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Title STATE OF WEATHERING OF SOME UPLAND SOILS IN THE ALSEA BASIN, OREGON

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Mineralogical analysis of 3 upland soil profiles over Tyee parent rock from the Alsea Basin Area, Oregon showed clear differences among the 4 soil series represented. Soils from the area of higher precipitation (over 80 inches, approximately) had no montmorillonite, lower base saturation and cation exchange capacity, but no lower or only slightly lower amounts of weatherable minerals than soils from the area of lower precipitation. Only the profiles in the lower precipitation area had significant ped coatings of oriented clay. Shallow, yellowish soils, in both precipitation zones were much fresher mineralogically than the corresponding deep, red soils. The most strongly weathered profiles had contents of weatherable minerals too high for Latosols or Oxisols. The change with depth in the red soils suggested that these soils had not formed entirely from rock in place. Fragments of clay skins in the red soils suggested that these soils had developed, with mixing, from older soils. Pyroclastic materials and local mixing are believed responsible for the higher contents of weatherable minerals in the surface horizons of the profiles. The soils were classified in the 1938 Yearbook system as well as in the Seventh Approximation.

STATE OF WEATHERING OF SOME UPLAND SOILS IN THE ALSEA BASIN, OREGON

by

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TABLE OF CONTENTS

STATE OF WEATHERING OF SOME UPLAND SOILS IN THE ALSEA BASIN, OREGON

INTRODUCTION

Upland soils of the Oregon (and Washington) Coast Range present problems in classification by the present 1938 Yearbook system (6). Two general climatic zones are involved. In the more humid areas with 60 to 140 inches of precipitation, the so-called Brown Latosols[1/] (14, 33) are dominant. Further inland where the precipitation is lower (40 to 60 inches), the so-called Reddish Brown Latosols[1/] (14, 33) are dominant. The "Reddish Brown Latosols" have much in common with the Reddish-Brown Lateritic soils and are now classified with them.[2/] The "Brown Latosols" are not so easily classified. They are relatively dark, clayey, well drained, strongly leached soils, mostly yellow-brown (hue of 10YR) but ranging to red (hue of 2.5YR). They have some similarities with Reddish-Brown Lateritic soils (6, 18, 39, 41, 46), Yellowish-Brown Lateritic soils (6, 46), the general group of Latosols (30, 31), Red-Yellow

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1/ Soil Correlation Staff. Provisional Family grouping of soils in the Far West States, Division of Soil Survey U. S. D. A. (unpublished) May 1952.

2/ Dr. Ellis G. Knox personal communication.

soils of Japan (29), Humic Latosols in Hawaii (16) and Sols Bruns Acides (7, 51). Information about the state of weathering and clay distribution is needed for better understanding and classification.

Both Reddish-Brown Lateritic soils and the so-called Brown Latosols were mapped in the Alsea Basin Area Soil and Vegetation Survey. Deep, red soils in relatively stable areas and shallow, yellow soils on steep slopes were found in both precipitation zones over a common rock type (Tyee formation) and seem to represent extremes in the state of weathering. In the higher rainfall area the deep, yellow-brown (hue of 10YR) profile most typical of the so-called Brown Latosol group is probably intermediate in its state of weathering. Only the deep, red soils and the shallow yellow soils of both zones were selected for this study.

In recent years, petrographic methods as used in petrography and sedimentary petrology have been used and modified by various workers in soils. The identification and chemical composition of the light minerals (specific gravity less than 2.75), mainly quartz, feldspars and mica, in the soils are of great importance when studying soil-weathering processes and for the purposes of correlation. The present of quartz, the most stable mineral, together with feldspar, which is relatively unstable and easily weathered, provides opportunity to use their ratios as a weathering index in comparing different types of soils.

Subsidiary investigations, involving the study of heavy minerals, thin-sections of oriented samples, and X-ray diffraction of clay, may be expected to yield additional information about the soils in question.

The objectives of this investigation were:

1) To determine the degree of weathering of soils in the Alsea Basin and to establish the sequence of weathering and clay distributions through the profiles of the soils.

2) To compare and contrast the degree of weathering of the soils in the high and low rainfall zones as well as the red and yellow soils of each particular zone.

3) To relate the characteristics found in so far as possible to the classification of these soils.

DESCRIPTION OF THE STUDY AREA

Geology and Topography

More than 70 to 80% of the parent rocks in the Alsea Basin belongs to the Middle Eocene, Tyee formation which was described by Baldwin (4, 5) as bluish grey to grey, rhythmically bedded, micaceous and arkosic sandstones and sandy siltstone, commonly 6000 to 7000 feet thick in this particular area. The sandstone is firmly compacted and characterized by an abundance of muscovite and bleached biotite flakes. Each bed represents a graded sequence of sediment in which medium grained sandstones make up most of the bed, but grade upward sharply into fine-grained sandstone and siltstone near the top.

The oldest rock in the central part of the Coast Range which uncomformably underlies the Tyee formation is the Siletz River volcanic series. It is composed of a thick sequence of basalt flows, pillow lavas and pyroclastic rocks and commonly outcrops along the eastern edge of the basin around Prairie Peak and east of the Marys Peak area. Other minor parent rocks in the area occurred in the forms of thin dioritic and gabbroic intrusives, sills and dikes throughout the basin (4). To the west, along the coast, the outcropping rocks belong to the Toledo formation (tuffaceous sandstone, shales and mudstones) of Upper Eocene and Oligocene age (58).

In recent years, sedimentary features, like the rhythmic beds and the flow casts and load casts in the sandstone which are commonly found in the Tyee formation, have been linked to sedimentation by turbidity currents in a deep water environment (48, p. 280).

The gradual uplift during Pliocene-Pleistocene time together with eustatic lowering of the sea level during Wisconsin age as much as 450 feet (47) resulted in a rugged mountainous topography of the Oregon Coast Range, with many shallowly or deeply dissected drainage patterns with streams flowing westward into the ocean. Slumping and landsliding are fairly common in this particular area, mainly due to the soft nature of the Tyee sandstone and siltstone rocks. Elevation of the upland areas range from 500 feet to 4000 feet, but the main streams are mostly below 1000 feet and throughout much of their course below 500 feet. Steep upland slopes dominate the landscape. Terraces of different elevations (1000, 600 to 650, 500 to 550, and 300 feet) are common but there are not as well developed or well preserved as in the area further south (5, p. 20).

Climate

The Alsea Basin has a marine climate, with high precipitation (relative to continental United States) concentrated in the winter and without wide range in temperature throughout the year. Most of the weather stations in the area are along the coast or further inland in the valleys so the records registered are either slightly too high or too low for the general upland area in the Alsea Basin.

In the high rainfall area along the coast the precipitation is 80 to 120 inches per year. The summer is dry. The average January and July temperatures are 38°F. and 60°F. respectively. The average frost free season is about 170 days. The low rainfall area which is further inland around the town of Alsea has moderate marine climate with precipitation of 60 to 80 inches per year. It has a strong dry season during the summer, the average January and July temperatures are 40°F. and 63°F. respectively. The average frost free season is about 180 days.

Vegetation

The vegetation type is largely Douglas-fir[3/] with some hemlock, western redcedar, and certain deciduous species such as big-leaf

3/ Scientific names of species mentioned in this study are shown in Appendix II.

maple, alder, and western dogwood. The understory varies considerably depending on aspect and precipitation. The most common species in the understory are vine maple, salal, sword fern, other less abundant species include ocean spray, hazel, red huckleberry, Oregon grape, western dewberry, salmonberry, bracken fern, and several small and generally inconspicuous herbaceous plants and grasses. The vegetation is dense and the growth rate of Douglas-fir and the other trees is rapid. Site indexes of 180 to 200 are common

MATERIALS AND METHODS

Field Procedure

Soil samples were collected and described from eight selected locations in the Alsea Basin, Oregon (Table 1). Deep, red (2.5 YR hue), apparently old and stable soils were taken to represent the most strongly weathered extreme. Shallow, yellow (10YR hue), stony, steep soils were taken to represent the least weathered extreme. Two red profiles in each of the rainfall areas were selected on ridge tops or on old stable slumps where there was no indication of mixing from recent slumping. One yellow profile was selected as closely as possible to each of the red profiles.

All soil sites studied were selected from Tyee sandstone parent materials, and all are from the upland area. Samples were collected by horizons (with arbitrary subdivision of thick horizons). These samples were used for physical and chemical determinations as well as grain counts and clay X-ray study. In addition, undisturbed, oriented block samples were also collected at selected intervals from surface to bed rocks (if possible) for the purpose of thin section study.

Due to the instability of the soft Tyee rock, with frequent slumping and landsliding, as mentioned earlier, old, stable, red soil surfaces are difficult to find. Most of these old red soils were subjected to slumping and mixing and, in many instances, occupied lower elevations than the stonier and shallow yellow soils.

