mt. St. Helens, suggesting that tephra from

both sources may have contributed to Parkdale soils.

### Characteristics of Clays

Clay Fraction CEC's. CEC measurements were made for both total clays and crystalline clays (Table 29). Total clay CEC's for Dee soil clays were in all cases somewhat lower than those for Parkdale soil clays from corresponding horizons or depths.

The method used to measure crystalline clay CEC's certainly had limitations (Chapter III, page 91).  $\text{NH}_4^+$  and  $\text{K}^+$  were the cations used. X-ray diffraction studies showed vermiculite as a component of those clays. The potential for "fixation" (Barshad, 1954) casts serious doubts on these CEC results. The results tended to be erratic and difficult to duplicate for the Parkdale soil crystalline clays. Crystalline clays from the Dee soil tended to give results that were more easily reproduced.

Amorphous Materials in Clay Fractions. Measurements on Parkdale soil clays (total clays) showed very high content of amorphous materials (Table 29). Dee soil clays had lower contents of amorphous materials.

Elemental Analyses of Clays. Analyses of Parkdale soil clays reveal that differences occur mostly in the upper three horizons;  $\text{SiO}_2$ ,  $\text{CaO}$ , and  $\text{K}_2\text{O}$  contents decrease while  $\text{Al}_2\text{O}_3$  content increases with depth (Table 30).  $\text{Fe}_2\text{O}_3$  content varies among horizons but not

Table 29. Selected properties of Parkdale and Dee soil clays.

Sample	Horizon	Depth (cm)	Amorphous <sup>a</sup> content (%)	Total <sup>b</sup> clay CEC	Crystalline <sup>b, c</sup> clay CEC
				meq/100 g	
<u>Parkdale</u>					
134-1	Ap	0-23	72.7	48.8	89.8
134-2	B2	23-46	78.0		
134-3	C2	61-91	81.0	43.5	44.4
134-4	C3	91-152	86.3		
134-5	C4	152-213	89.8	52.4	
134-6	C5	213-274	88.6		
134-7	C6	274-335	89.9	53.1	69.8
134-8	C7	335-371	90.8		
<u>Dee</u>					
178-1	Ap	0-20		35.9	
178-3	B21	48-86	59.8	31.1	46.2
178-5	C1	114-183	71.3	30.6	46.4
178-6	C2	191-203		47.2	

<sup>a</sup>Based on weight loss after alkali dissolution and free iron oxide removal.

<sup>b</sup>CEC measured by Method III as described in Chapter III.

<sup>c</sup>Crystalline clay obtained after removal of amorphous materials and free iron oxides.

Table 30. Chemical composition of Parkdale and Dee soil clays (percent).

Sample	Horizon	Depth (cm)	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	CaO	K <sub>2</sub> O	SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub>
<u>Parkdale</u>									
134-1	Ap	0-23	40.7	22.5	14.9	1.3	0.9	0.9	3.1
134-2	B2	23-46	38.5	24.0	15.7	1.4	0.4	0.8	2.7
134-3	C2	61-91	38.1	24.6	12.9	1.3	0.3	0.7	2.6
134-4	C3	91-152	37.5	26.3	14.4	1.2	0.2	0.6	2.4
134-5	C4	152-213	37.6	28.1	14.0	1.2	0.1	0.5	2.3
134-6	C5	213-274	37.1	26.3	12.9	1.1	0.1	0.4	2.4
134-7	C6	274-335	37.7	27.7	12.9	1.2	0.2	0.3	2.3
134-8	C7	335-371	37.7	27.9	12.2	1.3	0.1	0.2	2.3
<u>Dee</u>									
178-3	B21	48-86	52.7	19.7	14.8	1.4	0.4	1.2	4.5
178-5	C1	114-183	49.0	21.9	15.9	1.3	0.2	0.6	3.8

consistently with depth.  $\text{TiO}_2$  content remains relatively constant throughout the profile. The molar  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio decreases with depth.

Dee soil clays, in comparison to Parkdale clays, showed similar trends for elemental contents with depth. However, Dee soils have higher  $\text{SiO}_2$  contents than Parkdale soil clays. The molar  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratios for Dee soil clays decrease with depth.

Test for Allophane. A rapid test for allophane was made by the method of Fields and Perrott (1966). For Parkdale soils the initial pH measurements (after two minutes) gave values ranging from 10.1 to 10.5 (Table 31). After two hours, pH values ranged from 11.0 to 11.3. Fields and Perrott (1966), in introducing the test for allophane, report that the Papakauri soil, which is 62% clay of which 48% is allophane, gave pH readings of 10.2 and 11.2 after times of two minutes and one hour, respectively. The Patua soil, which has 54% clay of which 30% is allophane, gave pH readings of 10.4 and 11.4 respectively, after similar times. The high pH reading after two minutes as well as the increased pH after an hour are taken as evidence for allophane. The Parkdale soil gave comparable results to those for Papakauri and Patua soils while having only one-fourth to one-fifth as much total clay. This indicates that the clay fraction of Parkdale soils has a very high percentage of allophane.

The Dee soil showed overall lower initial pH values and less

Table 31. Rapid test for allophane for a Parkdale and a Dee soil.

Sample	Horizon	Depth (cm)	pH after 2 min.	pH after 1 hr.
<u>Parkdale</u>				
134-1	Ap	0-23	10.1	11.1
134-2	B2	23-46	10.5	11.3
134-3	C2	61-91	10.4	11.3
134-4	C3	91-152	10.5	11.3
134-5	C4	152-213	10.4	11.2
134-6	C5	213-274	10.4	11.2
134-7	C6	274-335	10.2	11.2
134-8	C7	335-371	10.1	11.0
<u>Dee</u>				
178-1	Ap	0-20	9.2	9.4
178-2	B1	20-48	8.7	9.1
178-3	B21	48-86	8.7	9.1
178-4	B22	86-114	8.6	9.0
178-5	C1	114-183	8.7	9.2
178-6	C2	191-203	8.9	9.5



increase after two hours compared to Parkdale soils (Table 31).

Highest pH readings were obtained from samples of the Ap horizon.

These results indicate very little allophane in the Dee soil.

X-ray Diffraction Analyses. X-ray diffraction analyses of Parkdale soil total clays show that due to the overwhelming amounts of amorphous material, the crystalline clay minerals are almost completely obscured (Figures 8 and 9). This result could be expected after viewing data from the amorphous material determination (Table 29) and the tests for allophane (Table 31).

Because of the lack of sufficient intensity for peaks, evaluation of the patterns from total clays is difficult. However, one observation is that Parkdale soil total clays are very high in amorphous materials as indicated by the high background noise. Comparison of total clay patterns in Figures 8 and 9 suggests that there is more crystalline clay in upper horizons than in lower horizons of the Parkdale soil. This trend supports previous estimates of amorphous clay (Table 29).

Crystalline clays from the Parkdale soil, obtained after treatments for removal of amorphous material and free iron oxide, are dominantly chloritic intergrades with smaller amounts of smectites and mica (Figures 8, 9, and 10). Feldspars, cristobalite, and quartz also occur in the crystalline clay fraction but give peaks at higher degrees  $2\theta$  than those shown. Kaolinite and/or halloysite

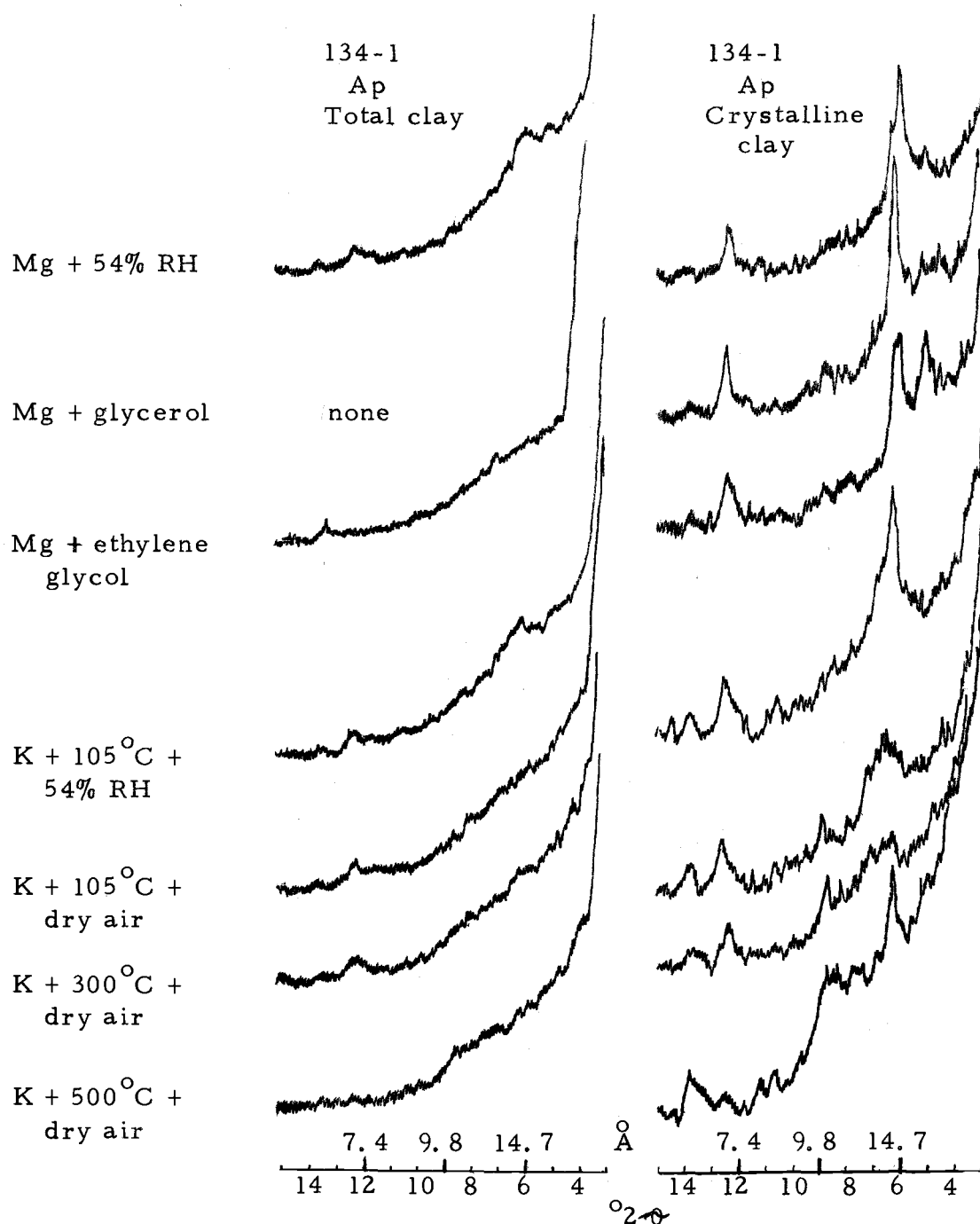


Figure 8. X-ray diffraction patterns for < 2 micron clay samples from a Parkdale soil Ap horizon.

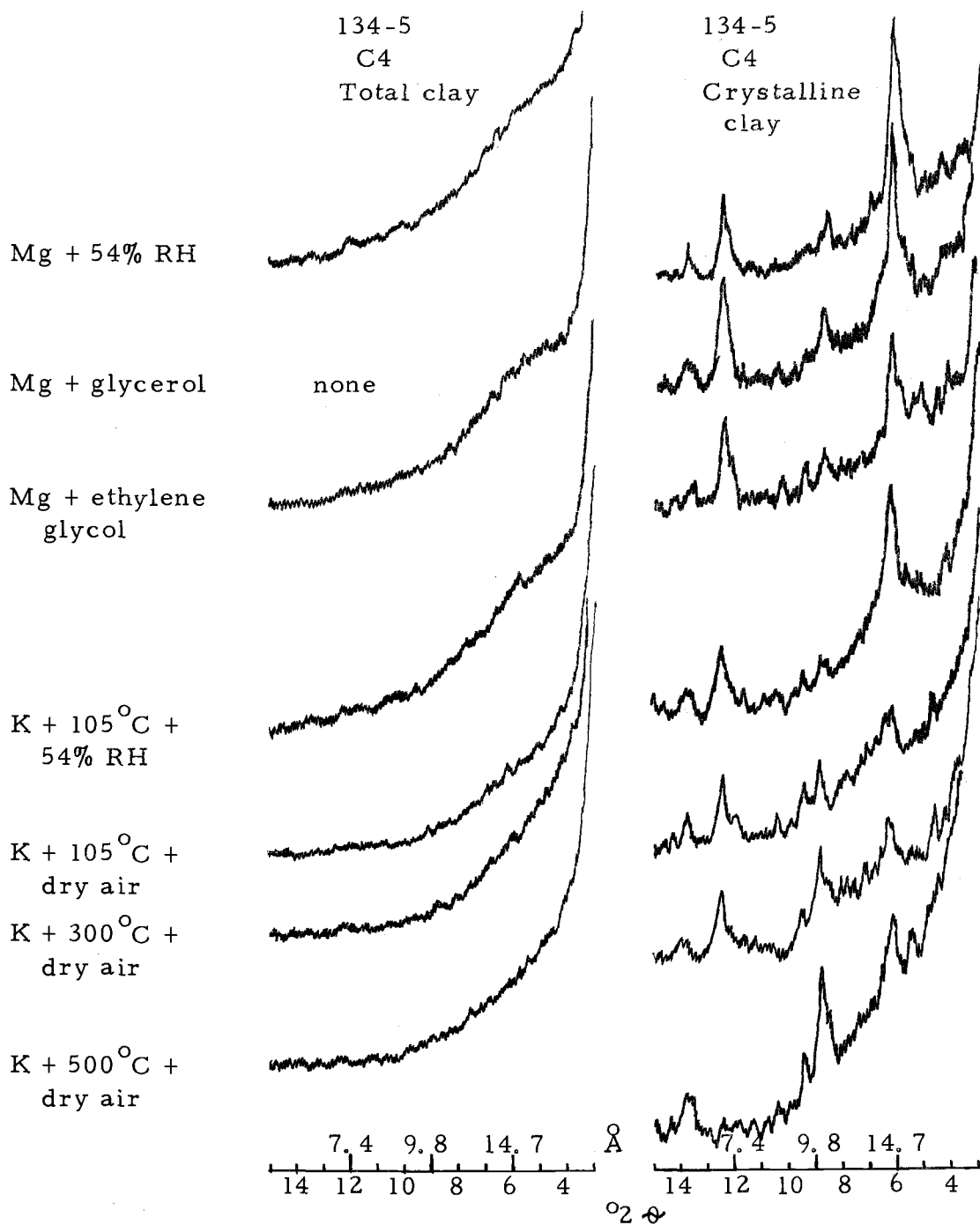


Figure 9. X-ray diffraction patterns for < 2 micron clay samples from a Parkdale soil C4 horizon.

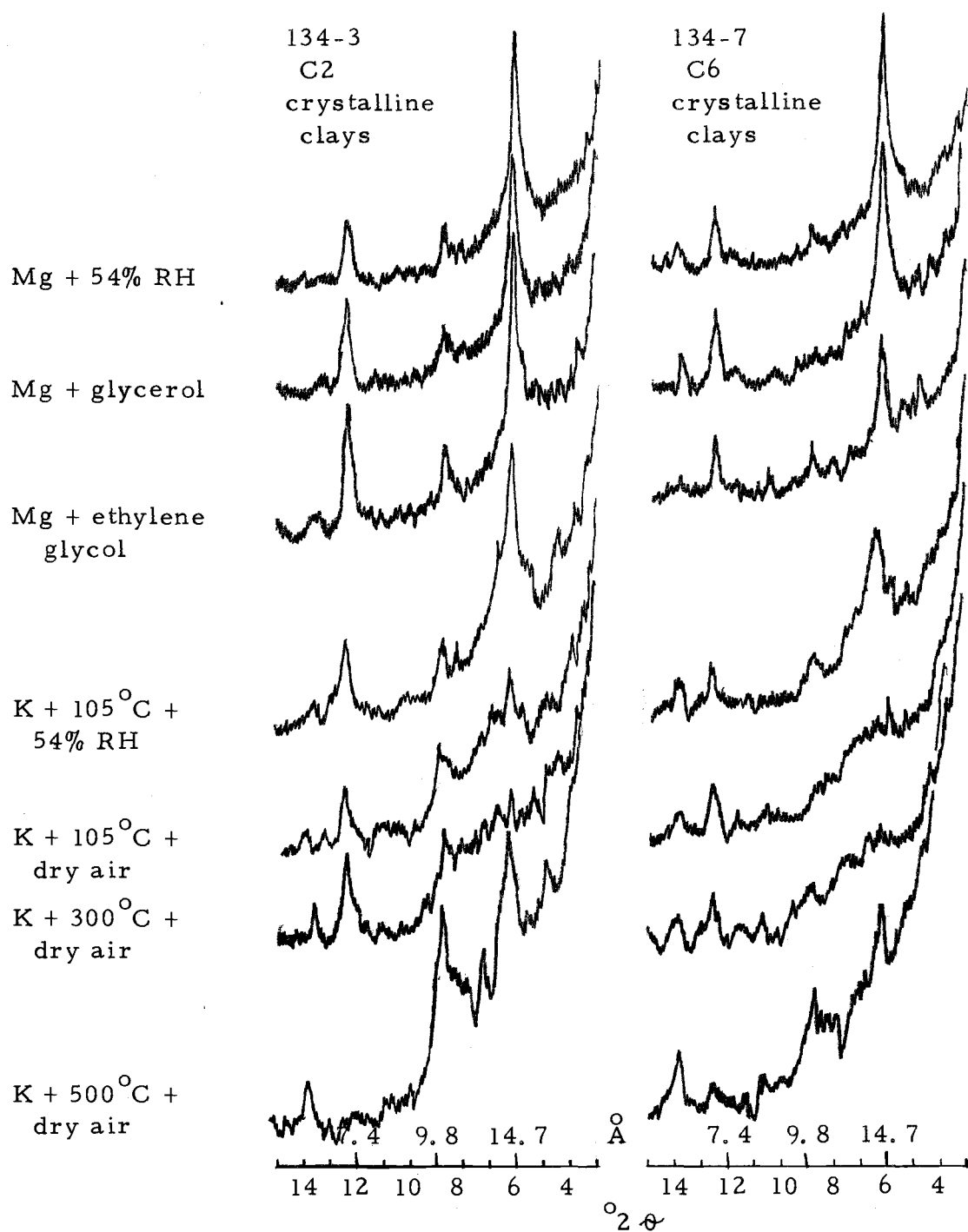


Figure 10. X-ray diffraction patterns for < 2 micron clay samples from Parkdale soil C2 and C6 horizons.

may be present in small amounts but their occurrence is difficult to establish in the presence of the chloritic intergrades. Few differences in mineralogy were noted when surface horizons were compared to subsoil horizons. There does seem to be a larger smectite component in the A horizon than in lower horizons. This smectite component expanded much more completely with ethylene glycol than with glycerol. This could be interpreted as indicating beidellite, but could also be due to hydroxy-interlayered montmorillonite (Harris and Harward, 1972).

Dee soil clays were also studied. X-ray diffractograms of both total clays and crystalline clays (Figures 11 and 12) reveal that the crystalline clays were dominantly halloysite (hydrated and/or non-hydrated), vermiculite, and mica. Cristobalite, quartz, and feldspar are also found in these clays but are not evident in the figures. There were some indications of smectites in the  $Mg^{++}$  ethylene glycol pattern. The broad peak, from about  $10.4^{\circ} 2\theta$  to  $12.6^{\circ} 2\theta$  (Figures 11 and 12), is indicative of halloysite. Kaolinite may also be present but would be difficult to recognize in the presence of the halloysite. Most of the halloysite is in the non-hydrated form, but there are some hydrated units that cause the peak to be broad and skewed toward larger lattice spacings. Although the diffractograms indicate that vermiculite is the dominant mineral responsible for the  $14 \text{ \AA}$  peak from the  $Mg^{++}$  saturated clay slides, vermiculite-chlorite

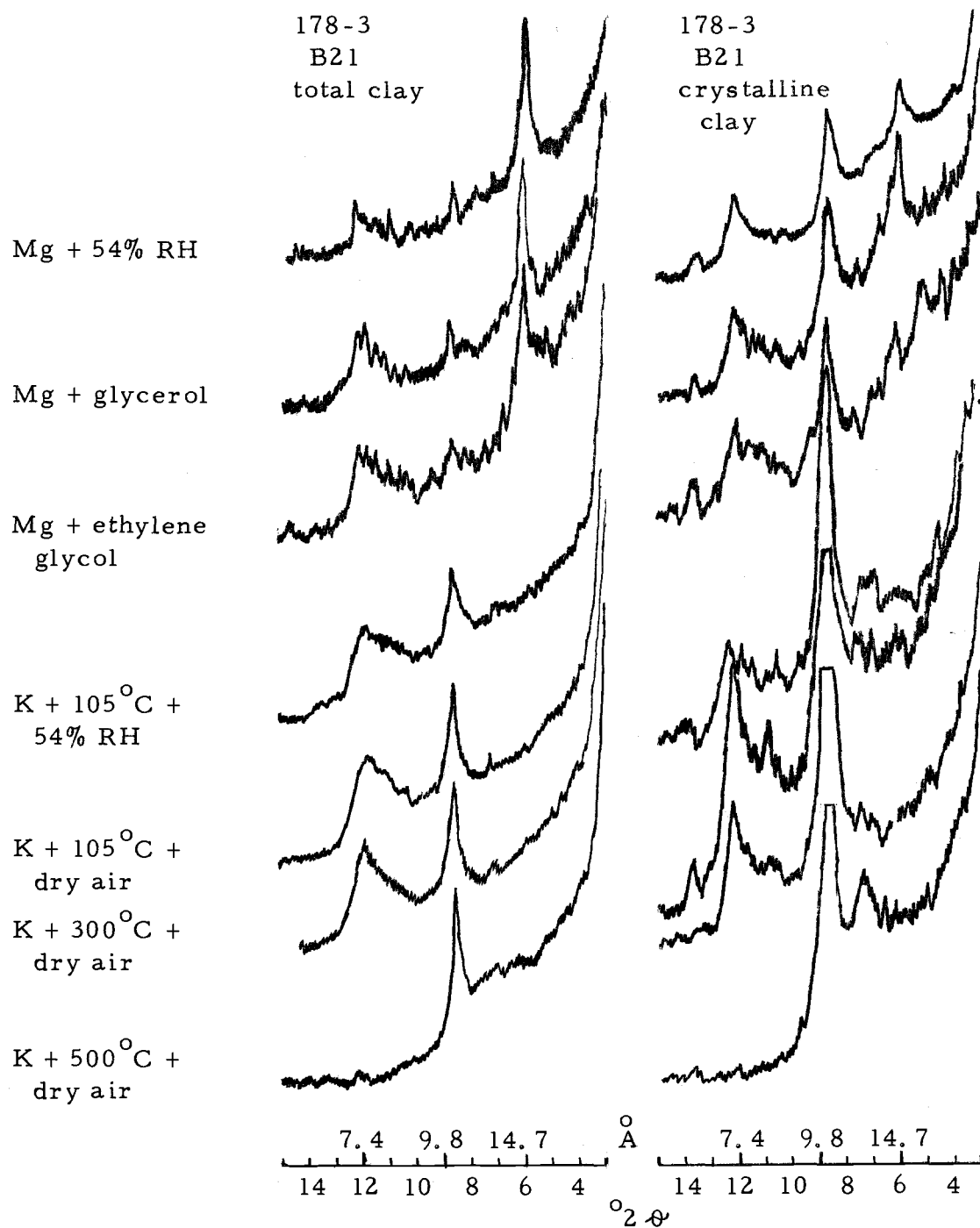


Figure 11. X-ray diffraction patterns for < 2 micron clay samples from a Dee soil B21 horizon.

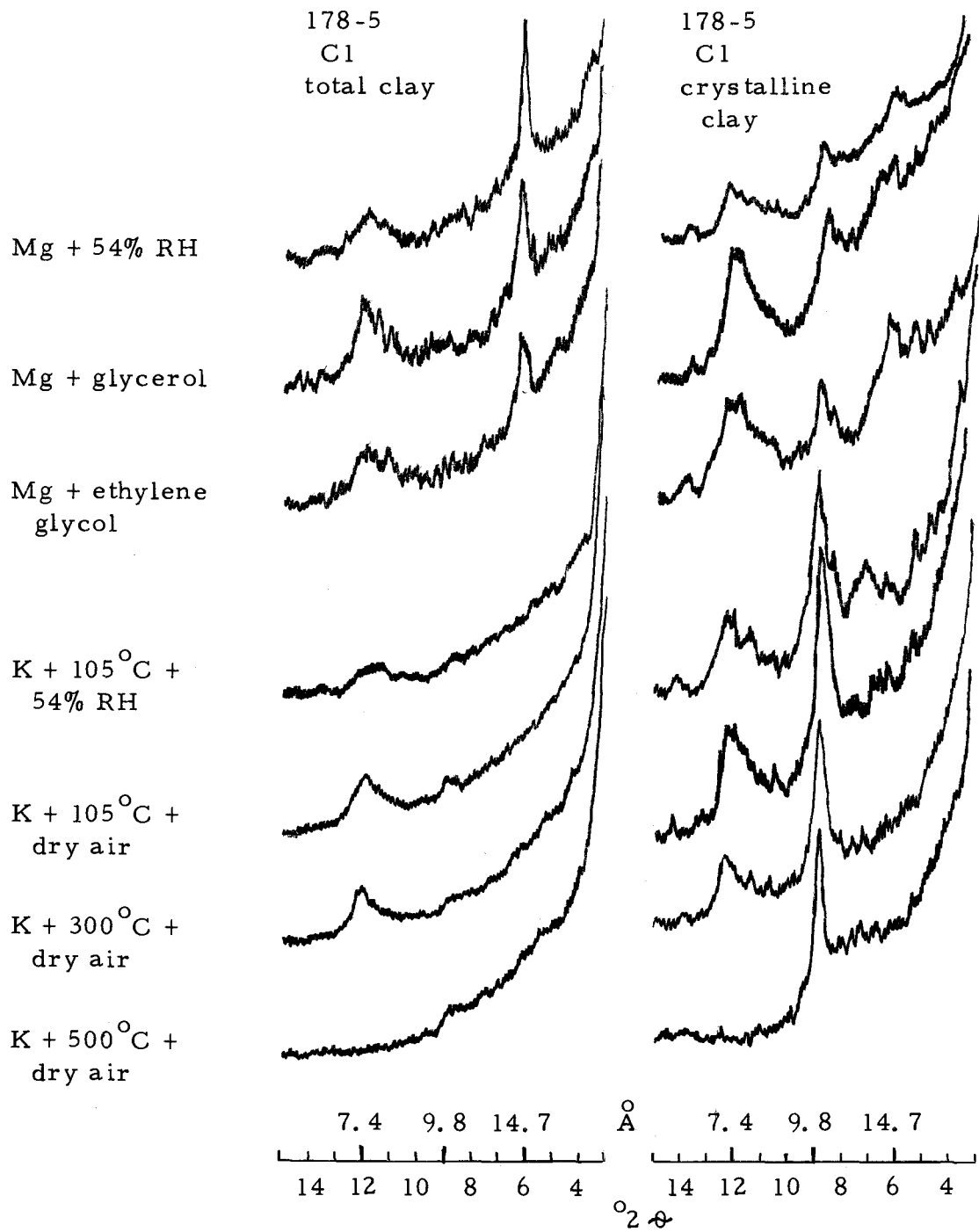


Figure 12. X-ray diffraction patterns for < 2 micron clay samples from a Dee soil C1 horizon.

intergrades are also present as indicated by the incomplete collapse evident in the  $K^+$  saturated slides.

In contrast to Parkdale clays, content of amorphous materials in Dee soils was not sufficient to completely mask crystalline clay peaks in total clay patterns. Comparison of X-ray patterns for Dee soil total clays, from the B21 horizon (Figure 11) and C1 horizon (Figure 12), indicates that amorphous clay is higher in the lower horizons. This is consistent with previous data from amorphous material determinations (Table 29).

Differential Thermal Analyses. DTA of Parkdale soil clays (Figure 13) dominantly gave a low temperature endotherm near  $130^{\circ}\text{C}$  and a high temperature exotherm near  $900^{\circ}\text{C}$ . These patterns closely resemble patterns shown by Miyauchi and Aomine (1966), Yoshinaga (1966), and Yoshinaga and Aomine (1962a) for allophane from Japanese soils. They are also like some of the patterns that Mitchell and Farmer (1962) and Birrell and Fields (1952) presented as indicative of allophane. Dudas (1973) reported similar results for a sample from Oregon. He also interpreted the pattern to be due dominantly to allophane. Parkdale soil clays were interpreted to be mostly allophane. The endothermic peak at about  $490^{\circ}\text{C}$  caused questions to arise, as few soil materials give peaks in that region. Halloysite typically gives a dehydroxylation endotherm at about  $550^{\circ}\text{C}$  (Mackenzie, 1966). Imogolite has an endotherm at about



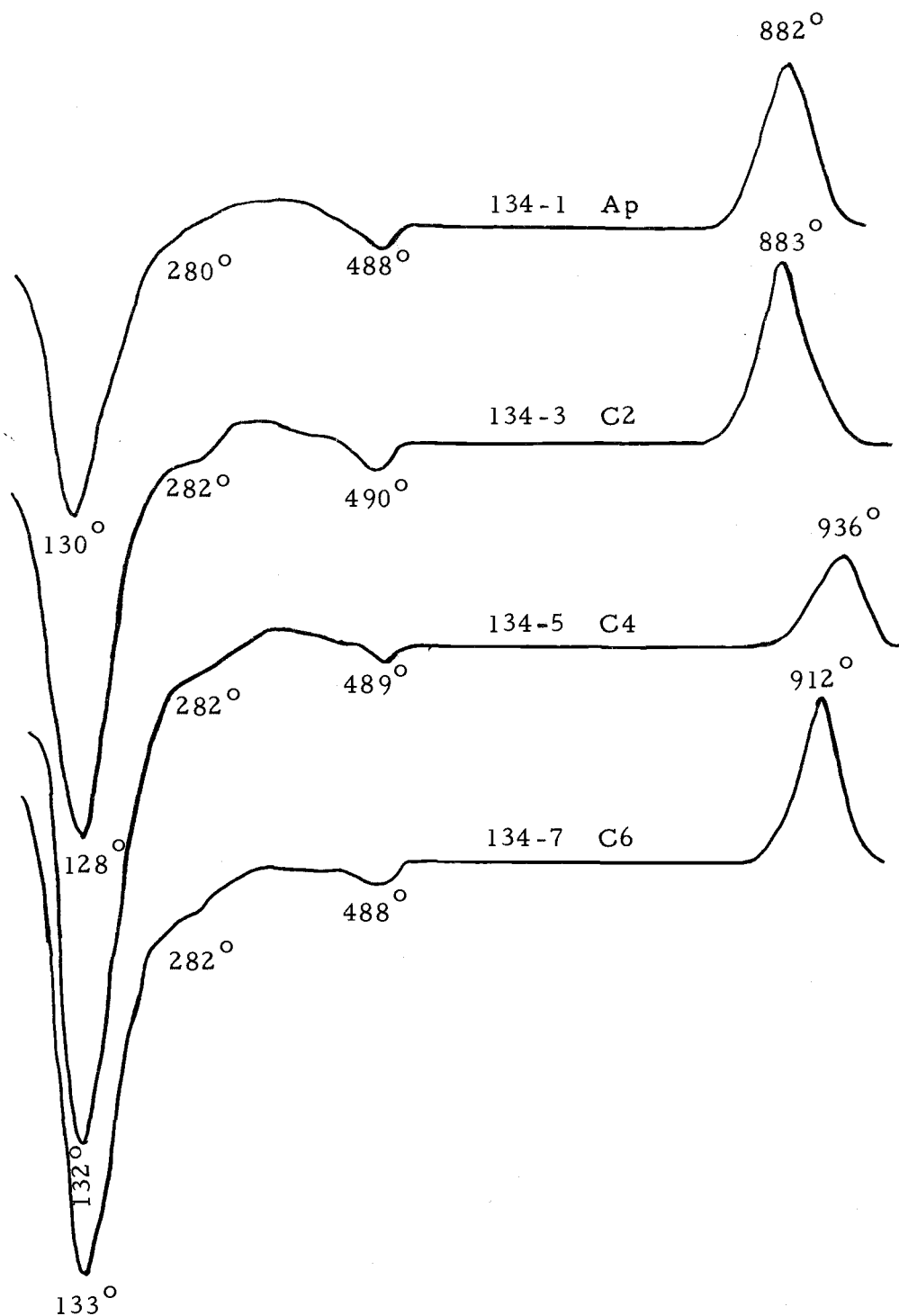


Figure 13. Differential thermal analyses curves from total clay for several horizons of a Parkdale soil (temperatures in °C; baselines adjusted).