The sample locations ranged from 650 to 1650 feet in elevation. The lowest locations were 650 and 900 feet respectively. This is well over the 500 foot "terrace", common in this area, especially in the western part of the basin. Allen and Baldwin (2, p. 44) found that the 500 foot terrace was quite extensive in the Coos Bay quadrangle, ranging from 400 to 600 feet in elevation.

Locations of all the soil profiles are shown in the Appendix I together with appropriate profile descriptions.

Laboratory Procedures

Preparation of soil samples

All samples were air dried, crushed and passed through a 2 mm. sieve. Various sizes of sandstone fragments were common in most of the samples collected. Care was taken in eliminating them as much as possible before the samples were crushed.

Table 1. Relationships of the profile names, symbols, climatic regions and elevation of the soil studied.

Profile name	Symbol	Proposed series[4/] name	Climate	Elevation (feet)
Trout Creek-Red	TC-R	Honeygrove	Lower rainfall area (60 to 80 in.)	1500
Trout Creek-Yellow	TC-Y	Digger		1500
Fern Prairie-Red	FP-R	Honeygrove		850
Fern Prairie-Yellow	FP-Y	Digger		900
Prairie Peak-Red	PP-R	Blachly	Higher rainfall area (80 to 120 in.)	1650
Prairie Peak-Yellow	PP-Y	Bohannon		1650
Red Creek-Red	RC-R	Blachly		650
Red Creek-Yellow	RC-Y	Bohannon		650

4/ Proposed series names were from Alsea Basin Area Soil and Vegetation Survey final field review report, Oregon Agricultural Experiment Station, Corvallis, Oregon. 1961.

Physical and chemical analyses[5/]

Mechanical analyses of a 10 g. sample, after organic matter removal by mean of digestion with 30% hydrogen peroxide, were performed by the pipette method (32). Calgon (sodium hexameta-phosphate) was used as the dispersing agent. In addition, bulk density and moisture percentages at 1/10 and 0.5 atmosphere were determined in some selected horizons.

Chemical analyses procedures used were those of Oregon State University, Soil Testing Laboratory (1). Cation exchange capacity was determined by the ammonium acetate method. pH was determined by glass electrode in 1:1 soil-water paste. Total nitrogen was determined by the Kjeldahl method. Organic matter was digested by the Walkley-Black wet digestion procedure. Flame photometer method was used to determine calcium, potassium, magnesium and sodium.

Tables of physical and chemical data were shown in Appendix I, following the appropriate soil profile descriptions.

5/ Physical and chemical analyses were performed by Soil Physics and Soil Testing Laboratories, Oregon State University, Corvallis, Oregon respectively as a part of the Alsea Basin Area soil and vegetation survey.

Pre-treatment for grain mounts

A 20 gram sample was taken from each of the horizons and sub-horizons collected. Organic matter removal, dispersion and segregation procedures were followed according to Kilmer and Alexander (32). Thirty to thirty-five percent hydrogen peroxide was used for organic matter removal. Calgon (sodium hexametaphosphate) was used as the dispersing agent. Free iron oxides were removed according to Mackenzie (36). The process was repeated at least three times to ensure the complete removal of free iron oxides.

The soil samples previously treated for organic matter and iron removal, were dispersed by an air jet stirrer apparatus, as modified by Chu and Davidson (15), for 10 minutes using pressure of 25 pounds per square inch. The separation for the sand fraction (50μ and above) was made by wet sieving through a 300 mesh sieve. The sand fraction was dried and weighed. Subsequent fractionation of the sand fraction was done with a mechanical shaker with appropriate sieves for very coarse and coarse sand (2000 to 500μ), medium sand (500 to 250μ), fine sand (250 to 100μ), and very fine sand (100 to 50μ).

Table 2 shows the percentages of total sand, very coarse and coarse sand, medium sand, fine sand, and very fine sand fractions. Total sand values are slightly lower than the percentages of sand in Appendix I because of iron removal. The sand fraction percentages were determined after the grain mounts were made, so that their sum may be slightly less than the total sand percentage.

Specific gravity separation

Gravity separation of the selected sand fractions was done by using bromoform heavy liquid with specific gravity 2.8885. The separatory apparatus as described by Krumbein and Pettijohn (34, p. 335) was used. This method was preferred for its simplicity and quickness in operation. The separation was reasonably accurate for the purpose required, since the main objective of this study was concentrated in the light mineral fraction.

Acetone which is miscible in all proportions with bromoform was used for washing the grains during the procedure. Bromoform can be recovered for reuse from bromoform - acetone solution as described by Krumbein and Pettijohn (34, p. 337).

It was found that bromoform liquid at 2.8885 specific gravity gave reasonably complete separation of quartz (sp. gr. = 2.66),

Table2. Particle size separation of the sand fractions

Horizon	(inches) Depth	Total sand (·/·)	Sand fractions (·/·) 2000-500μ	500-250μ	250-100μ	100-50μ
Trout Creek - Red						
A1	0-6	20.0	2.4	2.7	6.2	6.4
A3	6-12	18.5	2.0	1.7	6.0	8.0
B11	12-19	17.7	0.7	2.1	5.8	7.5
B12	19-27	13.5	0.9	1.4	4.3	5.8
B21	27-36	13.5	0.9	1.0	7.5	5.9
B22	36-45	14.6	0.9	1.2	4.9	6.5
B22	45-54	15.7	1.3	2.0	5.2	6.6
B22	54-63	8.6	0.7	1.4	2.9	2.6
B22	63-72	12.7	0.8	1.2	4.2	5.7
B23	72-80	13.7	0.8	1.3	4.4	6.0
B23	80-88	15.9	0.9	1.2	5.3	7.2
B23	88-95	18.2	0.9	1.7	5.1	7.1
B3	95-105	16.7	1.1	1.9	5.7	7.3
Fern Prairie - Red						
A11	0-5	14.4	1.9	1.4	3.7	5.4
A12	5-10	14.3	1.5	1.4	4.0	5.8
A3	10-16	12.0	0.9	0.9	3.2	4.9
B11	16-22	14.1	1.9	1.6	4.0	5.3
B12	22-28	14.5	1.8	1.4	4.2	5.5
B21	28-35	14.4	1.8	1.5	4.0	5.4
B22	35-41	12.9	1.7	1.5	3.9	4.8
B22	41-47	12.5	1.5	1.3	3.8	4.7
B23	47-56	11.6	1.4	1.2	3.3	4.6
B24	56-63	11.3	1.0	1.0	3.4	4.9
B24	63-71	12.3	1.0	1.1	3.8	5.1
B3	71-98	12.7	1.3	1.2	3.8	5.1

Table 2 (continued)

Horizon	(inches) Depth	Total sand (·/·)	Sand fractions (·/·) 2000-500 μ	500-250 μ	250-100 μ	100-50 μ
Prairie Peak - Red						
A1	0-10	17.6	1.7	0.8	4.1	6.2
B11	10-15	14.6	0.9	1.7	4.3	6.6
B11	15-20	16.3	1.6	1.8	4.9	7.1
B12	20-31	13.8	0.8	1.7	4.1	6.2
B21	31-37	8.8	0.4	1.5	2.7	3.1
B21	37-44	12.6	0.7	1.4	3.8	5.5
B22	44-53	13.7	0.8	1.6	4.2	6.7
B23	53-61	14.9	0.6	1.6	4.7	7.0
B23	61-69	14.7	0.8	2.1	4.9	6.2
B23	69-78	14.1	0.9	1.3	4.8	6.0
B3	78-86	14.0	0.6	1.5	4.7	5.7
B3	86-94	13.7	0.8	1.2	4.3	5.8
Dr	94-118+	27.5	0.2	0.1	0.7	1.9
Red Creek - Red						
A1	0-6	10.4	0.5	0.3	2.6	5.0
A3	6-12	10.0	0.5	0.3	2.6	5.0
B1	12-21	10.4	0.4	0.3	2.3	5.0
B1	21-31	10.4	0.4	0.4	2.8	5.3
B21	31-39	6.6	0.3	0.3	1.8	2.8
B21	39-48	10.3	0.4	0.4	2.6	4.9
B22	48-57	11.9	0.5	0.5	3.4	5.6
B22	57-66	11.4	0.5	0.4	3.0	5.4
B23	66-72	15.6	0.7	0.7	4.4	7.0
B23	72-78	27.5	1.2	1.9	8.2	13.0
B3	78-85	31.0	1.3	2.2	9.0	15.7
B3	85-92+	29.6	1.0	1.8	8.0	15.0

Table 2. (continued)