420° C (Yoshinaga and Aomine, 1962b). The peak in Parkdale soil clay patterns is intermediate between halloysite and imogolite. Neither of these minerals could be identified by XRD. The weak endothermic peak at about 280° C was attributed to vermiculite, shown to be present by XRD studies.

DTA patterns for Dee soil total clays (Figure 14) are greatly different from patterns of Parkdale soil clays. Instead of being dominated by a low temperature endotherm and a high temperature exotherm, patterns from Dee soil clays are dominated by an intermediate temperature endotherm. The patterns were interpreted as indicating mostly halloysite. The large dehydroxylation endotherm at intermediate temperatures, in addition to a low temperature endotherm and a high temperature exotherm, are characteristic for halloysite (Mackenzie, 1966). The intermediate endotherm occurs at a somewhat lower temperature than is typical for halloysite, but the patterns viewed in their entirety closely resemble data for halloysite. Dudas (1973) made similar interpretations of like data. The weak endotherm at about 270° C was attributed to vermiculite.

Dee soil clays, after removal of amorphous materials and free iron oxides, would still be interpreted to be mostly halloysite (Figure 15). However, comparisons with data from total clays suggests that the pretreatments have a destructive effect on halloysite as shown by reduction of all peaks and virtual removal of the low temperature

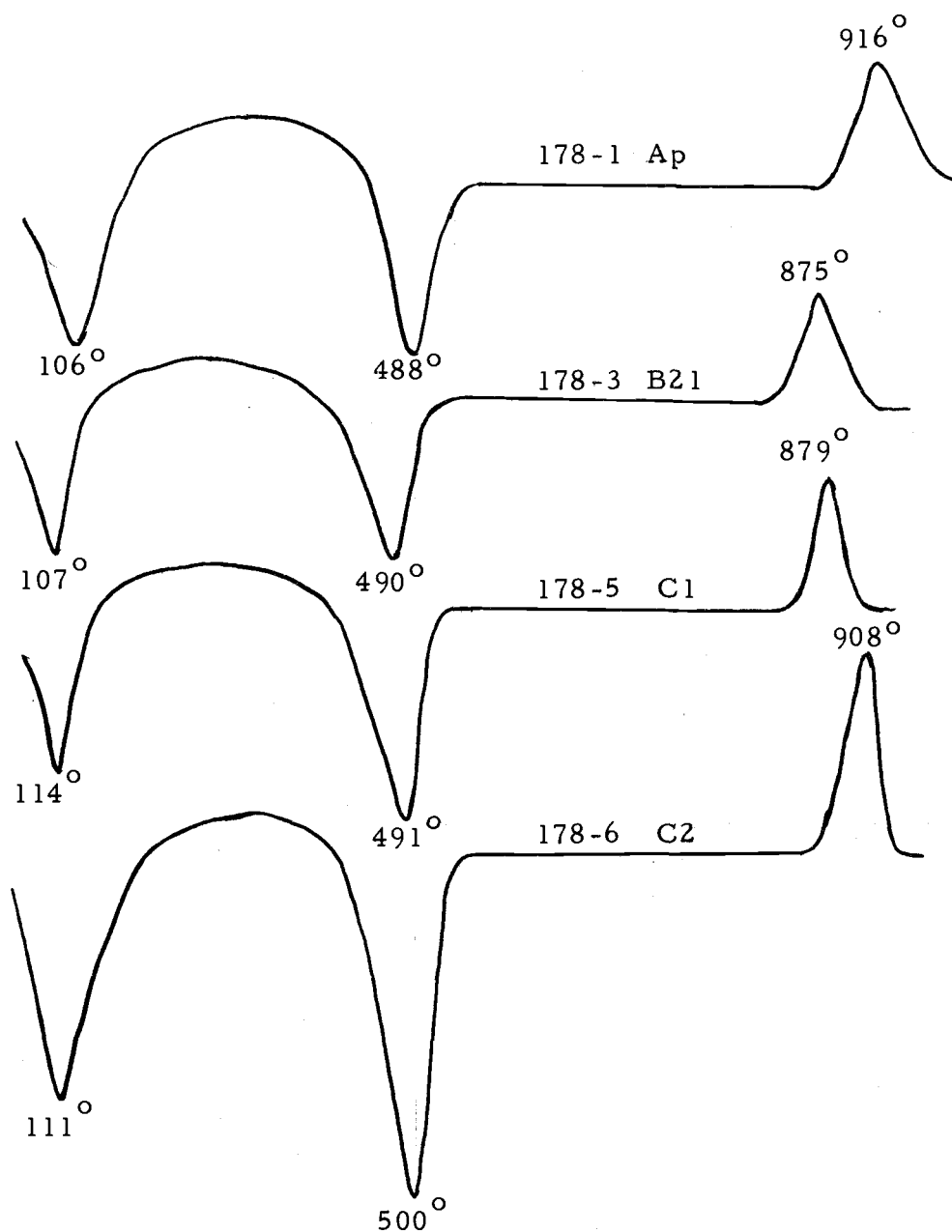


Figure 14. Differential thermal analyses curves from total clay for several horizons of a Dee soil (temperatures in °C; baselines adjusted).

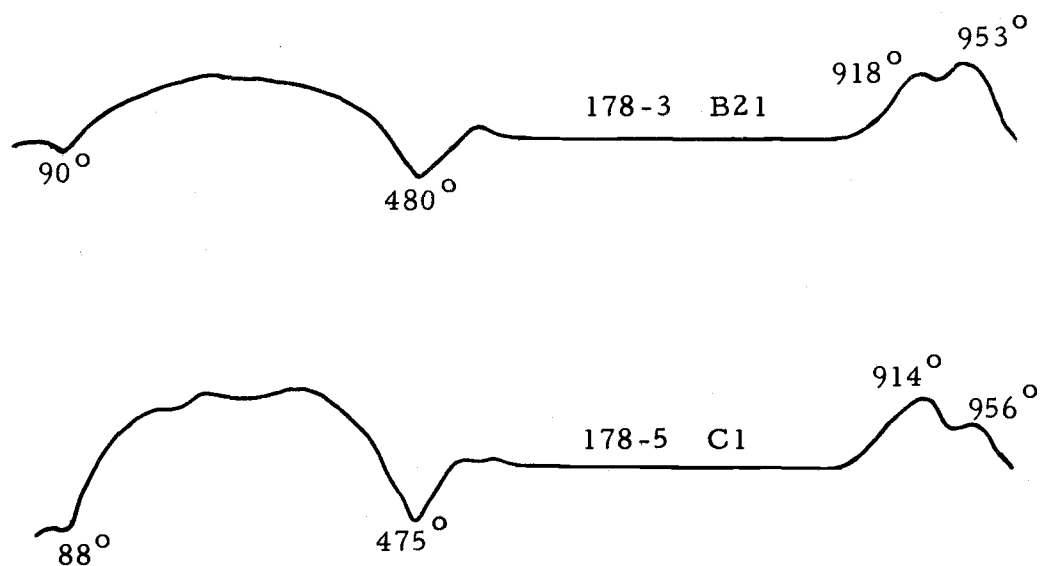


Figure 15. Differential thermal analyses curves for clays from B21 and C1 horizons of a Dee soil. Clays treated for removal of amorphous material and free iron oxides prior to analyses. (temperatures in °C; baselines adjusted)

endotherm. The high temperature exotherm doublet is probably due to halloysite and other phyllosilicates such as vermiculite.

Infra-red Analyses. Mitchell, Farmer and McHardy (1964) state that the typical Si-O absorption band around 9 microns ( $\mu$ ) is broadened and the maximum shifts toward longer wavelengths with increasing Al substitution for Si. Shift of the band is attributed to formation of a mixed polymer with Al-O-Si linkages which gives a different pattern from a mechanical mixture of phases. This type of bonding is indicative of allophane. A broad absorption band around 10  $\mu$  is typical of allophane (Yoshinaga and Aomine, 1962a; Russell et al., 1969). Spectra from Parkdale soil clays (Figure 16), therefore were interpreted to indicate considerable content of allophane. The absorption band between 6 and 6.5  $\mu$  is due to physically adsorbed water.

Spectra from Dee soil total clays show less broadening and shifting of the Si-O absorption bands, indicating less allophane than in Parkdale soil clays (Figure 17). Compared to Parkdale clay spectra, less shift of the Si-O absorption band to longer wavelengths in Dee clay spectra indicates a higher Si/Al ratio for Dee soil clays (Mitchell et al., 1964). The H-O-Al absorption band around 11  $\mu$  is probably mostly due to the halloysite which was confirmed earlier.

Electron Microscopy. As a result of other analyses, there were some uncertainties as to the presence or absence of poorly

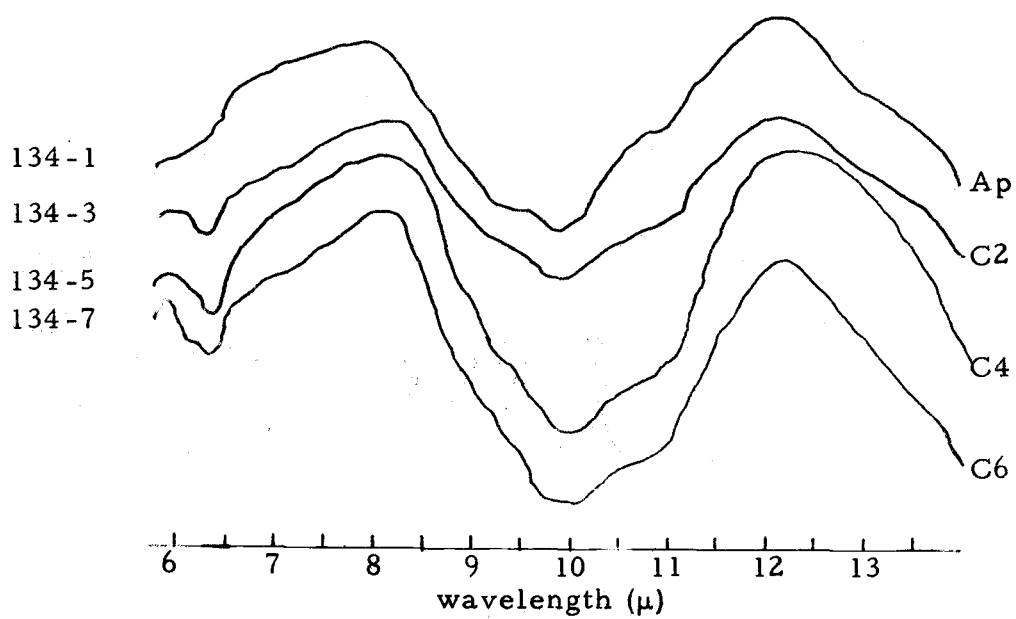


Figure 16. Infra-red spectra from Parkdale soil total clays.

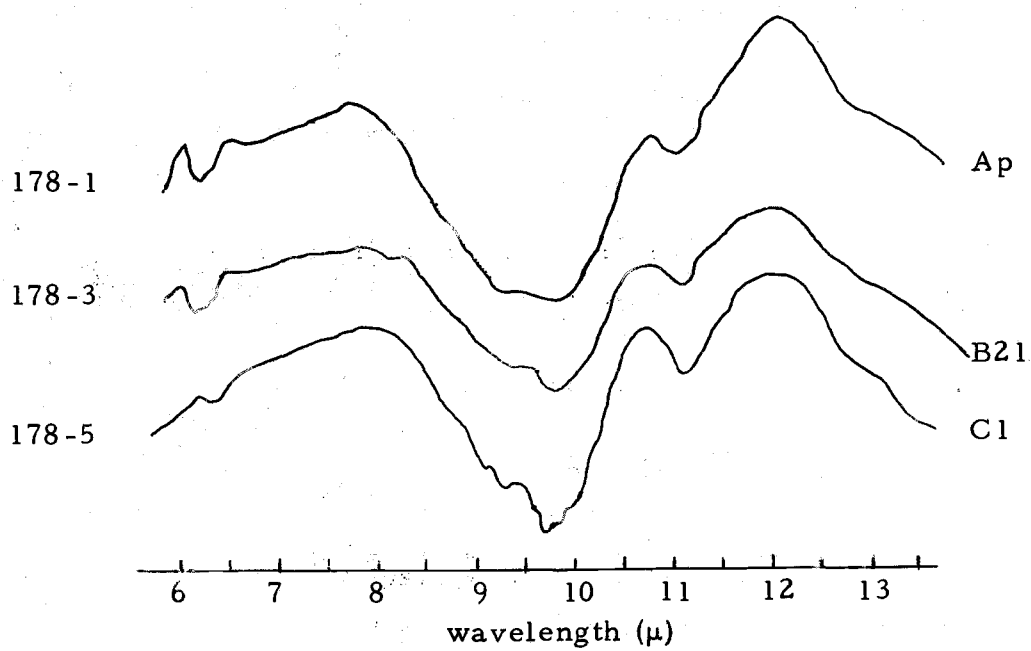


Figure 17. Infra-red spectra from Dee soil total clays.

crystalline halloysite, imogolite, or both in Parkdale soil clays. DTA showed results intermediate to these two minerals and XRD and infra-red analyses did not confirm the presence of either. It was felt that electron microscopy might aid in resolving these questions. R. N. Jones (University of Hawaii) and D. D. Dingus (Oregon State University) kindly consented to examine some specimens. They provided electron micrographs and Dr. Jones commented on interpretations.

Parkdale soil clays contain large amounts of amorphous materials and hydrated gels (Figure 18). Dr. Jones interpreted most of the fine grained crystalline material to be halloysite. He called the disk-shaped coils "sushi" (name adopted from a Japanese food of similar appearance). The exact nature of these "sushi" is not yet known. They appear to be very poorly crystalline. There is some indication of a thread-like substance in Figure 18. However, there are no discrete, well developed threads; therefore, the presence of imogolite was not confirmed.

## Discussion

### Soil Genesis

Parkdale Soils. Soil genesis involves the processes of parent material accumulation and horizon differentiation (Simonson, 1959).

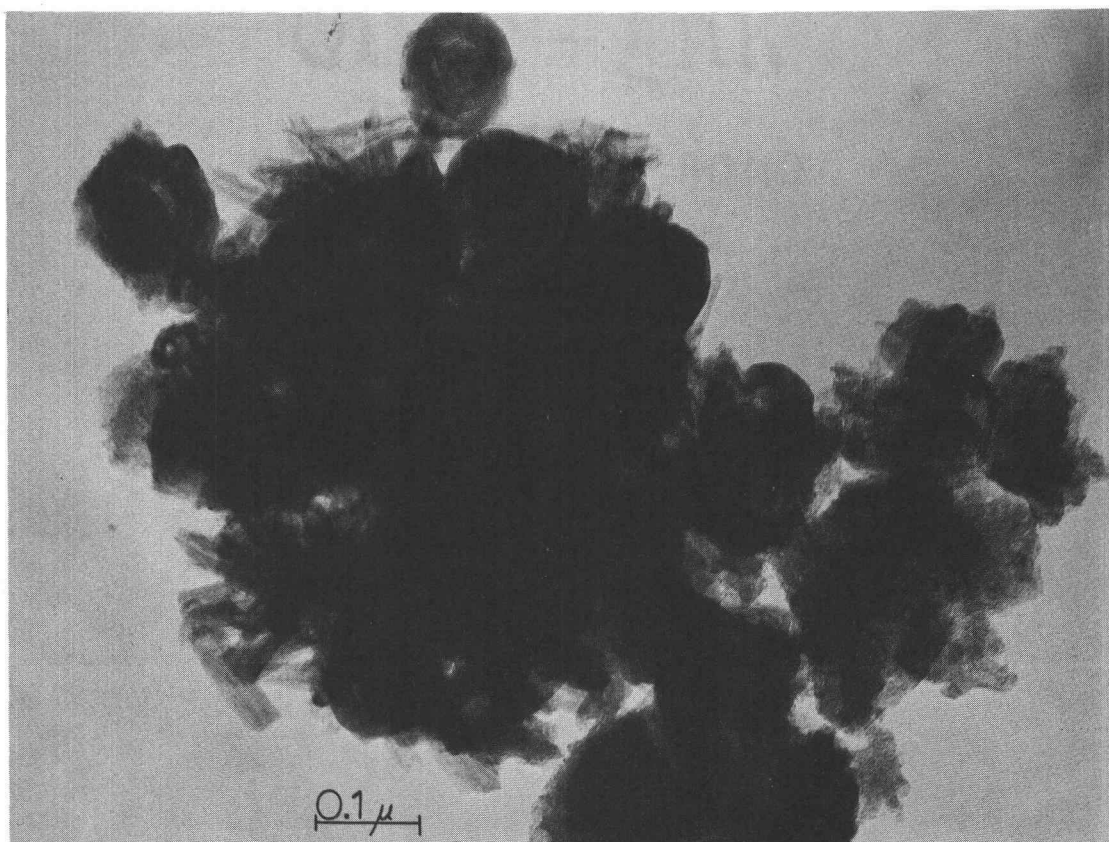
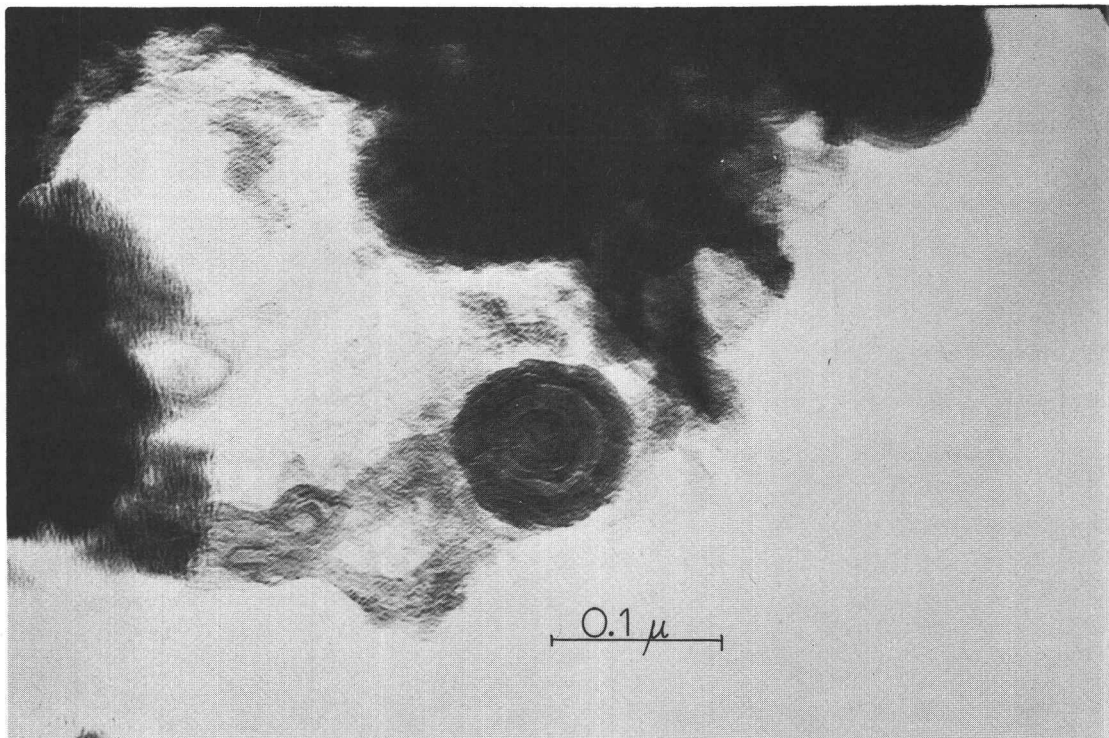


Figure 18. Electron micrographs of Parkdale soil total clays.



In Chapter II, parent materials were discussed. It was concluded that the most likely mode of deposition for Parkdale soil parent materials was by mudflow. The parent materials were shown to be from mixed rock types. Weathered and unweathered materials had been mixed together by the mudflow. The accumulated materials are dominantly fine sand, very fine sand, and silt. There has been contamination of surface horizons by a deposit of volcanic ash; however, amounts of this ash are limited. The parent materials are relatively uniform from site to site throughout the valley except in thickness. From this standpoint, analyses reported in this chapter for a modal Parkdale soil are considered to be typical of the entire deposit. To evaluate horizon differentiation, the nature of the parent material must be considered. This discussion will be concerned mostly with changes in the parent materials due to soil formation after emplacement.

Parkdale soils have had very little horizon differentiation even after being exposed to weathering processes for at least 6890 years and possibly as long as 12,270 years. These soils have no zones of marked eluviation or illuviation and only weakly developed structure. The entire solum is about 50 cm thick (Ames and Ness, 1971).

Parkdale soils have had a marked accumulation of organic carbon in upper horizons. The soil materials contain considerable amorphous materials, which, according to Broadbent et al. (1964),

promotes the establishment of high levels of organic carbon due to formation of relatively stable complexes. The organic buildup and darkening of the A horizon represent the most striking horizon differentiation in the entire profile. Parkdale soils have an umbric epipedon with weak granular or weak subangular blocky structure. There are more "shot" in the A horizon than in the remainder of the soil. Some of these "shot" may be of pedogenic origin. Their chemical composition is not too different from associated soil materials (Appendix VII).

The B2 horizon is lighter in color, lower in organic matter content than the A horizon and shows very little development. Weak structure is the primary distinction between the B2 and underlying C horizons. There has been no clay illuviation into the B horizon; in fact, it may have a slightly lower clay content than either the A or C horizons (Table 24 and Appendix V-c). However, this feature is difficult to establish since particle size measurements for Parkdale soils vary with the method used. This difficulty in measurement also complicates interpretations of mean particle size changes with soil development.

Moderate amounts of clay throughout the profile and accumulation of weathering products without significant profile differentiation suggests weathering prior to emplacement of the materials in the Upper Hood River Valley. There are indications that weathering of

volcanic ash, as well as other volcanic materials, contributed to the high amorphous material content of these soils. Weathering of biotite, shown to be present in parent materials, could provide a source for the 2:1 type phyllosilicates. It is not known to what degree weathering had proceeded at the time of emplacement. Also, contamination of the surface further complicates interpretations of changes due to weathering. Assuming little change in lower C horizons since deposition, much amorphous material was present initially and this may have contributed to the mudflow in the first place.

There is indication that amount of smectite is higher in the A horizon than in lower horizons. Grim (1968) indicates that there is little tendency for smectites to form in well drained conditions; however, Keller (1964) suggests that such formation is possible, especially for soils formed in mafic rock materials. The mechanism Keller proposes involves concentration of divalent cations, during periods when precipitation is less than potential evaporation, and their combination with silica and alumina compounds. Greater formation of smectite in the soil surface could be due to the more extreme changes in moisture content and temperature as compared to lower horizons.

The A horizon clays have a lower content of amorphous materials than in C horizons. This suggests adherence to the

transformational sequence, mentioned by Kanno (1956), of glass  $\longrightarrow$  allophane  $\longrightarrow$  halloysite. In Parkdale soils, conversion of allophane to halloysite is made more rapid in surface horizons than deeper in the profile.

Parkdale soils have an elemental distribution suggestive of leaching of iron and aluminum with concomitant accumulation of silica. This distribution is typical of well drained soils in cold, wet climates (Grim, 1968).

Parkdale soils are wet only during colder periods of the year; they are dry during warmer months (Appendix IV). Also, temperatures seldom exceed 80° even during warmest days. These climatic trends are thought to be a major reason for the lack of development and horizon differentiation in these soils. Dudas (1973), in studies of soils formed in volcanic ash from Mt. Mazama, found surprisingly little weathering and soil development after 6600 years which he also attributed to climatic effects.

Well Drained Sites vs More Poorly Drained Sites. After the parent materials were emplaced in the Upper Hood River Valley, drainages became established and soil development began. Parkdale soils formed in well drained sites and Dee soils formed in more poorly drained sites. Comparisons of these two soils were made to determine differences in clay mineral formation.

The effect of drainage on soil genesis is best evaluated with the

assurance of common parent materials. Little variation was found within and among Parkdale soil profiles (Chapter II). Since the Parkdale and Dee soils are on the same geomorphic surface and apparently formed in the same mudflow deposit, it was assumed they would have identical parent materials. Subsequent studies suggested that contents of  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  in lower C horizons may represent lithologic dissimilarities between the two soils. However, other whole soil elemental contents and sand subfraction distributions indicate that both soils have formed in the same material; all other differences can be attributed to weathering. Therefore, although there remains some doubt, differences between Parkdale and Dee soils are attributed primarily to differences in drainage.

Dee soils are developed deeper and show more horizon differentiation than Parkdale soils. Dee soils also have lower organic carbon content in the surface. This is unusual considering that more poorly drained soils generally accumulate greater amounts of organic materials than associated well drained soils. However, Dee soils have a lower amorphous material content than Parkdale soils and this often correlates with lower organic accumulations, since amorphous materials form such stable complexes with organic materials (Broadbent et al., 1964). Dee soils have weak granular structure in A horizons. They are grayer, more sticky, more plastic, more mottled, and have a higher clay content than Parkdale

soils. Dee soils also increase in clay content with depth, suggesting possible illuviation into lower horizons. However, no subsoil horizon shows clay films as evidence of clay illuviation.

The clay minerals in Parkdale and Dee soils are distinctly different. Clays in Dee soils have higher  $\text{SiO}_2$  and lower  $\text{Al}_2\text{O}_3$  than Parkdale clays. Allophane predominates in Parkdale soils, while halloysite predominates in the Dee. If these soils were originally similar in amorphous material content, Dee soils have had a much greater transformation of allophane to halloysite, following the sequence indicated by Kanno (1956). Kanno (1959) suggested that stagnant water enhanced the formation of halloysite. Stagnant water is more apt to occur in the somewhat poorly drained environment of Dee soils than in Parkdale soils. Dudas (1973) found, in his study of soils formed in volcanic ash from Mt. Mazama, that halloysite dominated the mineralogy of some poorly drained sites. He also found authigenic halloysite near the paleosol contact in well drained sites and he attributed this to a higher moisture content above the heavier textured paleosol. In Dee soils the B21 horizon has more halloysite and less amorphous materials than underlying C horizons. This further suggests formation of halloysite from amorphous materials in poorly drained conditions.

Elemental distribution with depth is the same for both Parkdale and Dee soils, suggesting similar processes of leaching and retention

However, Parkdale soils are lower in  $\text{SiO}_2$  and higher in  $\text{Al}_2\text{O}_3$  relative to Dee soils. Parkdale soils have less  $\text{Fe}_2\text{O}_3$  in upper parts of the profile than Dee soils, but at depth they have similar  $\text{Fe}_2\text{O}_3$  contents. These elemental distributions suggest that Dee soils are more highly weathered and contain more halloysite than Parkdale soils. Formation of halloysite causes retention of  $\text{SiO}_2$  and corresponding losses of  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$ .

In summary, Dee soils represent a more advanced stage of horizon differentiation and clay mineral formation than Parkdale soils. The restricted drainage of Dee soils may actually have accelerated soil development rather than retarding it. This facilitating of genetic processes in Dee soils compared to Parkdale soils can be attributed, not only to the more rapid formation of halloysite, but also to the more moist soil conditions during periods of highest temperatures which promote weathering and alteration processes.

### Classification

Parkdale soils are presently classified according to criteria in Soil Taxonomy (U. S. Department of Agriculture, Soil Conservation Service, Soil Survey Staff, 1970), in the medial, mesic family of Umbric Vitrandepts. In order to be classified in the suborder Andepts, a soil must have (a)  $> 60\%$  vitric tephra, cinders, or other vitric pyroclastic materials in the  $> 0.05$  mm fractions or have a

bulk density of  $< 0.85$  g/cc, and (b) an exchange complex dominated by amorphous materials. According to the Soil Survey Staff, vitric tephra includes crystalline particles coated with glass, partially devitrified glass, and discrete glass shards and pumice. Thin section studies show that Parkdale soils have much less than 60% vitric pyroclastic materials. Tests performed by the Materials Research Division of Oregon State University on Parkdale soil samples from two different locations revealed that the Ap, B2, and C horizons all have a bulk density of about 1.3 g/cc (Allen, 1963). Studies done in the Department of Soil Science at Oregon State University also show that Parkdale soils have a bulk density  $> 0.85$  g/cc (Harris et al., 1970). These data suggest that Parkdale soils might be better classified as Umbrepts indicating they are Inceptisols with an umbric epipedon. Parkdale soils would probably be in the Xerumbrept great group to reflect the climatic data given in Appendix IV. The subgroup name might be Andic Xerumbrept to illustrate the tendency of these soils to express properties similar to Andepts. There is no Andic subgroup of Xerumbrepts presently recognized, although provision apparently has been made in the classification criteria set out by the Soil Survey Staff.

Dee soils are presently classified as Aquic Vitrandepts. This classification indicates that Dee soils differ from Parkdale soils in that they express properties suggesting wetness. However, Dee



soils could probably be classified to more accurately reflect their properties. There is the possibility that Dee soils have mollic epipedons based on their base saturation of  $> 50\%$ ; values and chromas of 3 and 2, respectively; organic carbon content of  $0.9\%$ ; structural development; and depth. In this study, Dee soils were not the primary soils of interest and insufficient sampling and study was done to adequately classify them. However, it is doubtful that Dee soils are Andepts.

### Conclusions on Mineralogy, Genesis and Classification of Parkdale Soils

#### Mineralogy of Parkdale Soils

Allophane is the dominant clay-size material. Crystalline components of the clay size fraction include chloritic intergrades, cristobalite, feldspars, and small amounts of smectite, quartz, mica, and halloysite. Silt and sand mineralogy showed dominance of feldspars, fine-grained volcanic rock fragments, and aggregated weathering products. Smaller amounts of pyroxenes, amphiboles, magnetite, biotite, quartz, cristobalite, and pumice and glass were also present.

#### Soil Genesis

Parkdale Soils. Parkdale soils have formed in mudflow deposits from the northeastern flanks of Mt. Hood. Parent materials for these

soils were derived mostly from basalts, dacites, and andesites, with small amounts of volcanic ash. The parent materials were weathered prior to emplacement in the Upper Hood River Valley between 6890 and 12,270 years ago.

Parkdale soils lack pronounced horizon differentiation. They have a high content of organic carbon in A horizons which may be due to complexing of the organic substances with amorphous materials. Upper horizons contain larger amounts of "shot" than lower horizons. Parkdale soils have umbric epipedons (high organic carbon content, dark color, low base saturation). There is no evidence of eluvial or illuvial horizons in Parkdale soils.

The limited development of Parkdale soils is due at least in part, to the limited moisture availability during warmer periods and cool temperatures during moist periods.

Well Drained Sites vs More Poorly Drained Sites. Parkdale soils formed in well drained sites and Dee soils formed in somewhat poorly drained sites. Dee soils in comparison to Parkdale soils are grayer, developed deeper, more sticky, more plastic, more mottled, less sandy, more clayey, higher in  $\text{SiO}_2$ , and lower in  $\text{Al}_2\text{O}_3$ . In comparison to Parkdale soils, Dee soils have a lower organic carbon content correlating with a corresponding lower amorphous material content. Halloysite dominates the clay fraction of the Dee soils, while allophane dominates in Parkdale soils. In Dee soils the amount

of halloysite is higher in the B horizon than in C horizons suggesting its formation at the expense of amorphous material.

### Classification

Parkdale soils have < 60% pyroclastic materials and have a bulk density > 0.85 g/cc. They might be better classified as Andic Xerumbrepts rather than Umbric Vitrandepts. Dee soils also do not fit the criteria for Andepts.

## BIBLIOGRAPHY

- Allen, B. L. 1959. A mineralogical study of soils developed on tertiary and recent lava flows in northeastern New Mexico. Ph.D. thesis. East Lansing, Michigan State University. 140 numb. leaves.
- Allen, H. 1963. Engineering test data for soil samples taken from Hood River County, Oregon. Materials Research Division, Corvallis, Oregon State University. 1 sheet.
- Ames, D. F. and A. O. Ness. 1971a. Unpublished initial review draft description of the Dee soil series. Soil Conservation Service. U. S. Department of Agriculture. 3 p.
- Ames, D. F. and A. O. Ness. 1971b. Unpublished initial review draft description of the Parkdale soil series. Soil Conservation Service. U. S. Department of Agriculture. 3 p.
- Anderson, J. U. 1963. An improved pretreatment for mineralogical analysis of samples containing organic matter. *Clays and Clay Minerals* 10:380-388.
- Armstrong, J. E. 1956. Mankato drift in the lower Fraser valley of British Columbia, Canada. *Geological Society of America Bulletin* 67:1666-1667.
- Baird, A. K. 1961. A pressed-specimen die for the Norelco vacuum-path X-ray spectrograph. *Norelco Reporter* 8:108-109.
- Balster, C. A. and R. B. Parsons. 1968. Geomorphology and soils Willamette Valley, Oregon. Corvallis. 31 p. (Oregon Agricultural Experiment Station. Special Report 265)
- Barshad, I. 1954. Cation exchange in micaceous minerals, I. replacability of the interlayer cations of vermiculite with ammonium and potassium ions. *Soil Science* 77:460-463.
- Birrell, K. S. and M. Fields. 1952. Allophane in volcanic ash soils. *Journal of Soil Science* 3:156-166.