Horizon	(inches) Depth	Total sand (·/·)	Sand fractions (·/·) 2000-500μ	500-250μ	250-100μ	100-50μ
Trout Creek - Yellow						
A1	0-4	31.5	7.7	3.6	10.1	9.6
B1	4-11	34.9	3.7	3.9	11.1	13.5
B1	11-18	37.2	3.1	4.3	11.5	15.3
B2	18-24	35.9	1.6	3.1	11.7	14.9
B2	24-30	37.9	2.4	4.7	13.3	11.6
Dr	30+	46.4	5.8	7.2	14.4	15.7
Fern Prairie - Yellow						
A1	0-6	29.2	3.5	2.8	8.6	11.5
A3	6-14	28.5	2.6	3.4	8.6	11.4
B2	14-25	28.0	1.8	3.0	9.1	11.6
B3	25-33	30.6	1.7	3.4	9.9	12.7
B3	33-43	34.0	2.0	4.2	11.1	13.8
Dr	43-53+	42.4	3.3	4.8	12.4	18.2
Prairie Peak - Yellow						
A1	0-4	43.3	4.0	6.4	13.9	14.6
A3	4-11	41.1	5.3	6.1	12.6	13.9
B2	11-17	42.8	4.7	6.5	14.1	14.3
B3	17-24	44.9	4.4	6.8	14.7	14.2
C	24-58	34.4	6.0	6.0	10.7	9.2
Dr	58-120+	58.2	3.8	9.1	21.8	20.2
Red Creek - Yellow						
A11	0-7	32.9	1.6	3.3	10.3	14.9
A12	7-16	31.9	1.6	2.8	10.3	14.5
B2	16-22	38.4	1.7	3.6	13.0	17.6
B2	22-28	46.4	1.8	5.7	16.7	19.0
Dr	28-45+	52.8	2.7	7.7	17.3	20.6

potassium feldspar (sp. gr. = 2.54 to 2.57) and plagioclase feldspar (sp. gr. of albite = 2.60 to 2.62 to anorthite = 2.74 to 2.76) in the light mineral fraction. The mica groups, muscovite (sp. gr. = 2.76 to 3.0) and biotite, (sp. gr. = 2.7 to 3.1) were found in both heavy and light mineral fractions.

The light and heavy fractions were washed with acetone, dried and weighed.

Magnetic materials, notably magnetite, were removed with an eight ounce alnico (V) horseshoe magnet from the heavy fraction of selected horizons. Both weights of magnetic and non-magnetic fraction were then recorded.

Mounting of grain samples

The light minerals were mounted on petrographic glass slides in a thin film of Lakeside. Lakeside was applied to a heated slide on a hot plate. After the slide was cool, 500 to 600 grains were spread evenly on the thin Lakeside layer. The slide was again heated, and quickly removed after the grains were semi-embedded. Care was taken to use a very thin film of Lakeside so that a portion of each grain was exposed for etching and absorption of dyes during the the staining procedure.

The heavy minerals were mounted by spreading the grains on a gelatinized slide. The method of preparing the slide was similar to that described by Marshall and Jeffries (37, p. 402) and Olcott (42, p. 1099-1101). The use of the gelatin-coated slides (1% gelatin) permitted changing the refractive index liquids without losing the grains.

Staining procedure for light mineral fractions

Feldspar was differentiated by staining potassium feldspar yellow (21) and plagioclase feldspar red (3). Etching was done by putting the uncovered light mineral grain mount face down over the hydrofluric acid fume for 1 to 3 minutes, depending on the size fraction. The etched slides were quickly immersed in barium chloride solution for 5 to 10 seconds. Potassium feldspar grains (microcline and orthoclase) were stained yellow by immersing the slides in sodium cobaltinitrite solution for 3 to 4 minutes. The slides were then dipped in potassium rhodizonate solution for 2 to 3 minutes to stain plagioclase grains pink to brick red. The slides were washed with running water and blotted dry after each treatment.

The grains were treated with barium chloride solution to replace calcium ions in plagioclase for barium ions which subsequently react with the rhodizonate organic dyesolution. Pure albite (sodium plagioclase) will not take the stain. However, the staining can be quite successful even if only 3 percent of calcium is present (3). Some non-stained albite grains were present, but identification was relatively easy, since the grains appeared dull, white, and considerably etched by hydrofluric acid. Due to the unstable nature of potassium rhodizonate solution, the reagent needs to be freshly prepared.

Grain counting

The grain counting was done under a petrographic microscope using a mechanical stage to make line traverses. To obtain reasonably representative counting, only grains that passed on dead center under the cross-hairs along a lateral line were counted. The stained slides were counted for 200 grains in medium sand fractions (500 to 250 μ) and very fine sand fractions (100 to 50 μ), whereas 400 grains were counted for the fine sand fractions (250 to 100 μ). To avoid any personal bias in grain counting, slides were picked at random and identities were revealed only after completion of counting for each slide.

Heavy mineral grains from 5 horizons of the TC-R and PP-R soils and 2 horizons of the TC-Y and PP-Y soils were identified and counted in the same manner.

Thin section preparation

Thin sections were prepared from selected, undisturbed, oriented samples. Five to six thin sections were made for each of the red soils at intervals throughout the profiles. Three to four thin sections were made for each of the yellow soils including the weathered Tyee sandstone rock immediately underneath the profiles.

Impregnation[6/] of the clods was accomplished by using a polyester resin, Laminac[7/], diluted (1:1) with acetone. The mixture was prepared by slowly adding acetone to the resin with continuous stirring for about 4 to 5 minutes. Catalyst (P-102[8/]) was added while stirring (1 drop to every 10 ml. of the resin used) before impregnation.

6/ The method used is of the Soil Survey Laboratories Soil Conservation Service, Beltville, Maryland. Dr. John Cady, personal communication.

7/ "Laminac" polyester resin, Cyanamid Co. Stamford, Connecticut.

8/ P-102 (M.E.K. peroxides) Fiberclay Co. Seattle, Washington.

Clods were arranged in a container[9] so that vertically oriented slabs could be cut easily with a diamond saw. Small increments of the resin mixture were poured in along the side of the cup, in order to let the clods soak up the resin by capillary action, and hence to reduce the amount of air-lock as much as possible. Addition of the mixture was continued only until the clods were completely soaked. It was found that excessive amounts of resin tended to contract strongly and induce cracks upon polymerization. After the soaking was completed, the container was left in a hood with air drawing slowly for 1 to 2 days to allow the acetone to evaporate and the resin to harden.

After the resin was hardened, final heating was done in an oven by raising the temperature slowly to 100°C. in one hour. The heating continued at 100°C. for one more hour.

Thin sections were ground from thin slabs (0.5 to 1 mm.) cut by a diamond saw. Dry grinding with abrasive papers[10] was used as it produced better and cleaner thin sections than grinding with kerosene and corundum abrasive powder. The thin sections were then mounted in the usual manner.

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9 / Oven-proof small custard cups were used quite successfully.

10/ Any common abrasive papers with permanent securely abrasive grains can be used.

X-ray diffraction analysis of clay ($<2\mu$)

X-ray diffraction analysis of clay was carried out on representative A, B2, and B3 horizons of two red soils (PP-R and TC-R) and B horizons of two yellow soils (PP-Y and TC-Y). Two samples of weathered Tyee sandstone rock from each of the two areas were also included.

A 10 g. sample was treated for organic matter and free iron oxide removal in the same manner as described earlier in the preparation of grain mounts. After the separation of the sand fraction by wet sieving, removal of the silt fraction was carried out by sedimentation according to the clay minerals methods in use at the Soils Department, Oregon State University.

A small portion of the clay suspension ($< 2\mu$) was then used for the preparation of X-ray diffraction slides by the paste method of Theisen and Harward (53, p. 90-91).

The X-ray diffraction analyses were performed with a North American Phillips Norelco unit equipped with a Geiger-Muller tube and a Brown recorder. The radiation was Cu K_α with power settings of 20 milliamperes and 40 kilovolts. The scanning speed was 1 degree 2θ per minute and the divergence and scatter slits of $1/4^\circ$ with 0.006 receiving slit were used.

RESULTS

Grain Counts - Light Minerals

Grain counts of quartz, plagioclase, potassium feldspar, biotite, muscovite and other constituents of the light mineral fractions are shown in Table 3a, 3b and 3c. The percentages reported as 'others' include strongly etched and red-stained rock fragments, aggregates and iron oxide. The counts are reported as average percentage of grains in each of the medium sand (500 to 250 μ), fine sand (250 to 100 μ), and very fine sand (100 to 50 μ) light mineral fractions. The ratios of quartz/feldspar (plagioclase and potassium feldspar) are reported in Table 4 and Figure 1.