- Birrell, K. S. and M. Gradwell. 1956. Ion-exchange phenomena in some soils containing amorphous mineral constituents. *Journal of Soil Science* 7:130-147.
- Borchardt, G. A. 1970. Neutron activation analysis for correlating volcanic ash soils. Ph.D. thesis. Corvallis, Oregon State University. 219 numb. leaves. (Microfilm #30, 4870-B)
- Borchardt, G. A. and A. A. Theisen. 1971. Rapid X-ray spectrographic determination of major element homogeneity in Mazama pumice. *Soil Science and Plant Analysis* 2:11-16.
- Bray, R. H. and L. T. Kurtz. 1945. Determination of total organic, and available forms of phosphorus in soils. *Soil Science* 59: 39-45.
- Briner, G. P. and M. L. Jackson. 1969. Allophanic material in Australian soils derived from Pleistocene basalt. *Australian Journal of Soil Research* 7:163-169.
- Broadbent, F. E., R. H. Jackman and J. McNicoll. 1964. Mineralization of carbon and nitrogen in some New Zealand allophanic soils. *Soil Science* 98:118-128.
- Brown, G. and R. Farrow. 1956. Introduction of glycerol into flake aggregates by vapor pressure. *Clay Minerals Bulletin* 3:44-45.
- Callaghan, E. 1933. Some features of the volcanic sequence in the Cascade Range in Oregon. *American Geophysical Union Transactions*, 14th Annual Meeting, Washington, D. C. p. 243-249.
- Campbell, A. S., B. D. Mitchell and J. M. Bracewell. 1968. Effects of particle size, pH and organic matter on the thermal analysis of allophane. *Clay Minerals* 7:451-454.
- Crandell, D. R., D. R. Mullineaux and H. H. Waldron. 1958. Pleistocene sequence in southern part of the Puget Sound lowland, Washington. *American Journal of Science* 256: 384-397.
- Crandell, D. R. and H. H. Waldron. 1956. A recent volcanic mud-flow of exceptional dimensions from Mt. Rainier, Washington. *American Journal of Science* 254:349-362.

- Davies, E. B. 1933. Studies in the dispersion and deflocculation of certain soils. *New Zealand Journal of Science and Technology* 14:228-232.
- Doak, W. H. 1972. Cation retention and solute transport related to porosity of pumiceous soils. Ph.D. thesis. Corvallis, Oregon State University. 104 numb. leaves.
- Dudas, M. J. 1973. Mineralogy and trace element chemistry of Mazama ash soils. Ph.D. thesis. Corvallis, Oregon State University. 119 numb. leaves.
- Dudas, M. J. and M. E. Harward. 1971. Effect of dissolution treatment on standard and soil clays. *Soil Science Society of America, Proceedings* 35:134-140.
- Fairbairn, H. W. et al. 1951. A cooperative investigation of precision and accuracy in chemical, spectrochemical and modal analysis of silicate rocks. U. S. Geological Survey, Bulletin 980. 71 p.
- Fenneman, N. M. 1931. *Physiography of Western United States*. New York, McGraw-Hill. 534 p.
- Fields, M. 1960. Mechanisms of ion adsorption by inorganic soil colloids. *New Zealand Journal of Science* 3:563-570.
- Fields, M. and K. W. Perrott. 1966. The nature of allophane in soils: Part 3- rapid field and laboratory test for allophane. *New Zealand Journal of Science* 9:623-629.
- Flanagan, F. J. 1967. U. S. Geological Survey silicate rock standards. *Geochimica et Cosmochimica Acta* 31:289-308.
- Fleischer, M. and R. E. Stevens. 1962. Summary of new data on rock samples G-1 and W-1. *Geochimica et Cosmochimica Acta* 26:525-543.
- Franklin, W. T. 1970. Mineralogical and chemical characteristics of western Oregon andic soils. Ph.D. thesis. Corvallis, Oregon State University. 199 numb. leaves.

- Franklin, J. F. and C. T. Dyrness. 1969. Vegetation of Oregon and Washington. 216 p. U. S. Department of Agriculture, Forest Service Research Paper PNW-80. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.
- Grim, R. E. 1968. Clay mineralogy. 2d ed., New York, McGraw-Hill. 596 p.
- Handewith, H. 1959. Recent glacier variations on Mt. Hood. *Mazama* 40:23-28.
- Harris, B. L. and M. E. Harward. 1972. Unpublished data on swelling properties of interlayered montmorillonite. Corvallis, Oregon, Department of Soil Science, Oregon State University, 1972.
- Harris, B. L., A. A. Theisen, G. A. Borchardt, E. G. Knox and M. E. Harward. 1970. Particle size distribution and bulk density of soils from volcanic ash. Corvallis, Oregon, Department of Soil Science, Oregon State University. 9 p. Mimeographed.
- Harward, M. E., D. D. Carstea and A. H. Sayegh. 1969. Properties of vermiculites and smectites: expansion and collapse. *Clays and Clay Minerals* 16:437-447.
- Hodge, E. T. 1940. The Cascade Plateau Province. In: Physical and Economic Geography of Oregon. Salem, Oregon State Board of Higher Education. 319 p.
- Hodge, E. T. 1931. Statler Buried Forest. *Mazama* 13:82-86.
- Jackson, M. L. 1956. Soil chemical analysis-advanced course. Madison, Wisconsin, author, 991 p.
- Johnsgard, G. A. 1963. Temperature and the water balance for Oregon weather stations. Corvallis. 127 p. (Oregon Agricultural Experiment Station. Special Report 150)
- Kanno, I. 1959. Clay minerals of volcanic ash soils and pumices from Japan. *Advances in Clay Science* 1:213-233.
- Kanno, I. 1956. A pedological investigation of Japanese volcanic-ash soils. Sixth International Congress of Soil Science. Vol E:105-109.

- Kilmer, V. J. and L. T. Alexander. 1949. Methods of making mechanical analyses of soils. *Soil Science* 68:15-24.
- Kohn, B. P. 1970. Identification of New Zealand tephra layers by emission spectrographic analysis of their titanomagnetites. *Lithos* 3:361-368.
- Krumbein, W. C. and F. J. Pettijohn. 1938. *Manual of sedimentary petrography*. New York, Appleton-Century Co. 549 p.
- Kunze, G. W. 1955. Anomalies in the ethylene glycol solvation technique used in X-ray diffraction. *Clays and Clay Minerals* 3:83-93.
- Lavkulich, L. M. and J. H. Wiens. 1970. Comparison of organic matter destruction by hydrogen peroxide and sodium hypochlorite and its effects on selected mineral constituents. *Soil Science Society of America, Proceedings* 34:755-758.
- Lawrence, D. B. 1948. Mt. Hood's latest eruption and glacier advances. *Mazama* 30:22-29.
- Mackenzie, R. C. 1966. *The differential thermal investigation of clays*. London, Mineralogical Society. 456 p.
- Mason, R. S. 1954. Recent survey of Coe and Eliot glaciers (Oregon). *Mazama* 36:37-39.
- Mitchell, B. D. and V. C. Farmer. 1962. Amorphous clay minerals in some Scottish soil profiles. *Clay Minerals Bulletin* 5:128-144.
- Mitchell, B. D., V. C. Farmer and W. J. McHardy. 1964. Amorphous inorganic materials in soils. *Advances in Agronomy* 16:327-383.
- Miyauchi, N. and S. Aomine. 1966. Mineralogy of gel-like substance in the pumice bed in Kanuma and Kitakami districts. *Soil Science and Plant Nutrition* 12:19-22.
- Mullineaux, D. R., J. H. Hyde and R. Meyer. 1972. Preliminary assessment of upper Pleistocene and Holocene pumiceous tephra from Mount St. Helens, southern Washington. (Abstract) *Geological Society of America* 4:204-205.



- Parsons, R. B. 1972. Research Soil Scientist, Soil Conservation Service, U. S. Department of Agriculture. Associate Professor, Oregon State University. Personal communication. Corvallis, Oregon. Sept. 1972.
- Parsons, R. B., C. A. Balster and A. O. Ness. 1970. Soil development and geomorphic surfaces, Willamette Valley, Oregon. Soil Science Society of America, Proceedings 34: 485-491.
- Peck, D. L., A. B. Griggs, H. G. Schlicker, F. G. Wells and H. M. Dale. 1964. Geology of the central and northern parts of the western Cascade Range in Oregon. Washington, D. C. 56 p. (U. S. Geological Survey, Professional Paper 449)
- Peech, M. L., T. Alexander, L. A. Dean and J. F. Reed. 1947. Methods of soil analysis for soil fertility investigations. U.S. Department of Agriculture, Circular 757. 25 p.
- Ruhe, R. V. 1969. Quaternary landscapes in Iowa. Ames, Iowa State University Press. 255 p.
- Ruhe, R. V. and W. H. Scholtes. 1956. Ages and development of soil landscapes in relation to climate and vegetational changes in Iowa. Soil Science Society of America, Proceedings 20: 246-275.
- Rich. C. I. 1962. Removal of excess salt in cation-exchange-capacity determinations. Soil Science 93:87-94.
- Russell, J. D., W. J. McHardy and A. R. Fraser. 1969. Imogolite: a unique aluminosilicate. Clay Minerals 8:87-99.
- Simonson, R. W. 1959. Outline of a generalized theory of soil genesis. Soil Science Society of America, Proceedings 23: 152-156.
- Skipper, H. D. 1970. Hydrolysis and biological degradation of Atrazine in soils. Ph. D. thesis. Corvallis, Oregon State University. 70 numb. leaves.
- Strahorn, A. T. and E. B. Watson. 1914. Soil survey of the Hood River - White Salmon River Area, Oregon-Washington. 45 p. (U. S. Department of Agriculture. Bureau of Soils)

- Tan, K. H. 1965. The andosols in Indonesia. *Soil Science* 99: 375-378.
- Theisen, A. A. and M. E. Harward. 1962. A paste method for preparation of slides for clay mineral identification by X-ray diffraction. *Soil Science Society of America, Proceedings* 26:90-91.
- U. S. Bureau of Standards. 1931a. Certificate of analysis of standard sample number 91, opal glass. Washington, D. C. 1 sheet.
- U. S. Bureau of Standards. 1931b. Certificate of analysis of standard sample number 97, flint clay. Washington, D. C. 1 sheet.
- U. S. Bureau of Standards. 1931c. Certificate of analysis of standard sample number 98, plastic clay. Washington, D. C. 1 sheet.
- U. S. Department of Agriculture. Soil Conservation Service. Soil Survey Staff. 1970. Selected chapters from the unedited text of the Soil Taxonomy of the National Cooperative Soil Survey. Washington, D. C., U. S. Government Printing Office. 14 chapters.
- U. S. Department of Agriculture. Soil Conservation Service. Soil Survey Laboratory Staff. 1965. Riverside soil survey laboratory report for soils from Hood River County, Oregon. Unpublished research paper. Riverside, California.
- Wada, K. 1958. Reaction of phosphate with allophane and halloysite. *Soil Science* 87:325-330.
- Wada, K. and H. Ataka. 1958. The ion uptake mechanism of allophane. *Soil and Plant Food* 4:12-18.
- Waters, A. C. 1961. Stratigraphic and lithologic variations in the Columbia River Basalt. *American Journal of Science* 259: 283-611.
- Wilcox, R. E. 1965. Volcanic ash chronology. In: *The Quaternary of the United States: Review volume for the Seventh Congress of the International Association for Quaternary Research*, Boulder, Colorado, 1965, ed. by H. E. Wright, Jr. and D. G. Frey. Princeton, Princeton University. p. 807-816.

- Wise, W. S. 1969. Geology and petrology of the Mt. Hood area: A study of high Cascade volcanism. Geological Society of America, Bulletin 80:969-1006.
- Wise, S. 1968. Geology of the Mount Hood Volcano. In: Andesite conference guidebook. Portland, p. 81-98. (Oregon, Dept. of Geology and Mineral Industries. Bulletin 62)
- Wise, W. S. 1966. The last eruptive phase of the Mt. Hood volcano. *Mazama* 48:15-19.
- Wise, W. S. 1964. The geologic history of Mt. Hood, Oregon. *Mazama* 46:13-22.
- Yoshinaga, N. 1966. Chemical composition and some thermal data of eighteen allophanes from Ando soils and weathered pumices. *Soil Science and Plant Nutrition* 12:1-8.
- Yoshinaga, N. and S. Aomine. 1962a. Allophane in some andosols. *Soil Science and Plant Nutrition* 8:6-13.
- Yoshinaga, N. and S. Aomine. 1962b. Imogolite in some andosols. *Soil Science and Plant Nutrition* 8:22-29.

## APPENDICES

## APPENDIX I

## SAMPLE SITES

<u>Sample</u>	<u>Depth (cm)</u>	<u>Location</u>
101	-	NE1/4 NE1/4 sec. 18, T1N, R11E
102-1	5-10	NE1/4 NE1/4 sec. 6, T2S, R10E
102-2	11-20	
103-1	5-9	NW1/4 SW1/4 sec. 2, T2S, R10E
103-2	10-30	
104	99-109	SW1/4 NE1/4 sec. 32, T1N, R10E
105	15-30	SW1/4 SW1/4 sec. 34, T2S, R12E
106-1	5-15	SW1/4 NE1/4 sec. 1, T2S, R12E
106-2	35-50	
107	15-30	NW1/4 SW1/4 sec. 3, T7S, R9E
108-1	3-7	SW1/4 SW1/4 sec. 19, T2S, R11E
108-2	12-30	
109	15-23	SW1/4 SE1/4 sec. 4, T2S, R12E
110-1	1-15	SW1/4 SE1/4 sec. 6, T1S, R9E
110-2	15-23	
110-3	23-38	
110-4	38-51	
110-5	51-76	
110-6	76-140	
111-1	2-20	SE1/4 SW1/4 sec. 27, T1S, R9E
111-2	20-46	
112-1	0-23	SW1/4 NE1/4 sec. 11, T1S, R9E
112-2	23-81	
112-3	81-114	
112-4	114-259	
112-5	259-300	
113-1	5-15	NW1/4 NE1/4 sec. 1, T1N, R9E
113-2	15-51	
113-3	51-91	
113-4	96-122	
114-1	0-4	SE1/4 NE1/4 sec. 10, T2S, R9E
114-2	4-9	
114-3	9-43	
115-1	25-38	NW1/4 SW1/4 sec. 20, T1S, R9E
115-2	39-46	
116-1	0-41	SE1/4 SW1/4 sec. 31, T1S, R10E
116-2	41-117	
117-1	8-38	NE1/4 SE1/4 sec. 10, T2S, R9E
117-2	38-76	
118-1	0-23	NW1/4 SE1/4 sec. 2, T1S, R9E
118-2	23-69	
119-1	0-20	NE1/4 NW1/4 sec. 2, T1N, R9E
119-2	61-76	
119-3	200-220	
120-1	300-310	SW1/4 NW1/4 sec. 2, T1N, R9E
120-2	440-450	
120-3	450-460	

## Sample sites (continued)

<u>Sample</u>	<u>Depth (cm)</u>	<u>Location</u>
121	2-41	SW1/4 SW1/4 sec. 11, T1S, R9E
122	13-36	NE1/4 NE1/4 sec. 3, T1S, R9E
123	25-36	SE1/4 SW1/4 sec. 24, T1N, R9E
124-1	290-300	NW1/4 NW1/4 sec. 10, T1S, R8E
124-2	305-360	
124-3	360-370	
125-1	106-122	NE1/4 NW1/4 sec. 10, T1S, R8E
125-2	122-137	
125-3	137-152	
126	-	SE1/4 SE1/4 sec. 17, T2N, R9E
127-1	-	SE1/4 NW1/4 sec. 20, T1S, R9E
127-2	-	
127-3	-	
128	-	NE1/4 NW1/4 sec. 30, T1S, R9E
129-1	-	NE1/4 SE1/4 sec. 23, T1S, R9E
129-2	-	NE1/4 NW1/4 sec. 1, T1S, R9E
130-1	2-25	NW1/4 NE1/4 sec. 29, T1N, R9E
130-2	25-56	
130-3	56-70	
131-1	0-23	NW1/4 SE1/4 sec. 14, T1N, R9E
131-2	23-51	
131-3	51-122	
132-1	0-30	SE1/4 NW1/4 sec. 20, T1N, R10E
132-2	30-61	
132-3	61-91	
133-1	0-18	NE1/4 NW1/4 sec. 16, T1N, R10E
133-2	18-66	
133-3	66-102	
134-1	0-23	SE1/4 NW1/4 sec. 32, T1N, R10E
134-2	23-46	
134-3	61-91	
134-4	91-152	
134-5	152-213	
134-6	213-274	
134-7	274-335	
134-8	335-371	
135-1	0-15	SW1/4 NE1/4 sec. 32, T1N, R10E
135-2	30-41	
135-3	69-84	
135-4	99-109	
135-5	123-137	
136-1	0-20	SW1/4 SW1/4 sec. 34, T1N, R10E
136-2	20-51	
136-3	61-84	
137-1	0-25	NW1/4 SW1/4 sec. 20, T1S, R10E
137-2	25-61	
137-3	76-102	
138-1	0-25	NE1/4 SE1/4 sec. 6, T1S, R10E
138-2	25-46	
138-3	71-96	

## Sample sites (continued)

<u>Sample</u>	<u>Depth (cm)</u>	<u>Location</u>
138-4	96-152	
138-5	152-213	
138-6	213-274	
138-7	274-330	
139	90-100	SE1/4 NE1/4 sec. 8, T1N, R10E
140-1	0-23	NE1/4 SW1/4 sec. 28, T2N, R10E
140-2	23-46	
141-1	0-25	SE1/4 SW1/4 sec. 35, T2N, R10E
141-2	25-51	
141-3	76-102	
142-1	10-25	SE1/4 SE1/4 sec. 3, T2S, R10E
142-2	25-38	
142-3	38-46	
142-4	46-53	
142-5	53-64	
142-6	64-76	
143-1	0-15	NW1/4 SW1/4 sec. 34, T2S, R10E
143-2	15-23	
143-3	23-56	
143-4	56-86	
143-5	86-94	
144-1	0-13	SW1/4 NW1/4 sec. 32, T3S, R10E
144-2	13-38	
144-3	38-51	
144-4	51-52	
144-5	52-61	
145-1	13-38	SE1/4 SE1/4 sec. 1, T5N, R11E
145-2	4-10	
147-1	0-13	SE1/4 SW1/4 sec. 4, T5N, R9E
147-2	13-51	
148-1	0-10	NE1/4 SW1/4 sec. 20, T5N, R9E
148-2	13-30	
148-3	200-225	
149	56-58	SW1/4 NW1/4 sec. 35, T2S, R10E
150-1	60-102	SE1/4 NW1/4 sec. 11, T3S, R9E
150-2	229-396	
151-1a	11-15	SW1/4 SE1/4 sec. 32, T2S, R10E
151-1b	15-18	
151-1c	18-24	
151-1d	24-27	
151-2	27-51	
151-3	60-67	
151-4	72-84	
152-1	6-10	SW1/4 SE1/4 sec. 10, T2S, R9E
152-2	16-36	
152-3	36-40	
152-4	40-43	
152-5	44-49	
152-6	53-56	

## Sample sites (continued)

<u>Sample</u>	<u>Depth (cm)</u>	<u>Location</u>
152-7	56-75	
152-8	75-110	
153-1	70-85	SE1/4 SW1/4 sec. 2, T2S, R9E
154	38-58	NE1/4 SW1/4 sec. 31, T1S, R10E
155	38-40	NW1/4 SW1/4 sec. 20, T1S, R9E
156	0-120	SW1/4 SW1/4 sec. 20, T1S, R9E
157-1	5-7	NW1/4 NW1/4 sec. 20, T1S, R9E
157-2	7-15	
157-3	15-17	
157-4	17-18	
157-5	18-28	
157-6	28-38	
157-7	38-55	
158	0-63	SE1/4 NE1/4 sec. 32, T10S, R9E
159-1	-	SE1/4 SW1/4 sec. 1, T10S, R9E
159-2	-	
160-1	0-60	NE1/4 NW1/4 sec. 9, T10S, R10E
160-2	60-175	
162	150-155	SW1/4 SW1/4 sec. 31, T1N, R10E
163	78-80	SW1/4 SW1/4 sec. 20, T1N, R10E
164	173-183	SW1/4 SW1/4 sec. 31, T1N, R10E
165	168-295	NW1/4 NE1/4 sec. 2, T1S, R9E
166-1a	5-25	SE1/4 SW1/4 sec. 31, T1N, R10E
166-1b	51-76	
166-2a	102-127	
166-2b	165-198	
166-3	198-267	
166-4	198-267	
166-5	267-318	
166-6	318-389	
166-7	389-488	
166-8	488-569	
166-9	569-645	
166-10	645-683	
167-1	229-259	NE1/4 NW1/4 sec. 10, T1S, R8E
167-2	244-259	
167-3	259-274	
167-4	274-290	
167-5	290-305	
167-6	259-274	
167-7	229-259	
168-1	30	NW1/4 NW1/4 sec. 25, T5N, R2E
168-2	76	
168-3	244-274	
168-4	305-366	
168-5	610-620	
168-6	620-627	
168-7	627-640	



## Sample sites (continued)

<u>Sample</u>	<u>Depth (cm)</u>	<u>Location</u>
169-1	23-38	SW1/4 SE1/4 sec. 18, T2N, R10E
169-2	107-175	
170	28-43	NW1/4 NE1/4 sec. 22, T2N, R10E
171	15-41	SE1/4 SW1/4 sec. 36, T3N, R10E
172	46-61	SW1/4 NW1/4 sec. 2, T1N, R10E
173	-	SE1/4 SE1/4 sec. 23, T1S, R10E
175	53-147	NW1/4 NE1/4 sec. 29, T1N, R10E
176	0-152	SW1/2 sec. 22, T2N, R10E
177	-	SE1/4 NW1/4 sec. 35, T2N, R10E
178-1	0-20	NE1/4 SW1/4 sec. 33, T1N, R10E
178-2	20-48	
178-3	48-86	
178-4	86-114	
178-5	114-183	
178-6	191-203	
179-1	13-30	SE1/4 NW1/4 sec. 25, T1N, R14E
179-2	46-61	
179-3	152-165	
180	-	SW1/4 sec. 13, T3S, R8E
62-19 (Doak, 1972)	183-193	NE1/4 sec. 36, T27S, R9E
St. Helens J	-	sec. 9, T8N, R6E
St. Helens M (upper)	-	sec. 9, T8N, R6E
St. Helens M (lower)	-	sec. 9, T8N, R6E
St. Helens W	-	sec. 9, T8N, R6E
St. Helens Z	-	sec. 9, T8N, R6E
St. Helens (unnamed)	-	sec. 12, T8N, R5E

## APPENDIX II

## ANALYTICAL CONDITIONS FOR X-RAY FLUORESCENCE

Element	Analytical line	Analyzing crystal	Exciting radiation	KV	ma	Detector (with pulse-height discrimination)	Path
<u>Total samples and clays</u>							
Al	K $\alpha$	EDDT	Cr	40	35	flow proportional	vacuum
Ca	K $\alpha$	EDDT	Cr	40	35	flow proportional	vacuum
K	K $\alpha$	EDDT	Cr	40	35	flow proportional	vacuum
Ti	K $\alpha$	LiF	W	50	40	scintillation	vacuum
Fe	K $\alpha$	LiF	W	50	30	scintillation	air
Zr	K $\alpha$	LiF	W	50	40	scintillation	air
Si	K $\alpha$	EDDT	Cr	40	35	flow proportional	vacuum
<u>Magnetite</u>							
Mn	K $\alpha$	LiF	Cr	40	30	scintillation	vacuum
Fe	K $\alpha, \beta$	LiF	Cr	40	30	scintillation	vacuum
Ti	K $\alpha, \beta$	LiF	Cr	40	30	scintillation	vacuum

## APPENDIX III-a

## DESCRIPTION OF PARKDALE SERIES

Description by D.F. Ames and A.O. Ness (1971b) (Soil Conservation Service) (11/4/71)

The Parkdale series is a member of the medial, mesic family of Umbric Vitrandepts. Typically, Parkdale soils have dark brown loam A horizons and brown silt loam C horizons.

Typifying Pedon: Parkdale loam - cultivated (orchard)

(Colors are for moist conditions unless otherwise noted.)

- Ap1 (0-13 cm)<sup>1</sup>--Dark brown (7.5YR 3/2) loam, brown (7.5YR 4/3) dry; weak fine granular structure; soft, very friable, nonsticky, nonplastic; many very fine and fine roots; many very irregular pores; 5% shot, 1 to 5 mm in diameter; slightly acid (pH 6.4); clear smooth boundary. (8 to 18 cm thick)
- Ap2 (13-25 cm)--Dark brown (7.5YR 3/2) loam, brown (7.5YR 4/3) dry; weak fine granular parting to weak medium subangular blocky structure; soft, very friable, nonsticky, slightly plastic; common very fine and fine roots; common very fine tubular pores; 5% shot, 1 to 5 mm in diameter; neutral (pH 6.6); abrupt wavy boundary. (0 to 15 cm thick)
- B2 (25-45 cm)--Brown (7.5YR 4/4) silt loam, brown (7.5YR 5/4) dry; weak very fine granular structure; soft, very friable, nonsticky, slightly plastic; common very fine or fine roots; few very fine tubular pores; 5% shot, 1 to 5 mm in diameter; neutral (pH 6.6); clear wavy boundary. (0 to 20 cm thick)
- C1 (45-69 cm)--Brown (7.5YR 4/4) silt loam, light yellowish-brown (10YR 6/4) dry; massive; soft, very friable, nonsticky, slightly plastic; common very fine and fine roots; common very fine tubular pores; 5% shot, 1 to 5 mm in diameter; neutral (pH 6.6); clear wavy boundary. (20 to 30 cm thick)
- C2 (69-125 cm)--Brown (7.5YR 4/4) silt loam, light yellowish-brown (10YR 6/4) dry; massive; soft, very friable, nonsticky, slightly plastic; common very fine roots; many very fine tubular pores; 10% firm nodules or shot, 2 to 10 mm in diameter; neutral (pH 6.6); clear smooth boundary. (46 to 64 cm thick)
- C3 (125-187 cm)--Yellowish-brown (10YR 5/4) loam, very pale brown (10YR 7/4) dry; massive; soft, friable, nonsticky, slightly plastic; common very fine and fine roots; many very fine tubular pores; 10% firm nodules and shot, 2 to 10 mm in diameter; 3% pebbles or andesite; neutral (pH 6.6).

---

<sup>1</sup> Units of measure changed to metric units to conform with those used throughout the thesis.

Type Location: Hood River County, Oregon, (40 m) west and (15 m) south of quarter corner in the NE NE SE Section 6, T1S, R10E.

Range in Characteristics: The soils are usually moist and dry between (20 to 61 cm) for 60 days or more during the summer months. Depth to bedrock is more than (152 cm). The mean annual soil temperature ranges from 45° to 49° F. The soils are slightly acid to neutral. The solum is (18 to 51 cm) thick. The profile lack coarse fragments in the control section. The umbric epipedon is (18 to 30 cm) thick. The A horizon has hues of 7.5YR or 10YR, values of 2 to 3 moist and 4 or 5 dry, and chromas of 2 or 3 moist and dry. It has 5 to 30% of "shot," 1 to 5 mm in diameter. The B2 or AC horizon has hues of 10YR or 7.5YR, values of 4 or 5 moist and 5 to 7 dry, and chroma of 4 moist and dry. It is loam or silt loam with 4 to 10% clay. It has weak granular or very fine subangular blocky structure. The horizon may be massive and more like a C horizon. The C horizon has hues of 10YR or 7.5YR, values of 4 or 5 moist and 6 dry, and chroma of 4 to 6 moist and dry.

Competing Series and their Differentiae: These are the Chemawa, Cinebar, Crater Lake, Forward, Stabler, and Yacolt series. Chemawa, Crater Lake, Forward, Stabler, and Toutle soils have ochric epipedons. Cinebar soils have sola thicker than (102 cm) and are medium to very strongly acid. Yacolt soils have more than 15% coarse fragments in the control section and are medium to strongly acid.

Setting: Parkdale soils are on nearly level to very steep upland slopes at elevations of (304 to 760 m). These soils formed in deep volcanic ash deposits over coarse glacial outwash materials. The mean annual precipitation is (89 to 114 cm). The mean annual temperature is about 45° to 49° F., the mean January temperature is about 29° to 33° F, and the mean July temperature is about 61° to 65° F. The frost-free (32° F) season is 100 to 120 days and for 28° F is 160 to 180 days.

Principal Associated Soils: These are the Culbertson and Dee soils. Culbertson soils have less than 60% ash. Dee soils are mottled and somewhat poorly drained.

Drainage and Permeability: Well drained; slow to medium runoff; moderate permeability.

Use and Vegetation: Orchard crops. Native vegetation includes Douglas-fir, ponderosa pine, grand fir, forbs and shrubs.

Distribution and Extent: Uplands of north-central Oregon and south-central Washington. The series is of moderate extent.<sup>1</sup>

Series Established: Hood River-White Salmon River area, Oregon-Washington, 1912.

Remarks: The Parkdale soils were formerly classified as a Regosol.

---

<sup>1</sup> Considering the distribution of these soils, their extent may be more accurately described as "limited" or "inextensive."

## APPENDIX III-b

## DESCRIPTION OF DEE SERIES

Description by D.F. Ames and A.O. Ness (1971a) (Soil Conservation Service) (11/3/71)

The Dee series is a member of the medial, mesic family of Aquic Vitrandepts. Typically, Dee soils have very dark grayish-brown silt loam A horizons and brown loam B2 horizons.

Typifying Pedon: Dee silt loam- cultivated

(Colors are for moist soil unless otherwise noted.)

- Ap (0-20 cm)<sup>2</sup>--Very dark grayish-brown (10YR 3/2) silt loam, light brownish-gray (10YR 6/2) dry; weak fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine roots; many very fine irregular pores; slightly acid (pH 6.4); clear wavy boundary. (18 to 23 cm thick)
- B1 (20-48 cm)--Brown (10YR 4/3) loam, light gray (10YR 7/2) dry; common fine distinct (7.5YR 4/4 and 5/2) mottles; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine roots; many very fine irregular and tubular pores; slightly acid (pH 6.2); clear wavy boundary. (0 to 30 cm thick)
- B21 (48-85 cm)--Brown (10YR 4/3) loam, very pale brown (10YR 7/3) dry; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many fine roots; many very fine tubular pores; many fine distinct (10YR 5/2, 7.5YR 4/4, 5/4) mottles; about 3% pebbles 2 to 3 mm in diameter; slightly acid (pH 6.2); gradual smooth boundary. (25 to 51 cm thick)
- B22 (85-112 cm)--Brown (10YR 5/3) loam, very pale brown (10YR 7/3) dry; weak medium subangular blocky structure; slightly hard, slightly brittle when moist, slightly sticky, slightly plastic; common very fine roots; many very fine tubular pores; many medium distinct (7.5YR 4/4, 5/4, 5/2) mottles; about 5% pebbles 2 to 3 mm in diameter; medium acid (pH 6.0); gradual smooth boundary. (25 to 36 cm thick)
- C (112-180 cm)--Dark yellowish-brown (10YR 4/4) sandy loam, very pale (10YR 7/3) dry; massive; hard, friable, slightly sticky, slightly plastic; few very fine roots; few very fine tubular pores; many medium distinct (7.5YR 5/2 and 4/4) mottles; about 10% pebbles 2 to 3 mm in diameter; medium acid (pH 6.0).

Type Location: Hood River County, Oregon; SW NE SW section 33, T1N, R10E.

Range in Characteristics: The profiles are usually moist but dry during the summer months for more than 60 days in most years between (20 and 61 cm). The mean annual soil temperature ranges from

---

<sup>2</sup> Units of measure changed to metric units to conform with those used throughout the thesis.

47° to 52° F. Thickness of the sola ranges from (76 to 127 cm) and depth to bedrock is greater than (152 cm). The solum is slightly to medium acid. Coarse fragments, 2 to 3 mm, range from 2 to 10% in the B horizons. The A horizon has hues of 10YR to 7.5YR, values of 3 or 4 moist and 6 or 7 dry, and chromas of 2 or 3 dry and moist. It is silt loam or loam. The B horizon has values of 4 or 5 moist and 6 or 7 dry and chromas of 2 or 3 moist and dry. Chroma of 3 is in some part between (18 and 51 cm). It has many fine to medium distinct to prominent mottles with values of 4 or 5 and chromas of 2 to 6 when moist. It has mottles with chroma of 2 or less within 1 meter. The C horizon has values of 4 or 5 moist and 6 or 7 dry, and chromas of 2 to 4 moist and dry. It is loam, sandy loam, or sandy clay loam. It has 5 to 20% pebbles 2 to 3 mm in diameter.

Competing Series and their Differentiae: These are the Baugh, Chemawa, Crater Lake, Forward, Stabler, and Toutle series. Baugh soils are cindery. Chemawa, Crater Lake, Forward, Stabler, and Toutle soils lack mottles with chromas of 2 or less within 1 meter.