Study of the grains before staining revealed that iron oxide removal was essential to remove reddish coatings on most of the grains, especially in the red soil samples. In all samples, rock fragments and aggregated grains were fairly common and all of them stained deep red. These rock fragments were soft and cloudy before staining and some could have been plagioclase grains that had weathered beyond recognition. By adjusting etching and staining times, the intensity of the red color was kept low enough for the identification of constituent grains in the rock fragments.

Table 3a. Mineral composition of medium sand, light mineral fraction.

Hori-zon	(inches) Depth	Minerals (·/·) (500-250μ) Quartz	Plagio-clase	K-feldspar	muscovite	biotite	Others
Trout Creek - Red							
A1	0-6	47.5	25.5	6.0	0.5	0.0	20.5
A3	6-12	44.0	34.5	3.5	0.5	0.0	19.0
B11	12-19	46.5	28.0	5.0	1.0	0.0	19.9
B12	19-27	45.0	33.0	4.5	1.5	0.0	16.0
B21	27-36	47.0	32.5	4.0	0.0	1.0	15.5
B22	36-45	46.0	30.0	3.0	1.0	0.5	19.5
B22	45-54	45.5	25.0	7.0	1.0	0.0	21.5
B22	54-63	50.5	29.5	6.5	1.0	0.0	12.5
B22	63-72	53.0	31.5	5.5	1.5	0.0	8.5
B23	72-80	54.0	30.0	5.5	0.0	0.0	10.5
B23	80-88	50.0	34.5	3.5	3.0	0.0	9.0
B23	88-95	53.5	35.0	3.0	0.5	0.5	7.0
B3	95-105	51.5	29.5	2.5	2.5	0.0	14.0
Fern Prairie - Red							
A11	0-5	27.0	30.5	6.5	0.0	0.0	36.0
A12	5-10	33.0	22.0	12.0	1.0	0.5	31.5
A3	10-16	36.0	21.5	11.5	1.5	0.0	29.5
B11	16-22	25.0	32.0	6.5	0.0	0.0	36.5
B12	22-28	29.0	31.0	9.0	0.5	0.0	30.5
B21	28-35	23.5	25.5	9.5	0.5	0.5	40.5
B22	35-41	27.0	20.5	10.0	1.5	0.5	40.5
B22	41-47	27.0	25.5	5.5	0.0	0.0	42.0
B23	47-56	28.0	29.0	9.0	1.0	0.5	32.5
B24	56-63	34.0	28.5	6.0	0.5	0.0	31.0
B24	63-71	36.0	29.0	7.0	0.5	1.0	26.5
B3	71-98	25.0	33.5	10.5	0.5	0.0	30.5

Table 3 a. (continued)

Hori-zon	(inches) Depth	Minerals (·/·) (500-250μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Prairie Peak - Red							
A1	0-10	44.0	30.5	8.0	0.5	0.0	17.0
B11	10-15	48.5	34.5	4.0	0.0	0.0	13.0
B11	15-20	42.0	34.0	7.0	0.0	0.0	21.5
B12	20-31	43.0	30.0	5.0	0.5	0.0	21.5
B21	31-37	42.0	33.0	6.0	1.0	0.0	18.0
B21	37-44	46.5	43.0	4.0	1.0	0.5	5.5
B22	44-53	54.5	41.0	0.5	0.0	0.0	4.0
B23	53-61	55.0	38.0	3.0	0.0	0.0	4.0
B23	61-69	61.0	35.5	1.5	0.0	0.0	2.0
B23	69-78	58.5	35.5	3.0	0.5	0.0	2.5
B3	78-86	60.0	30.5	1.5	0.0	0.0	8.0
B3	86-94	59.5	32.5	4.0	0.0	0.5	4.0
Dr	94-118+	6.0	4.0	1.5	7.5	0.0	81.0
Red Creek - Red							
A1	0-6	49.5	38.0	4.5	0.5	0.0	6.5
A3	6-12	50.5	37.5	4.0	0.0	0.0	8.0
B1	12-21	44.0	38.0	2.0	0.5	0.0	18.0
B1	21-31	53.5	32.5	5.5	0.0	0.0	8.5
B21	31-39	50.0	40.0	4.0	0.5	0.0	5.5
B21	39-48	49.5	40.5	3.5	0.5	0.0	6.0
B22	48-57	50.0	41.5	2.5	0.5	0.0	5.5
B22	57-66	54.5	36.5	3.5	0.5	0.0	5.0
B23	66-72	52.0	35.0	4.0	0.5	0.0	8.5
B23	72-78	45.0	30.5	2.5	2.0	0.5	19.5
B3	78-85	47.0	30.0	5.0	2.5	0.0	15.5
B3	85-92+	46.5	31.0	4.5	4.0	0.5	13.5

Table 3 a. (continued)

Hori-zon	(inches) Depth	Minerals (·/·)(500-250μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Trout Creek - Yellow							
A1	0-4	22.5	27.0	13.0	2.5	1.0	34.5
B1	4-11	27.5	31.5	8.5	2.5	0.0	30.0
B1	11-18	25.0	26.5	19.0	0.5	1.5	27.5
B2	18-24	27.0	33.5	14.0	5.0	1.5	19.0
B2	24-30	30.0	31.0	18.5	1.5	1.5	17.5
Dr	30+	29.0	42.0	14.8	2.5	1.0	11.8
Fern Prairie - Yellow							
A1	0-6	23.0	23.5	7.5	0.5	0.0	47.0
A3	6-14	34.0	24.0	13.0	1.0	0.5	27.5
B2	14-25	32.5	23.5	13.0	2.0	0.0	29.0
B3	25-33	29.5	30.0	11.0	1.0	0.5	28.0
B3	33-43	28.5	28.0	7.0	1.0	1.5	34.0
Dr	43-53+	29.8	36.0	8.3	1.5	1.0	23.5
Prairie Peak - Yellow							
A1	0-4	32.5	35.0	11.0	1.5	0.0	20.0
A3	4-11	31.0	26.5	10.0	2.5	0.5	29.5
B2	11-17	31.5	26.0	15.5	1.5	1.0	24.5
B3	17-24	29.5	30.0	13.5	1.5	0.0	25.5
C	24-58	31.0	29.5	12.0	1.0	1.0	30.0
Dr	58-120+	24.0	23.8	11.3	2.5	0.5	38.0
Red Creek - Yellow							
A11	0-7	33.5	38.0	6.5	1.0	1.5	19.5
A12	7-16	32.0	35.5	13.0	2.5	1.0	16.0
B2	16-22	31.5	32.0	9.5	3.0	0.0	23.0
B2	22-28	34.5	26.5	15.5	1.0	1.5	21.0
Dr	28-45+	32.5	24.3	16.8	1.5	0.0	25.0

Table 3b. Mineral composition of fine sand, light mineral fraction.

Hori-zon	(inches) Depth	Minerals (°/°)(250-100μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Trout Creek - Red							
A1	0-6	40.7	18.5	8.0	7.5	0.5	24.7
A3	6-12	43.5	15.7	10.5	2.7	1.0	26.5
B11	12-19	41.7	20.7	9.7	4.0	1.5	21.2
B12	19-27	41.7	19.7	9.5	2.3	0.7	26.2
B21	27-36	45.7	15.5	9.5	2.0	0.2	27.0
B22	36-45	43.2	17.7	8.2	4.0	0.2	26.5
B22	45-54	40.2	20.5	9.0	2.5	2.2	25.5
B22	54-63	54.5	13.5	12.0	1.5	1.2	17.2
B22	63-72	52.2	17.7	7.5	4.0	0.5	18.2
B23	72-80	44.2	16.7	9.5	3.7	0.5	24.0
B23	80-88	45.5	18.7	10.2	6.5	1.2	17.7
B23	88-95	47.0	20.0	9.0	6.0	0.2	17.7
B3	95-105	46.5	14.0	10.5	9.0	1.2	18.7
Fern Prairie - Red							
A11	0-5	40.0	23.2	17.5	4.0	0.0	15.5
A12	5-10	40.2	36.5	11.0	1.0	0.5	10.7
A3	10-16	33.2	38.0	10.7	2.0	0.2	15.7
B11	16-22	36.5	35.7	13.5	1.2	0.5	12.5
B12	22-28	28.0	36.0	9.5	1.5	1.5	23.5
B21	28-35	32.0	31.5	12.7	1.0	0.2	22.5
B22	35-41	33.5	21.2	13.7	5.2	0.0	26.7
B22	41-47	31.7	33.2	12.0	0.7	1.0	21.2
B23	47-56	30.0	28.7	13.2	2.0	1.5	24.5
B24	56-63	32.7	23.0	13.0	2.5	2.5	26.2
B24	63-71	31.2	30.5	9.5	4.0	1.7	23.0
B3	71-98	30.7	25.5	9.5	3.0	2.5	28.7