Setting: Dee soils are on nearly level to moderately steep uplands at elevations of (304 to 760 m). These soils formed in deep volcanic ash deposits over coarse glacial outwash materials. The mean annual precipitation is (89 to 114 cm). The mean annual temperature is 47° to 49° F, the mean January temperature is 29° to 33° F, and the mean July temperature is 61° to 65° F. The frost-free period (32° F) is 100 to 120 days and 28° F is 150 to 180 days.

Principal Associated Soils: These are the Parkdale soils. The Parkdale soils have an umbric epipedon and are well drained.

Drainage and Permeability: Somewhat poorly drained; slow to medium runoff; moderate permeability.

Use and Vegetation: Irrigated crops, hay and pasture. Native vegetation includes Douglas-fir, grand fir, ponderosa pine, vine maple, wild cherry, red alder, golden chinquapin, dogwood and other forbs and shrubs.

Distribution and Extent: Upper Hood River Valley, Oregon. The series is inextensive.

Series Proposed: Hood River County, Oregon, 1959.

Remarks: The Dee series was formerly classified as a Regosol.

## APPENDIX III-c

## DESCRIPTION OF SAMPLE SITE 152

Described by: B. L. Harris (1971)

Location: SW1/4 SE1/4 sec. 10, T2S, R9E

<u>Sample number</u>	<u>Depth (cm)</u>	<u>Description</u>
	0 - 3	Organic matter mixed with buff colored ash, fine sand to very fine sand texture.
	3 - 4-1/2	Organic matter layer, forest litter.
	4-1/2 - 6	Light, cream colored ash layer, few medium sand grains but mostly fine sand and very fine sand, loam to silt loam texture.
152-1	6 - 10	Yellow-brown fine to very fine sand, silt loam to loam texture.
	10 - 14	Pink with spots of gray, loam texture.
	14 - 14-1/2	Discontinuous ash, light grayish colored silt size material.
	14-1/2 - 15-1/2	Dark brown, much organic matter.
	15-1/2 - 16-1/2	Light gray layer.
152-2	16-1/2 - 36	Mottled-buff with reddish yellow mottles silt loam to loam texture with occasional coarser fragments.
152-3	36 - 40	Pink colored, silt loam to loam texture with occasional coarser fragments.
152-4	40 - 43	Light purple, grayer at top with pumice particles (approximately 0.75 cm maximum diameter) mixed with lithics, becoming finer at bottom, very fine sandy loam to loam texture.
	43 - 44-1/2	Yellowish-brown apparent fine sand to very fine sand breaking down on rubbing
152-5	44-1/2 - 49	Coarse gray material, sandy loam texture, much medium sand.
	49 - 53	Mixed sands, light purple.
152-6	53 - 55-1/2	Light purple, very fine sand texture.
152-7	55-1/2 - 75	Yellowish-brown material with lithics and yellow sand size pumice mixed in, highly weathered.
152-8	75 - 110	Weathered and yellowish material mixed with more lithics than above and increasing lithics with depth, sandy loam texture with much medium sand and fine sand with some yellowish sand size pumice particles.



# APPENDIX IV

CLIMATIC DATA FROM PARKDALE STATION, HOOD RIVER COUNTY, ELEVATION 529 m (after Johnsgard, 1963, p. 58)

Calendar period	Temperature data (°F)			Precipitation and water balance data (cm) <sup>b</sup>			
	Average max.	Average min.	Average	Average (ppt)	Average PE <sup>a</sup>	Surplus (ppt-PE)	Deficit (PE-ppt)
January	37.3	22.3	30.4	20.6	0.00	20.6	
February	42.7	25.2	34.3	14.7	0.5	14.2	
March	50.9	30.2	40.3	12.7	2.3	10.4	
April	60.8	34.0	47.0	5.8	5.1	0.8	
May	68.1	38.8	53.1	4.6	6.9		2.3
June	73.2	43.4	58.0	3.3	8.9		5.6
July	80.6	46.5	63.2	0.8	11.2		10.4
August	80.0	45.1	62.4	0.8	10.2		9.4
September	74.0	41.2	57.6	3.3	7.1		3.8
October	61.5	36.3	48.8	9.9	4.3	5.0	
November	47.0	29.7	38.6	17.5	1.3	16.3	
December	40.3	26.9	33.7	22.9	0.00	22.9	
Annual	59.7	35.0	47.3	116.8			

<sup>a</sup> Potential evapotranspiration

<sup>b</sup> Precipitation and water balance data converted from inches to cm.

## APPENDIX V-A

## SAND SUBFRACTION ANALYSES

Sample <sup>a</sup>	Depth (cm)	Percent of soil < 2 mm					
		sand	vcs	cs	ms	fs	vfs
101	-	51.2	0.2	2.8	10.2	18.6	4.9
102-1	5-10	59.6	1.0	5.9	7.8	12.8	32.0
102-2	11-20	54.4	4.9	5.9	6.0	16.0	21.6
103-1	5-9	50.6	0.2	2.5	4.1	14.8	29.0
103-2	10-30	53.7	4.1	5.8	5.6	17.0	21.2
104	99-109	59.6	0.3	9.8	19.2	19.9	10.3
105	15-30	41.4	2.1	3.9	4.9	8.2	22.3
106-1	5-15	36.1	0.4	1.9	4.5	14.5	14.9
106-2	35-50	24.4	0.7	2.3	4.4	12.4	4.7
107	15-30	39.7	2.7	5.8	5.8	15.1	10.4
108-1	3-7	44.6	0.8	2.2	3.5	7.4	30.7
108-2	12-30	47.7	3.1	4.7	4.9	15.3	19.7
109	15-23	41.0	1.5	2.8	4.9	15.0	16.8
110-1	1-15	43.8	N.D.	N.D.	N.D.	N.D.	N.D.
110-2	15-23	21.9	N.D.	N.D.	N.D.	N.D.	N.D.
110-3	23-38	23.8	4.6	7.0	4.4	5.4	2.4
110-4	38-51	38.6	9.0	10.8	6.3	8.2	4.3
110-5	51-76	48.7	N.D.	N.D.	N.D.	N.D.	N.D.
110-6	76-140	30.0	2.4	5.9	5.8	9.4	6.5
111-1	2-20	46.7	7.0	4.8	6.6	12.6	15.7
111-2	20-46	56.6	6.9	6.9	7.8	17.3	17.7
112-1	0-23	43.0	5.9	4.8	6.6	12.8	12.9
112-2	23-81	30.6	5.8	4.4	4.3	8.3	7.7
112-3	81-114	34.5	3.5	4.1	5.5	10.9	10.6
112-4	114-259	27.6	2.1	4.1	4.4	8.6	8.4
112-5	259-300	38.4	2.6	5.0	6.9	12.9	10.9
113-1	5-15	27.0	1.2	3.1	5.0	9.0	8.7
113-2	15-51	20.4	1.1	2.4	3.0	6.6	7.3
113-3	51-91	36.8	1.6	4.8	6.2	12.7	11.5
113-4	96-122	56.9	6.7	9.9	7.9	12.4	20.0
115-1	25-38	37.4	0.5	3.2	6.4	18.5	13.5
115-2	39-46	33.3	0.1	1.5	6.6	19.0	6.2
117-1	8-38	56.4	1.7	5.4	5.1	18.8	25.5
117-2	38-76	61.4	2.9	9.2	8.5	17.8	23.0
118-1	0-23	31.7	2.6	3.3	3.6	14.2	15.2
118-2	23-69	32.0	2.5	3.8	4.5	6.6	14.6

## Sand subfraction analyses (continued)

Sample	Depth (cm)	Percent of soil < 2 mm					
		sand	vcs	cs	ms	fs	vfs
119-1	0-20	39.0	2.6	4.4	8.6	13.2	10.2
119-2	61-76	33.0	1.7	4.0	6.8	11.1	9.3
119-3	200-220	25.7	1.0	3.2	3.3	8.1	8.4
121	2-41	56.8	20.4	6.1	6.4	12.8	11.2
122	13-36	43.2	6.7	4.8	7.9	13.1	10.7
123	25-36	42.5	8.2	4.6	5.9	13.6	10.2
130-1	2-25	49.7	4.9	4.5	10.4	17.5	12.4
130-2	25-56	43.7	N. D.	N. D.	N. D.	N. D.	N. D.
130-3	56-70	48.9	0.1	3.7	9.7	19.8	15.7
131-1	0-23	47.2	5.2	5.9	10.9	14.4	10.8
131-2	23-51	37.9	N. D.	N. D.	N. D.	N. D.	N. D.
131-3	51-122	33.2	0.4	3.9	7.9	12.4	8.6
132-1	0-30	40.3	1.6	4.5	8.9	14.3	11.0
132-2	30-61	34.6	N. D.	N. D.	N. D.	N. D.	N. D.
132-3	61-91	35.3	1.2	4.1	8.3	12.0	9.8
133-1	0-18	38.7	2.6	4.3	8.7	12.7	10.5
133-2	18-66	35.8	N. D.	N. D.	N. D.	N. D.	N. D.
133-3	66-102	34.8	1.3	4.3	6.9	11.3	11.0
134-1	0-23	37.7	1.7	3.8	7.3	13.3	11.6
134-2	23-46	36.9	N. D.	N. D.	N. D.	N. D.	N. D.
134-3	61-91	32.6	1.1	4.0	7.0	11.0	9.6
134-4	91-152	32.3	0.6	3.4	8.2	11.9	8.2
134-5	152-213	35.3	0.7	4.1	8.9	13.6	9.1
134-6	213-274	29.1	1.2	3.2	5.5	10.4	8.7
134-7	274-335	35.0	2.2	4.3	5.8	12.4	10.2
134-8	335-371	38.1	3.9	5.1	6.5	12.6	10.0
136-1	0-20	34.2	2.4	3.7	6.3	11.7	9.9
136-2	20-51	30.3	N. D.	N. D.	N. D.	N. D.	N. D.
136-3	61-84	22.8	0.8	2.4	4.1	8.1	7.5
137-1	0-25	44.9	2.1	3.8	6.8	14.7	17.5
137-2	25-61	41.0	2.6	3.6	6.1	13.3	15.4
137-3	76-102	41.8	0.8	1.8	3.1	6.8	8.2
138-1	0-25	42.9	0.8	3.7	8.3	15.3	14.8
138-2	25-46	41.3	0.8	4.3	7.8	15.6	13.2
138-3	71-96	38.7	0.4	3.8	8.6	14.6	11.4
138-4	96-152	38.7	0.7	4.2	9.4	14.1	10.3
138-5	152-213	38.2	0.9	4.0	1.7	19.2	12.4
138-6	213-274	33.3	2.5	3.8	6.2	10.7	10.0
138-7	274-330	37.0	2.6	3.9	3.7	14.4	12.4
140-1	0-23	38.0	1.6	5.4	9.5	13.0	8.5
140-2	23-46	34.1	0.9	4.7	8.0	12.2	8.4

## Sand subfraction analyses (continued)

Sample	Depth (cm)	Percent of soil < 2 mm					
		sand	vcs	cs	ms	fs	vfs
141-1	0-25	30.7	1.1	3.9	7.3	10.5	7.9
141-2	25-51	29.5	0.8	3.2	6.9	10.1	8.1
141-3	76-102	33.1	0.8	3.5	7.3	12.0	9.5
142-1	10-25	27.3	0.2	1.1	4.1	10.3	11.7
142-2	25-38	32.6	0.1	0.9	1.9	9.8	20.0
142-3	38-46	44.5	0.8	3.0	5.9	15.3	19.5
142-4	46-53	29.4	0.3	0.9	3.5	11.0	13.6
142-5	53-64	33.7	0.3	1.5	4.5	14.7	12.6
142-6	64-76	59.2	0.6	1.6	4.0	10.2	12.8
143-1	0-15	30.7	0.1	0.8	2.3	9.7	17.8
143-2	15-23	34.8	0.3	1.2	2.5	9.1	21.8
143-3	23-56	30.4	0.2	0.8	1.9	9.0	18.4
143-4	56-86	36.3	0.2	1.5	3.7	12.7	18.2
143-5	86-94	37.5	0.7	1.5	4.1	14.3	16.9
144-2	13-38	29.6	0.5	1.2	2.0	9.2	16.6
144-3	38-51	32.2	0.2	2.4	5.8	12.9	10.8
144-5	52-61	14.6	0.1	0.8	2.2	6.6	5.1
145-1	13-38	46.8	2.8	8.6	8.6	15.1	11.7
145-2	4-10	67.8	2.0	12.5	14.5	23.3	15.6
147-2	13-51	67.1	12.3	19.0	9.7	13.7	12.5
148-2	13-30	67.1	16.3	21.4	8.9	10.8	9.7
150-1	60-102	23.7	trace	0.2	0.3	2.7	20.4
151-2	27-51	36.4	0.6	2.5	3.1	10.3	19.9
151-3	60-67	49.0	1.2	4.6	3.9	16.3	23.1
151-4	72-84	68.2	3.2	6.6	9.2	25.4	23.7
152-1	6-10	35.7	0.6	2.8	3.9	10.8	17.7
152-2	16-36	30.4	0.2	0.4	1.0	7.5	21.3
152-3	36-40	31.9	0.7	0.8	1.3	8.3	20.7
152-4	40-43	42.9	1.1	2.2	3.4	13.8	22.5
152-5	44-49	67.7	4.1	16.3	13.3	18.7	15.3
152-6	53-55	39.5	0.3	2.3	3.8	12.5	20.6
152-7	55-75	71.9	3.8	5.6	10.3	28.0	24.2
152-8	75-110	69.1	4.6	7.3	10.0	25.2	22.0
157-2	7-15	37.5	0.2	1.6	9.1	15.4	11.2
157-3	15-17	22.8	0.1	0.7	1.7	6.2	14.1
157-5	18-33	38.5	0.1	3.3	11.2	17.0	6.9
157-6	28-38	26.3	trace	1.4	5.4	14.3	5.2
166-1a	5-25	43.4	10.1	3.3	4.9	7.3	17.7
166-1b	51-76	35.4	2.1	3.1	4.6	4.9	20.7
166-2a	102-127	43.4	1.7	4.5	4.0	19.4	13.8
166-2b	165-198	41.8	1.4	4.6	7.9	14.3	13.5
166-3	198-267	44.8	3.7	4.6	5.9	14.4	16.1

## Sand subfraction analyses (continued)

Sample	Depth (cm)	Percent of soil < 2 mm					
		sand	vcs	cs	ms	fs	vfs
166-5	267-318	45.7	1.1	2.4	4.5	16.0	21.7
166-6	318-389	41.2	2.5	3.2	5.4	15.0	15.2
166-7	389-488	79.6	31.8	18.8	6.1	15.3	7.6
166-8	488-569	35.2	2.8	4.4	4.3	12.7	11.0
166-9	569-645	82.7	23.5	20.4	4.8	23.9	10.2
166-10	645-683	42.6	0.6	3.1	3.0	22.0	13.8

<sup>a</sup> Sample site locations given in Appendix I.

## APPENDIX V-B

## SAND SUBFRACTION RATIOS AND CORRELATIONS

Sample <sup>a</sup>	Depth (cm)	vfs/fs		fs/ms		ms/cs	
		ratio	within 95% CI <sup>b</sup>	ratio	within 95% CI <sup>c</sup>	ratio	within 95% CI <sup>d</sup>
101	-	0.3	no	1.8	yes	3.6	no
102-1	5-10	2.5	no	1.6	yes	1.3	yes
102-2	11-20	1.4	no	2.7	no	1.0	yes
103-1	5-9	2.0	no	3.6	no	1.6	yes
103-2	10-30	1.3	no	3.0	no	1.0	yes
104	99-109	0.5	no	1.0	no	2.0	yes
105	15-30	2.7	no	1.7	yes	1.3	yes
106-1	5-15	1.0	yes	3.2	no	2.4	yes
106-2	35-50	0.4	no	2.8	no	1.9	yes
107	15-30	0.7	yes	2.6	no	1.0	yes
108-1	3-7	4.1	no	2.1	yes	1.6	yes
108-2	12-30	1.3	no	3.1	no	1.0	yes
109	15-23	1.1	no	3.1	no	1.7	yes
110-3	23-38	0.4	no	1.2	no	0.6	no
110-4	38-51	0.5	no	1.3	yes	0.6	no
110-5	51-76	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
110-6	76-140	0.7	yes	1.6	yes	1.0	yes
111-1	2-20	1.2	no	1.9	yes	1.4	yes
111-2	20-46	1.0	yes	2.2	yes	1.1	yes
112-1	0-23	1.0	yes	1.9	yes	1.4	yes
112-2	23-81	0.9	yes	1.9	yes	1.0	yes
112-3	81-114	1.0	yes	2.0	yes	1.3	yes
112-4	114-259	1.0	yes	2.0	yes	1.1	yes
112-5	259-300	0.8	yes	1.9	yes	1.4	yes
113-1	5-15	1.0	yes	1.8	yes	1.6	yes
113-2	15-51	1.1	no	2.2	yes	1.3	yes
113-3	51-91	0.9	yes	2.0	yes	1.3	yes
113-4	96-122	1.6	no	1.6	yes	0.8	no
115-1	25-38	0.7	yes	2.9	no	2.0	yes
115-2	39-46	0.3	no	2.9	no	4.4	no
117-1	8-38	1.4	no	3.7	no	0.9	no
117-2	38-76	1.3	no	2.1	yes	0.9	no
118-1	0-23	1.1	no	3.9	no	1.1	yes
118-2	23-69	2.2	no	1.5	yes	1.2	yes
119-1	0-20	0.8	yes	1.5	yes	2.0	yes
119-2	61-76	0.8	yes	1.6	yes	1.7	yes
119-3	200-220	1.0	yes	2.5	no	1.0	yes

## Sand subfraction ratios and correlations (continued)

Sample	Depth (cm)	vfs/fs		fs/ms		ms/cs	
		ratio	within 95% CI	ratio	within 95% CI	ratio	within 95% CI
121	2-41	0.9	yes	2.0	yes	1.0	yes
122	13-36	0.8	yes	1.7	yes	1.6	yes
123	25-36	0.8	yes	2.3	no	1.3	yes
130-1	2-25	0.7	yes	1.7	yes	2.3	yes
130-2	25-56	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
130-3	56-70	0.8	yes	2.0	yes	2.6	yes
131-1	0-23	0.8	yes	1.3	yes	1.8	yes
131-2	23-51	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
131-3	51-122	0.7	yes	1.6	yes	2.0	yes
132-1	0-30	0.8	yes	1.6	yes	2.0	yes
132-2	30-61	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
132-3	61-91	0.8	yes	1.4	yes	2.0	yes
133-1	0-18	0.8	yes	1.5	yes	2.0	yes
133-2	18-66	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
133-3	66-102	1.0	yes	1.6	yes	1.6	yes
134-1	0-23	0.9	yes	1.8	yes	1.9	yes
134-2	23-46	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
134-3	61-91	0.9	yes	1.6	yes	1.8	yes
134-4	91-152	0.7	yes	1.5	yes	2.4	yes
134-5	152-213	0.7	yes	1.5	yes	2.2	yes
134-6	213-274	0.8	yes	1.9	yes	1.7	yes
134-7	274-335	0.8	yes	2.1	yes	1.3	yes
134-8	335-371	0.8	yes	1.9	yes	1.3	yes
136-1	0-20	0.8	yes	1.9	yes	1.7	yes
136-2	20-51	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
136-3	61-84	0.9	yes	2.0	yes	1.7	yes
137-1	0-25	1.2	no	2.2	yes	1.8	yes
137-2	25-61	1.2	no	2.2	yes	1.7	yes
137-3	76-102	1.2	no	2.2	yes	1.7	yes
138-1	0-25	1.0	yes	1.8	yes	2.2	yes
138-2	25-46	0.8	yes	2.0	yes	1.8	yes
138-3	71-96	0.8	yes	1.7	yes	2.3	yes
138-4	96-152	0.7	yes	1.5	yes	2.2	yes
138-5	152-213	0.6	yes	11.1	no	0.4	no
138-6	213-274	0.9	yes	1.7	yes	1.6	yes
138-7	274-330	0.9	yes	3.9	no	0.9	no
140-1	0-23	0.7	yes	1.4	yes	1.8	yes
140-2	23-46	0.7	yes	1.5	yes	1.7	yes
141-1	0-25	0.8	yes	1.4	yes	1.9	yes
141-2	25-51	0.8	yes	1.5	yes	2.2	yes
141-3	76-102	0.8	yes	1.6	yes	2.1	yes

Sand subfraction ratios and correlations (continued)

Sample	Depth (cm)	vfs/fs		fs/ms		ms/cs	
		ratio	within 95% CI	ratio	within 95% CI	ratio	within 95% CI
142-1	10-25	1.1	no	2.5	no	3.7	no
142-2	25-38	2.0	no	5.2	no	2.1	yes
142-3	38-46	1.3	no	2.6	no	2.0	yes
142-4	46-53	1.2	no	3.1	no	3.9	no
142-5	53-64	0.9	yes	3.3	no	3.0	no
142-6	64-76	1.3	no	2.6	no	2.5	yes
143-1	0-15	1.8	no	4.2	no	2.9	no
143-2	15-23	2.4	no	3.6	no	2.1	yes
143-3	23-56	2.0	no	4.7	no	2.4	yes
143-4	56-86	1.4	no	3.4	no	2.5	yes
143-5	86-94	1.2	no	3.5	no	2.7	yes
144-2	13-38	1.8	no	4.6	no	1.7	yes
144-3	38-51	0.8	yes	2.2	yes	2.4	yes
144-5	52-61	0.8	yes	3.0	no	2.8	no
145-1	13-38	0.8	yes	1.8	yes	1.0	yes
145-2	4-10	0.7	yes	1.6	yes	1.2	yes
147-2	13-51	0.9	yes	1.4	yes	0.5	no
148-2	13-30	0.9	yes	1.2	no	0.4	no
150-1	60-102	7.6	no	9.0	no	1.5	yes
151-2	27-51	1.9	no	3.3	no	1.2	yes
151-3	60-67	1.4	no	4.2	no	0.8	no
151-4	72-84	0.9	yes	2.8	no	1.4	yes
152-1	6-10	1.6	no	2.8	no	1.4	yes
152-2	16-36	2.8	no	7.5	no	2.5	yes
152-3	36-40	2.5	no	6.4	no	1.6	yes
152-4	40-43	1.6	no	4.1	no	1.5	yes
152-5	44-49	0.8	yes	1.4	yes	0.8	no
152-6	53-56	1.6	no	3.3	no	1.7	yes
152-7	56-75	0.9	yes	2.7	no	1.8	yes
152-8	75-110	0.9	yes	2.5	no	1.4	yes
157-2	7-15	0.7	yes	1.7	yes	5.7	no
157-3	15-17	2.3	no	3.6	no	2.4	yes
157-5	18-28	0.4	no	1.5	yes	3.4	no
157-6	28-38	0.4	no	2.6	no	3.9	no
166-1a	5-25	2.4	no	1.5	yes	1.5	yes
166-1b	51-76	4.2	no	1.1	no	1.5	yes
166-2a	102-127	0.7	yes	4.9	no	0.9	no
166-2b	165-198	0.9	yes	1.8	yes	1.7	yes
166-3	198-267	1.1	no	2.4	no	1.3	yes
166-5	267-318	1.4	no	3.6	no	1.9	yes
166-6	318-389	1.0	yes	2.8	no	1.7	yes
166-7	389-488	0.5	no	2.5	no	0.3	no



## Sand subfraction ratios and correlations (continued)

Sample	Depth (cm)	vfs/fs		fs/ms		ms/cs	
		ratio	within 95% CI	ratio	within 95% CI	ratio	within 95% CI
166-8	488-569	0.9	yes	3.0	no	1.0	yes
166-9	569-645	0.4	no	5.0	no	0.2	no
166-10	645-683	0.6	yes	7.3	no	1.0	yes

<sup>a</sup> Sample site locations given in Appendix I.

<sup>b</sup> 95% confidence interval around mean of values from all horizons of modal Parkdale soil profiles, sites 134 and 138 ( $0.81 \pm 0.23$ ).

<sup>c</sup> 95% confidence interval around mean of values from all horizons of modal Parkdale soil profiles, sites 134 and 138 ( $1.75 \pm 0.45$ ).

<sup>d</sup> 95% confidence interval around mean of values from all horizons of modal Parkdale soil profiles, sites 134 and 138 ( $1.89 \pm 0.83$ ).

## APPENDIX V-C

## PARTICLE SIZE DISTRIBUTION FOR TWO TYPICAL PARKDALE SOILS

(after Soil Survey Staff, 1965)

Depth (cm)	Horizon	Particle size distribution in mm (%) <sup>a</sup>								
		<u>vcs</u>	<u>cs</u>	<u>ms</u>	<u>fs</u>	<u>vfs</u>	<u>silt</u>	<u>clay</u>		
		2-1	1-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.002	< 0.002	0.2-0.02	0.02-0.002
<u>Profile 1<sup>b</sup></u>										
0-13	Ap1	0.7	6.0	8.1	16.0	13.3	49.8	6.1	46.2	25.9
13-25	Ap2	1.0	5.9	8.2	15.9	13.5	49.7	5.8	47.1	25.1
25-46	B2	0.8	5.1	8.3	15.4	14.2	51.9	4.3	49.3	25.7
46-69	C1	0.7	6.2	8.2	15.6	13.7	51.1	4.5	51.8	21.8
69-127	C2	0.3	4.3	7.6	15.2	14.6	52.9	5.1	49.5	26.7
127-190	C3	0.8	6.1	8.6	15.5	14.1	48.2	6.7	44.5	26.7
190-254	C4	1.0	7.5	10.1	16.1	12.0	45.5	7.8	41.4	25.7
<u>Profile 2<sup>c</sup></u>										
0-13	Ap1	3.7	7.2	8.1	13.9	10.6	48.5	8.0	40.9	26.0
13-23	Ap2	4.7	7.1	8.2	13.3	10.7	48.6	7.4	38.9	27.5
23-46	B2	2.9	6.9	8.1	12.9	11.7	51.0	6.5	42.5	27.4
46-69	C1	1.3	6.5	8.5	13.4	11.6	52.7	6.0	43.6	28.2
69-117	C2	0.6	4.9	8.2	12.9	12.0	54.3	7.1	43.7	29.7
117-188	C3	1.0	7.4	11.1	16.0	11.8	43.9	8.8	40.2	24.1
188-254	C4	1.2	10.3	12.8	21.0	13.6	33.4	7.7	37.8	20.7

<sup>a</sup> vcs = very coarse sand; cs = coarse sand; ms = medium sand; fs = fine sand; vfs = very fine sand<sup>b</sup> Profile 1 Location: NE1/4 NE1/4 SE1/4 sec. 6, T1S, R10E<sup>c</sup> Profile 2 Location: NE 1/4 SE1/4 NW1/4 sec. 32, T1N, R10E

## APPENDIX VI

PERCENTAGE OF MATERIAL  $\geq 2$  MM AND  $< 2$  MM FOR  
TWO PARKDALE SOIL PROFILES AND A SOIL AT CLOUD CAP

Sample	Depth (cm)	Percent $\geq 2$ mm	Percent $< 2$ mm
<u>Parkdale</u>			
134-1	0-23	9.5	90.5
134-2	23-46	9.5	90.5
134-3	61-91	4.4	95.6
134-4	91-152	3.6	96.4
134-5	152-213	8.1	91.9
134-6	213-274	8.8	91.2
134-7	274-335	13.2	86.8
134-8	335-371	22.2	77.8
<u>Parkdale</u>			
138-1	0-25	4.0	96.0
138-2	25-46	3.7	96.3
138-3	71-96	2.2	97.8
138-4	96-152	1.6	98.4
138-5	152-213	3.9	96.1
138-6	213-274	8.1	91.9
138-7	274-330	27.7	72.3
<u>Cloud Cap</u>			
152-1	6-10	0.1	99.9
152-2	16-36	0.3	99.7
152-3	36-40	0.8	99.2
152-4	40-43	6.7	93.3
152-5	44-49	0.7	99.3
152-6	53-56	0.0	100.0
152-7	56-75	31.8	68.2
152-8	75-110	31.9	68.2

<sup>a</sup> Sample site locations given in Appendix I.

## APPENDIX VII

## CHEMICAL ANALYSES

Sample	Depth (cm)	% SiO <sub>2</sub>	% Al <sub>2</sub> O <sub>3</sub>	% Fe <sub>2</sub> O <sub>3</sub>	% ZrO <sub>2</sub>	% TiO <sub>2</sub>	% CaO	% K <sub>2</sub> O
134-1	0-23	53.2	19.3	7.5	0.03	1.0	3.8	1.2
134-2	23-46	53.7	20.9	8.2	0.03	1.1	3.2	1.2
134-3	61-91	53.2	21.4	8.2	0.03	1.1	3.0	1.2
134-4	91-152	50.6	23.1	8.5	0.03	1.1	3.2	0.9
134-5	152-213	49.0	24.1	9.0	0.03	1.2	2.8	0.8
134-6	213-274	49.0	24.2	9.3	0.03	1.2	2.5	0.8
134-7	274-335	47.9	24.5	9.2	0.03	1.2	2.4	0.7
134-8	335-371	48.5	24.4	9.4	0.03	1.3	2.5	0.8
St. Helens J	-	52.7	24.1	4.8	0.03	0.6	4.0	0.9
St. Helens M (upper)	-	60.6	20.5	3.5	0.02	0.5	3.8	1.2
St. Helens M (lower)	-	52.7	24.2	5.7	0.03	0.7	4.6	0.8
St. Helens (unnamed)	-	50.6	27.2	4.6	0.03	0.7	5.0	0.4
129	-	52.7	19.6	8.5	0.01	1.1	6.5	0.7
180	-	60.6	20.1	5.1	0.03	0.7	5.4	1.4
Concretions I	-	48.5	24.7	8.8	0.03	1.1	2.9	0.8
Concretions II	-	50.0	23.5	8.1	0.03	1.0	3.2	0.9
62-19	183-193	67.4	16.1	2.3	0.04	0.6	2.0	2.4
115-2	39-46	52.7	22.3	4.9	0.04	0.9	2.3	1.5
133-3	66-102	49.5	21.7	12.5	0.02	1.8	2.0	1.0
143-3	23-56	61.6	16.2	4.5	0.03	0.7	3.7	1.6
142-2	25-38	66.9	15.8	3.4	0.03	0.7	3.6	1.6
145-2	4-10	52.7	20.8	7.1	0.03	1.0	4.7	0.8
160-2	60-175	54.3	22.6	6.3	0.02	0.7	6.9	0.5
168-6	620-627	60.1	22.0	1.6	0.03	0.4	5.8	0.6
169-2	107-175	54.3	22.2	9.4	0.03	1.2	2.7	1.1
152-1	6-10	64.3	17.1	4.6	0.02	0.7	4.2	1.6
152-2	16-36	57.9	16.4	5.2	0.03	0.7	3.7	1.7
152-3	36-40	64.3	15.6	4.8	0.03	0.7	3.7	1.7
152-4	40-43	63.1	16.4	4.4	0.03	0.6	4.2	1.6
152-5	44-49	59.5	17.9	5.9	0.02	0.8	5.1	1.3
152-6	53-56	60.6	17.6	5.6	0.02	0.8	4.6	1.4
152-7	56-75	53.2	20.5	7.4	0.02	1.0	4.9	1.1

(Continued on next page)

## Chemical analyses (continued)

Sample	Depth (cm)	% SiO <sub>2</sub>	% Al <sub>2</sub> O <sub>3</sub>	% Fe <sub>2</sub> O <sub>3</sub>	% ZrO <sub>2</sub>	% TiO <sub>2</sub>	% CaO	% K <sub>2</sub> O
170	28-43	65.3	16.3	6.2	0.04	1.2	2.1	2.0
173	-	59.0	18.9	6.2	0.03	0.9	5.7	1.5
178-1	0-20	62.7	17.6	6.5	0.03	1.0	3.6	1.3
178-2	20-48	62.7	17.4	7.2	0.03	1.0	3.4	1.3
178-3	48-86	62.7	17.4	7.4	0.03	1.1	2.9	1.2
178-4	86-114	61.1	18.2	7.7	0.03	1.0	3.3	0.9
178-5	114-183	57.7	19.3	9.3	0.03	1.1	2.8	0.8
178-6	191-203	56.4	20.4	9.4	0.03	1.1	2.1	0.8
179-2	46-61	65.3	15.6	6.1	0.04	0.9	2.9	2.0
110-1	1-15	54.8	18.9	5.3	0.04	1.1	2.3	1.1
110-2	15-23	44.3	27.8	6.4	0.05	1.2	1.7	0.9
110-3	23-38	44.3	23.7	14.6	0.02	1.6	0.8	0.8
110-4	38-51	41.6	24.0	16.4	0.01	1.9	0.4	0.4
110-5	51-76	43.2	26.8	13.9	0.02	2.0	0.4	0.3
110-6	76-140	44.3	26.2	14.1	0.02	2.0	0.4	0.4