Table 3b. (continued)

Hori-zon	(inches) Depth	Minerals (·/·)(250-100μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Prairie Peak - Red							
A1	0-10	45.5	24.0	11.0	2.0	0.2	17.2
B11	10-15	46.0	23.5	10.7	1.5	1.0	16.2
B11	15-20	42.2	21.2	10.7	2.5	1.7	21.5
B12	20-31	54.0	17.7	13.2	1.5	0.0	13.5
B21	31-37	52.0	22.7	8.5	0.5	0.2	16.0
B21	37-44	58.0	27.5	5.5	2.5	0.0	6.5
B22	44-53	63.0	22.5	7.2	0.7	0.0	6.5
B23	53-61	62.5	21.5	8.5	1.5	0.0	6.0
B23	61-69	62.7	26.2	5.5	0.7	0.0	4.7
B23	69-78	67.7	16.7	7.7	1.5	0.0	6.2
B3	78-86	63.2	22.0	5.5	2.2	0.0	7.0
B3	86-94	58.0	23.0	4.5	1.0	0.0	13.5
Dr	94-118+	15.0	6.5	3.0	20.5	9.5	45.5
Red Creek - Red							
A1	0-6	57.2	19.2	6.5	4.5	0.0	13.0
A3	6-12	50.7	23.5	9.2	1.2	1.0	14.2
B1	12-21	54.7	19.5	9.5	1.3	0.2	14.7
B1	21-31	60.7	21.2	8.0	1.7	1.0	7.2
B21	31-39	56.2	27.2	8.0	1.2	0.0	7.2
B21	39-48	63.0	16.7	9.2	2.5	1.2	7.2
B22	48-57	58.5	17.7	7.0	4.2	0.5	12.0
B22	57-66	57.2	23.7	8.2	3.7	1.0	6.0
B23	66-72	45.7	22.0	6.7	5.7	2.5	17.2
B23	72-78	27.7	14.7	5.5	6.5	5.7	40.2
B3	78-85	30.5	15.2	6.5	8.5	5.7	33.5
B3	85-92+	24.0	16.5	6.2	18.0	7.7	27.5

Table (continued) 3 b.

Hori-zon	(inches) Depth	Minerals (·/·)(250-100μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Trout Creek - Yellow							
A1	0-4	26.2	26.5	12.7	2.5	4.5	27.5
B1	4-11	24.0	29.5	15.0	3.3	3.2	25.0
B1	11-18	21.0	29.2	11.2	4.3	4.7	29.5
B2	18-24	19.7	19.7	13.7	14.3	11.2	21.2
B2	24-30	25.7	20.0	14.5	7.5	7.7	24.5
Dr	30+	25.2	26.0	16.2	6.3	6.7	19.5
Fern Prairie - Yellow							
A1	0-6	27.7	30.7	12.5	2.8	3.2	23.2
A3	6-14	27.0	32.0	15.5	2.3	1.2	22.0
B2	14-25	20.7	23.7	15.0	4.7	6.5	29.2
B3	25-33	20.2	27.7	10.7	7.0	3.5	30.7
B3	33-43	17.2	21.7	9.7	3.5	5.2	42.2
Dr	43-53+	12.7	26.0	9.2	4.2	10.0	37.7
Prairie Peak - Yellow							
A1	0-4	28.2	21.2	16.0	3.8	2.7	28.0
A3	4-11	29.7	20.7	11.5	5.8	2.2	30.0
B2	11-17	24.7	30.7	14.2	4.2	3.0	23.0
B3	17-24	19.7	19.0	10.0	6.0	6.7	38.5
C	24-58	16.5	10.7	12.0	4.2	5.0	51.5
Dr	58-102+	22.5	18.7	11.7	3.8	5.2	38.0
Red Creek - Yellow							
A11	0-7	19.2	21.0	13.5	3.8	4.2	38.2
A12	7-16	27.5	20.5	10.7	8.5	1.7	31.0
B2	16-22	16.7	16.2	10.5	7.0	10.0	39.2
B2	22-28	18.0	17.0	7.0	7.3	7.2	43.5
Dr	28-45+	17.7	14.5	12.0	1.5	4.7	49.5

Table 3 c. Mineral composition of very fine sand, light mineral fraction.

Hori-zon	(inches) Depth	Minerals (·/·) (100-50μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Trout Creek - Red							
A1	0-6	39.0	12.2	6.7	16.0	3.2	32.7
A3	6-12						
B11	12-19						
B12	19-27						
B21	27-36	38.0	16.5	13.0	7.5	4.0	21.0
B22	36-45						
B22	45-54	33.0	11.5	11.2	7.0	5.5	31.7
B22	54-63						
B22	63-72						
B23	72-80	33.0	14.0	11.5	9.5	4.0	28.0
B23	80-88						
B23	88-95						
B3	95-105	31.0	12.0	11.5	11.5	2.5	31.5
Fern Prairie - Red							
A11	0-5	38.2	19.5	18.2	8.2	2.2	13.2
A12	5-10						
A3	10-16						
B11	16-22	37.5	26.5	15.0	3.5	4.0	13.5
B12	22-28						
B21	28-35						
B22	35-41	38.0	18.7	14.7	3.8	3.7	21.0
B22	41-47						
B23	47-56						
B24	56-63	32.5	22.5	8.0	6.5	3.5	27.0
B24	63-71						
B3	71-98	26.2	17.0	14.0	7.0	7.5	28.2

Table 3 c. (continued)

Hori-zon	(inches) Depth	Minerals (·/·)(100-50μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Prairie Peak - Red							
A1	0-10	41.0	23.0	9.0	3.0	1.5	22.5
B11	10-15						
B11	15-20	36.0	18.5	10.0	5.5	3.0	27.0
B12	20-31	36.5	18.0	12.0	5.0	4.0	24.5
B21	31-37						
B21	37-44	45.7	23.0	11.7	5.5	1.0	13.0
B22	44-53						
B23	53-61						
B23	61-69	59.5	18.0	11.5	1.5	1.0	8.5
B23	69-78	51.0	17.5	11.5	6.5	2.0	11.5
B3	78-86						
B3	86-94	55.5	24.2	13.0	3.0	0.0	4.2
Dr	94-118+	11.5	9.5	2.0	38.0	25.0	14.0
Red Creek - Red							
A1	0-6	45.5	20.0	10.5	4.5	3.0	16.5
A3	6-12						
B1	12-21						
B1	21-31	45.0	19.0	13.0	6.5	3.0	13.5
B21	31-39						
B21	39-48						
B22	48-57	34.5	14.2	11.0	9.7	2.5	28.0
B22	57-66						
B23	66-72						
B23	72-78	16.5	10.5	4.0	10.0	16.5	42.5
B3	78-85						
B3	85-92+	13.2	11.0	6.2	14.3	10.7	44.5

Table 3 c. (continued)

Hori-zon	(inches) Depth	Minerals (·/·)(100-50μ) Quartz	Plagio-clase	K-feldspar	Muscovite	Biotite	Others
Trout Creek - Yellow							
A1	0-4						
B1	4-11	29.0	20.2	14.2	5.7	8.5	22.2
B1	11-18						
B2	18-24	23.2	20.2	14.2	9.7	7.5	25.0
B2	24-30						
Dr	30+	12.0	19.5	10.0	13.0	19.0	27.0
Fern Prairie - Yellow							
A1	0-6						
A3	6-14	25.5	19.7	12.0	10.7	7.0	25.0
B2	14-25						
B3	25-33	23.7	20.7	8.5	12.3	8.2	26.5
B3	33-43						
Dr	43-53+	7.0	16.5	11.0	7.5	15.5	42.5
Prairie Peak - Yellow							
A1	0-4						
A3	4-11	23.7	18.2	15.2	6.75	2.0	34.0
B2	11-17						
B3	17-24	21.0	15.0	14.0	8.0	8.0	34.0
C	24-58						
Dr	58-102+	14.5	17.5	14.0	11.0	10.0	33.0
Red Creek - Yellow							
A11	0-7						
A12	7-16	14.0	18.2	8.2	9.7	7.5	42.2
B2	16-22						
B2	22-28	12.5	18.0	8.0	3.7	9.5	48.2
Dr	28-45+	11.5	17.5	9.0	6.0	16.0	40.0

Table 4. Quartz - Feldspars ratios

Horizon	Depth (inches)	Medium sand 500-250μ	Fine sand 250-100μ	Very fine sand 100-50μ
Trout Creek - Red				
A1	0-6	1.51	1.54	2.05
A3	6-12	1.16	1.66	
B11	12-19	1.41	1.37	
B12	19-27	1.20	1.43	1.29
B21	27-36	1.29	1.83	
B22	36-45	1.39	1.66	
B22	45-54	1.42	1.36	1.45
B22	54-63	1.40	2.14	
B22	63-72	1.43	2.07	
B23	72-80	1.52	1.69	1.29
B23	80-88	1.32	1.60	
B23	88-95	1.41	1.62	
B3	95-105	1.61	1.90	1.32
Trout Creek - Yellow				
A1	0-4	0.56	0.67	
B1	4-11	0.69	0.54	0.84
B1	11-18	0.55	0.52	
B2	18-24	0.57	0.59	0.67
B2	24-30	0.61	0.75	
Dr	30+	0.51	0.60	

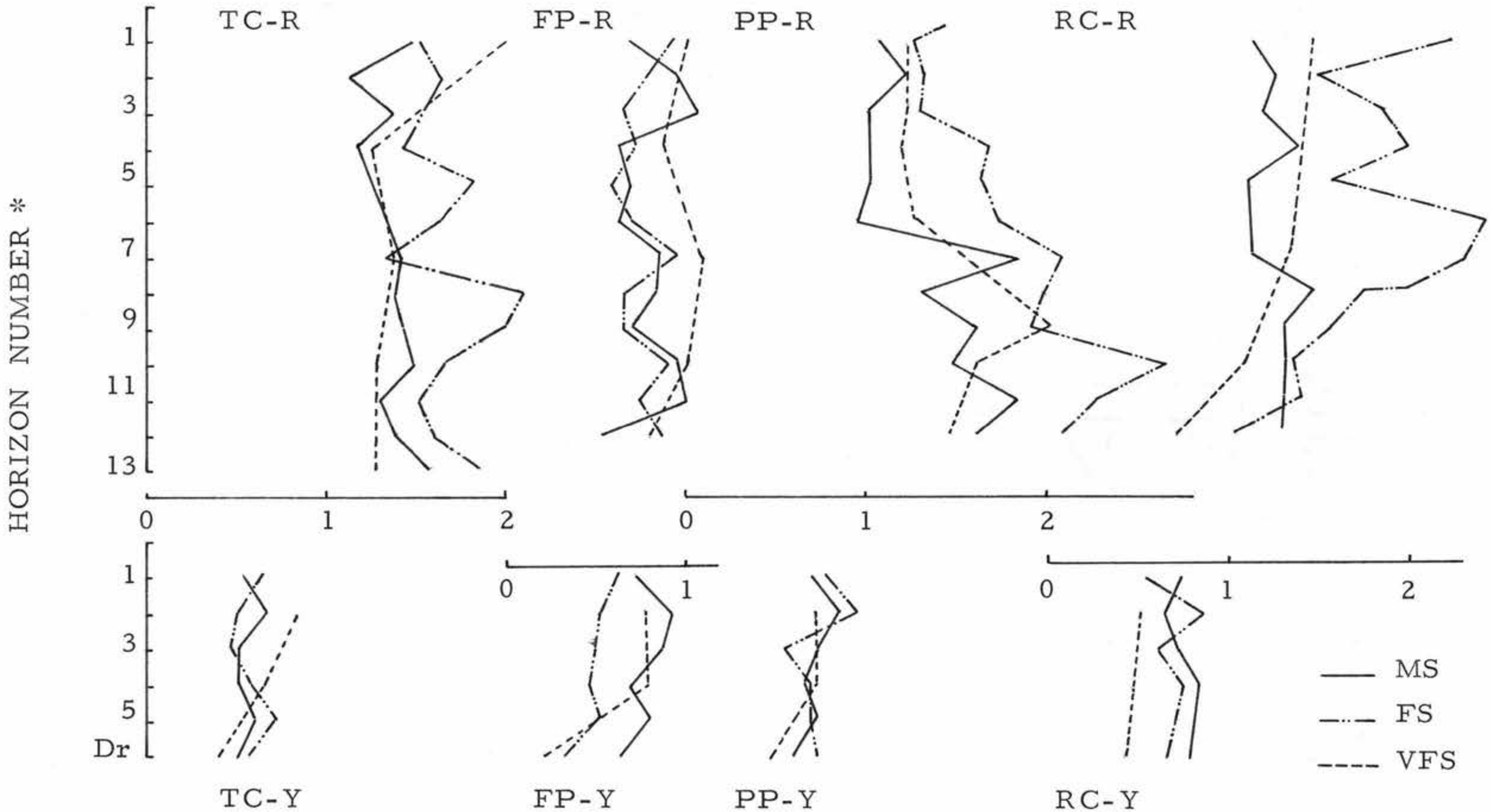
Horizon	Depth	Medium sand 500-250μ	Fine sand 250-100μ	Very fine sand 100-50μ
Fern Prairie - Red				
A11	0-5	0.73	0.98	1.01
A12	5-10	0.97	0.85	
A3	10-16	1.09	0.68	
B11	16-22	0.65	0.74	0.90
B12	22-28	0.72	0.61	
B21	28-35	0.67	0.72	
B22	35-41	0.88	0.96	1.13
B22	41-47	0.87	0.70	
B23	47-56	0.74	0.71	
B24	56-63	0.98	0.91	1.06
B24	63-71	1.00	0.78	
B3	71-98	0.57	0.88	0.85
Fern Prairie - Yellow				
A1	0-6	0.74	0.64	
A3	6-14	0.92	0.57	0.80
B2	14-25	0.89	0.53	
B3	25-33	0.72	0.53	0.81
B3	33-43	0.81	0.55	
Dr	43-53+	0.67	0.36	0.25

Table 4. (continued)

Horizon	(inches) Depth	Medium sand 500-250μ	Fine sand 250-100μ	Very fine sand 100-50μ
Prairie Peak - Red				
A1	0-10	1.14	1.30	1.28
B11	10-15	1.26	1.34	
B11	15-20	1.05	1.32	1.26
B12	20-31	1.05	1.74	1.22
B21	31-37	1.08	1.66	
B21	37-44	0.99	1.76	1.32
B22	44-53	1.18	2.12	
B23	53-61	1.34	2.08	
B23	61-69	1.65	1.98	2.02
B23	69-78	1.52	2.76	1.63
B3	78-86	1.87	2.30	
B3	86-94	1.63	2.11	1.49
Dr	94-118+		1.58	1.00
Prairie Peak - Yellow				
A1	0-4	0.71	0.76	
A3	4-11	0.85	0.92	0.73
B2	11-17	0.76	0.55	
B3	17-24	0.68	0.68	0.72
C	24-58	0.75	0.72	
Dr	58-120+	0.61	0.74	0.46

Horizon	Depth	Medium sand 500-250μ	Fine sand 250-100μ	Very fine sand 100-50μ
Red Creek - Red				
A1	0-6	1.16	2.22	1.49
A3	6-12	1.27	1.55	
B1	12-21	1.10	1.89	
B1	21-31	1.41	2.08	1.41
B21	31-39	1.14	1.59	
B21	39-48	1.12	2.42	
B22	48-57	1.14	2.36	1.37
B22	57-66	1.49	1.79	
B23	66-72	1.33	1.59	
B23	72-78	1.36	1.37	1.14
B3	78-85	1.34	1.40	
B3	85-92+	1.31	1.05	0.77
Red Creek - Yellow				
A11	0-7	0.75	0.56	
A12	7-16	0.66	0.88	0.53
B2	16-22	0.76	0.60	
B2	22-28	0.82	0.75	0.48
Dr	28-45+	0.79	0.67	0.43

Figure 1. Quartz-Feldspar ratios of medium sand (MS) fine sand (FS) and very fine sand (VFS) fractions.



*In sequence from top to bottom. The depth interval for each horizon is given in Table 4.

Plagioclase feldspar, therefore, stained pink to light red instead of deep red. In spite of these difficulties, the results are still meaningful for the practical purpose of comparison, which is the objective of this study.

In comparing the red soils and the yellow soils of the two climatic zones, the differences were quite distinct. Mineralogically the red soils had, as a whole, relatively higher quartz, lower plagioclase and potassium feldspar (less evident in FP-R soil) and lower muscovite and biotite (less true as the grain size decreases, especially in TC-R and RC-R soils). The percentages of 'others' were also lower for the red soils.

Among the four red soils, quartz was higher in the PP-R and RC-R soils than in the TC-R and FP-R soils, whereas the reverse was true in the case of plagioclase. The amount of potassium feldspar appeared less variable but roughly followed the trends of plagioclase. Biotite and muscovite (present also in the heavy mineral fractions) occurred in relatively low amount and mostly concentrated in the smaller size fractions (fine sand and very fine sand). In all the red soils, biotite was less common than muscovite. The TC-R and RC-R soils appeared to have the highest amount of mica as well as increasing content with depth.

The percentages reported as 'others', which are the percentage of rock fragments and iron oxides, showed a similar range within the profiles, but the amount in the FP-R and RC-R soils appeared to increase with depth, whereas, the PP-R soil and to a lesser extent the TC-R soil showed the amount decreasing down the profile.

The differences between the four yellow soils were small and no definite trend of any significance was recognized in the amount of constituents, apart from variations among grain sizes. Any difference between the profiles was probably controlled by variability in the parent rock itself.

Grain size variation was noticed in both the red and yellow soils. The amount of biotite and muscovite increased with decreasing grain size. Potassium feldspar followed a similar pattern, but showed only a slight increase with decreasing size fraction in the red soils and remained more constant in the yellow soils. Quartz and plagioclase feldspar appeared to decrease with grain size, but the amount of fine sand quartz was the highest in the TC-R, PP-R, and RC-R soils, and in the FP-R soil there was little variation among the size fractions. The percentage of 'other' constituents revealed no definite trend in either the red or yellow soils.

It is interesting to note that potassium feldspar, biotite, and muscovite, which are relatively more stable than plagioclase, showed increasing amounts with grain size. These minerals which are more resistant to chemical weathering should tend to persist in greater quantities in the finer size fractions (25, p. 244). Plagioclase is considered quite unstable, especially in the calcic end of the series (22, 25, 43). Therefore, it should be reduced in amount in the finer fractions, and in these soils, this is the case. Nevertheless attempts to establish a strict particle size relationship in these soils was unsuccessful, perhaps because of the strong influence of grain size differences within the parent rock. Quartz, in particular, suggests a strong influence of the parent rock by having highest amounts in the fine sand fraction of the red soils and showing a slightly decrease with grain size in the yellow soils.

Establishment of depth function and further comparison of the degree of weathering were best shown in the quartz/feldspar ratios of these soils (Figure 1).

1) All yellow soils had lower quartz/feldspar ratios (contained larger amounts of unstable minerals) than the red soils, although the FP-R soil showed only slightly higher ratios than the FP-Y soil.

2) In general, the PP-R and RC-R soils (high rainfall area) had higher quartz/feldspar ratios than the TC-R and FP-R soils in the fine sand fraction. In other fractions, the PP-R soil was high and the FP-R soil was low, but the RC-R and TC-R soils were similar.

3) In the red soils, the FP-R soil showed the lowest degree of weathering and the least variation throughout the profile. The PP-R soil, on the contrary, showed the highest degree of weathering increasing with depth. The RC-R fine sand fractions had ratios decreasing strongly from the highest values in the middle horizons. The TC-R fine sand ratios were greatest in horizons of intermediate depth, as in the RC-R profile, but they did not decrease strongly with depth. The yellow soils generally had ratios decreasing slightly with depth.

4) The very fine sand fractions were more uniform with depth than the others but this fraction was not counted for every horizon and possibly the accuracy of identification was lower due to the smaller grain size.

Grain Counts - Heavy Minerals

Results of the heavy mineral counts are shown in Table 5. The amounts of minerals were reported on a frequency scale relative to the amount present. The frequency scale was used according to Hutton (24, p. 650), after Evan, Hayman and Majeed (19), with two additional designations. The scale makes comparison between samples simpler and reduces the chance of interpreting the data in more detail than justified by the level of error. The frequency numbers are in geometric progression except for those lower than 3.

Frequency	Approximate percentage
8+	90-100
8	75-89
8-	60-74
7+	45-59
7	35-44
7-	28-34
6+	23-27
6	18-22
6-	14-17
5	7-13
4	4-6
3	2-3
2	1-2
1*	1 grain only
x	present on the slide but not on the counting transect.
-	not found on the slide.

The heavy mineral component of the total 500 to 50μ fraction was very small in all cases. It ranged from 0.69 to 2.36%.

Only biotite, muscovite, hematite, garnet, and hypersthene (with some epidote) occurred in larger grains (200 to 500μ). The rest of the minerals had grains from 50 to 200μ. Grain size

Table 5. Frequency numbers of the heavy minerals in the 500 to 50 μ fraction.

Profile name	Horizon	Depth (inches)	Magnetic minerals *	Non-magnetic minerals #									
				Opaque min	Zircon	Rutile	Tourmaline	Epidote	Garnet	Amphibole	Pyroxene	Biotite	Muscovite
TC-R	A1	0-6	7-	7+	3	2	x	5	1	5	4	2	5
	B11	12-19	6+	7+	3	1	3	5	1	4	3	4	6-
	B22	36-45	6+	8-	4	4	1	4	-	4	2	1	3
	B22	63-72	6-	7+	4	3	1	1	-	1	x	6-	5
	B23	88-95	6	7+	4	2	1	2	-	4	x	5	6
TC-Y	B1	4-11	6+	6+	x	1	1	6-	2	5	4	6-	4
	B2	18-24	6	7-	1	1	x	5	4	6-	2	6	4
	Dr	30+	8-	6	1	x	x	5	4	6-	x	6+	4
PP-R	A1	0-10	7-	7+	2	2	3	3	1	5	5	3	5
	B11	15-20	7	7+	4	4	4	3	1	5	4	5	4
	B21	37-44	7-	7+	4	4	4	x	-	2	3	1	1
	B23	61-69	7	8-	5	5	2	1	-	1	x	1	5
	B3	86-94	7-	8-	4	4	3	1	-	2	x	2	4
PP-Y	A3	4-11	6-	7	2	2	2	2	1	5	4	6	5
	B3	17-24	5	7+	5	4	3	3	2	4	5	5	4
	Dr	58-120 +	7+	6-	4	2	2	4	4	5	x	7	5

Other minerals identified were, Chlorite, clinozoisite, kyanite, monazite, staurolite, sphene, apatite, and leucoxene.

*Mostly magnetite. Frequency numbers derived from weight percentages of heavy mineral fractions.

#Frequency numbers derived from percentages of grains count in the non-magnetic fractions.

x Present on the slide but not on the counting transect.

differences between the red and yellow soils were quite distinct. The average grain size in the yellow soils was larger (100 to 200 μ) than in the red soils. In the red soils, the grain size of the lower horizons (50 to 100 μ) as well as the number of minerals increased slightly towards the surface.

Magnetic minerals

Magnetite was dominant, but hematite (or goethite or both) as well as mostly large grains of garnet, hypersthene, epidote, and emphibole were also present.

Non-magnetic Minerals

Opaque minerals. Magnetite, if properly identified by color in reflected light, was present in the non-magnetic fraction, either because the magnetic separation was not complete or because the grains were not sufficiently magnetic to be removed. Magnetite, ilmenite, hematite and goethite were consistently abundant throughout the profiles. The amount was slightly higher in the red soils than in the yellow soils. Leucoxene was commonly found as an earthy white alteration product of ilmenite.

Zircon. Small, euhedral crystals were common and the majority were fresh. The amounts were highest in the red soil profiles especially in the lower horizons.

Rutile. Normally, prismatic to euhedral grains, yellow and reddish brown in color, followed a trend similar to that of zircon.

Tourmaline. Prismatic, strongly pleochroic grains, without cleavage,of green and brown varieties were present. Amounts were greater in the red soils.

Epidote. Epidote was generally as common as amphibole. The amount was higher in the TC-R and TC-Y soils. In the red soils, the amount was higher in the upper horizons (A and B1).

Garnet. Large, high relief, isotropic, pink and colorless grains were common in the rock (Dr) of the yellow soils, and gradually decreasedtoward the top of the profiles. Only a small amount was found on the upper horizons of the red soils, and some garnet was in the magnetic fraction of the TC-Y and PP-R rocks.

Amphibole. The amount present, was high in all four soils studied, especially in the upper two horizons (A and B1) of both red and yellow soils. The types present were common green and bluish green hornblende with some glaucophane. In the rocks (Dr), both common green and bluish green types were present, and the latter appeared to be the dominant one. The grains were small (100 to 200μ) and weathered with ragged edges. In the soils, similar types were found in the red and yellow soil profiles, but their amounts were low when compared with the large primatic, relatively fresh common green type which occurred in appreciable amount in the yellow soils and in the top three horizons of the red soils. This large prismatic and clear greenish type of hornblende was not found in the parent rock beneath the profiles.

Pyroxene. The occurrence of pyroxene was similar to that of amphibole. Hypersthene was the dominant pyroxene in these soils, and it was commonly found in the yellow soil profile as well as in the upper three horizons of the red soils studied. In the rock (Dr) and B2 and B3 horizons of the red soils, hypersthene was not counted, however, upon further investigation, it was found that a few hypersthene grains were present. They were small, broken and appeared to be weathered considerably and were distinctly different from the slightly weathered, large, prismatic grains found in the yellow soils and upper horizons of the red soils.

Biotite and Muscovite. Both brown and green varieties of biotite were common. Muscovite was colorless. Biotite was distinctly low in amount in the B2 horizons of the PP-R soil. Muscovite was at least as common in the red soils as in the yellow soils. Due to the large size of the mica flakes, the counts may be too high.

Weathering sequences have been proposed by various workers (22, 43, 44). Individual minerals were listed differently in the various proposed weathering sequences, however, most of these sequences were conformable in their broad grouping. With these points in mind, the minerals identified in this study could be grouped into three classes:

Very stable: zircon, tourmaline, rutile, muscovite.

Stable: garnet, epidote, biotite, magnetite, ilmenite.

Least stable: amphibole, pyroxene (hypersthene).

It was found that in the deep red soils, the very stable minerals were concentrated in the B2 and B3 horizons, suggesting that these were the most weathered horizons. The stable minerals, garnet, epidote and biotite as well as the least stable minerals, amphibole and hypersthene showed their highest amount in the upper horizons of the red soils and in the yellow soils, these horizons, therefore seem less weathered than the lower ones of the red soils.

Thin section study

Thin sections from selected horizons were studied, with emphasis on weathering and variability of the skeleton grains as well as distribution and kinds of matrix or plasma. The term "skeleton" and "matrix" (plasma) were used according to Kubiena (35, p. 128) and Brewer (10, 11).

Trout Creek-Red (TC-R)

In the A horizon, dark brown, granular aggregates of quartz, feldspar and rock fragments of medium sand to silt size incorporated with organic matter, were set in a loose matrix of silt and clay. Remains of plant roots and stems and flecks of charcoal were abundant. Dark, round, very coarse sand to coarse sand iron oxide concentrations (shot) with randomly arranged skeleton grains of sand and silt were common throughout the slide.

Quartz and feldspar grains were mostly angular, while the rock fragments were rounded to sub-rounded. Quartz showed a tendency to crack and break into smaller grains by physical means in this horizon (and in A horizon of all profiles). Feldspar grains appeared slightly weathered and some were more strongly weathered along the cleavage and twinning planes. The rock fragments were mostly fine grained to very fine grained volcanic rocks with devitrified glass, and had been completely weathered to clay minerals. This type of rock fragment was common in all the soils studied as well as in the Tyee sandstone parent rock. Coatings were absent apart from one area of material mixed in from below which contained flakes and chips of oriented clay skins.

In the top part of the B horizon, B12 (19 to 22 inches), there were subangular to angular blocks with sand and silt grains of quartz, feldspar and rock fragments imbedded within a dense, yellowish red clayey matrix. The matrix included common minute specks and laths of high birefringence mica (probably sericite). These were common in all the red soils studied. Thin, oriented clay skins were fairly common in medium and large cracks, pores, and on ped surfaces. In some pores, oriented clay skins were thick and laminated. The main bulk of clay, in the matrix, was unoriented, darker and had lower birefringence than the oriented clay. Chips and flakes of oriented clay skins were also common in the horizon. Quartz and feldspar grains and rock fragments were similar to those in the A horizon. Muscovite and biotite flakes were few and small in size but distributed throughout the whole soil. Many of the feldspar grains showed signs of weathering along the cleavage traces and twinning planes, but the content was about the same as in the A horizon. One feldspar grain (Figure 2) demonstrated the contact between coated skins and weathered clay from feldspar *in situ*.

The B22 (36 to 39 inches) was very much similar to the B12, but nearly all pores, cracks and ped surfaces were coated with thin to medium oriented clay skins. Oriented, laminated clay skins in pores were common. The fine and very fine pores were almost completely filled with oriented clay and in many cases oriented clay seemed to be a part of the matrix itself. Coatings were also common around the skeleton grains.

In the B23 and B3 (72 to 75 inches and 95 to 99 inches), dark red, oriented clay was abundant. It not only filled cracks and openings and lined pores as an oriented skin, but it also seemed to have infiltrated the matrix away from any visible opening. Oriented skins around coarse skeleton grains were common. Quartz and rock fragments appeared to increase. Muscovite and biotite increased in number and size. Examples of laminated clay skins in the B22 (36 to 39 in.) are shown in Figure 4.

In the profile as a whole, the quantity of oriented clay was as great as or greater than the quantity of unoriented clay. In the lower B horizons, some of the oriented clay was in flecks arranged in elongated clusters with optical continuity throughout, and it was difficult to attribute them to very fine pore fillings. A few fragments of oriented clay were scattered throughout the matrix. Most of the weatherable minerals were low. Feldspar and weathered volcanic rock fragments, which were quite abundant in the Tyee parent rock, occurred in relatively low amount and gave the appearance of being preserved by being imbedded in the dense matrix. The high clay content of the soil could well be the result of the weathering of the very large amount of readily broken down matrix of the Tyee rocks with subsequent addition from the weathering of volcanic rock fragments and feldspar grains.

Trout Creek-Yellow (TC-Y)

Thin sections were made for B1 (4 to 7 inches) and B2 (18 to 21 inches) horizons and the Tyee sandstone rock (Dr, at 120 inches).

The B1 is composed of weakly aggregated blocky peds with abundant skeleton grains of sand and silt loosely packed in a brown matrix of silt and clay. Feldspar and volcanic rock fragments, which were quite abundant, showed signs of breaking physically and in feldspar the cracking was as prominent as weathering found along cleavage traces and twinning planes. There were many grains that appeared no more weathered than those in the rock beneath the profile.

Fern roots and stems, charcoal fragments, and iron oxide concentrations, normally very coarse sand to fine sand in size, were common. Both biotite and muscovite laths were abundant throughout the slide. Amphibole and pyroxene were few and weathered to some extent but still present more than in the red soil profile. Large and medium pieces of broken sandstone rock were also present. The B2 had better aggregation than the B1, but the constituents were similar. The appearance of physical break up was less and the amounts of roots, fern parts and iron oxide concentrations were less. Oriented, yellowish brown clay skins commonly appeared as coating along medium and fine pores and cracks as well as around large skeleton grains and sandstone pieces. The coatings were not as extensive as in the red soils, but they were quite distinct.

Fern Prairie-Red (FP-R)

This profile was very much similar to the TC-R soil in both A and B horizons, but differed in having darker color of the matrix, more iron oxide concentrations and higher amounts of weatherable material, especially feldspar and rock fragments. The rock fragments in the lower B horizons, however, were lower in this profile than the lower B horizon of the TC-R soils. The dark brown color of the soil was probably due to the minute specks of iron oxide and organic matter incorporated in the dense silty and clayey matrix. Examples of the imbedded weathered feldspar described in the TC-R profile are shown in Figure 3.

Fern Prairie-Yellow (FP-Y)

The profile is similar to the TC-Y soil in having thin, oriented clay skins coating pores and cracks in the lower B horizons. Fern roots and stems, and charcoal fragments were numerous in the top horizon and slightly lower in the B horizon. They were more abundant than in the TC-Y soil. These roots and charcoal fragments as well as iron oxide concentrations were commonly very coarse sand and coarse sand in size.

Prairie Peak-Red (PP-R)

Generally, this soil was similar to the TC-R and FP-R soils, but differed especially in the distribution and amount of the oriented clay skins.

The A horizon had fine and medium, strong, granular aggregates composed of sand and silt grains of quartz, feldspar and rock fragments in a matrix of organic matter, silt and clay. In the amount and extent of charcoals, fern roots and iron oxide concentrations (or shot), this horizon is like the A horizons of the TC-R and FP-R soils. The amount of skeleton grains, especially feldspar, appeared higher than in the lower horizons. They were relatively fresh and were imbedded in the clayey matrix. Feldspar weathering along cleavage traces and twinning planes was commonly seen here as well as in the lower horizons. There was no evidence of oriented clay skins apart from chips and flakes from the B horizon.

The upper B horizon, related to the A horizon, had more angular peds, a definite increase in yellowish brown silt and clay matrix, and a decrease in iron oxide concentrations, charcoal fragments and fern roots. Weathering of the skeleton grains was like that of the TC-R soil. Feldspar was slightly lower than in the upper horizon.

Oriented clay skins were common in medium to large pores, but in fine and very fine pores they were few. Many flakes and chips of clay skins occurred in the matrix. Oriented clay skins were not as extensive as in the TC-R and FP-R soils. The oriented clay had definitely lower birefingence and was more difficult to see, when the nicols were crossed, than in the TC-R and FP-R soils, but appeared to be as well oriented. This indicates a difference in the composition of the oriented clay.

The lower B horizons were slightly more compact and had better blocky ped aggregates than the horizons above. Charcoal fragments roots and iron oxide concentrations were few. Many coatings and few concentrations of brownish-black materials similar to manganese oxides were found in the clay matrix and in cracks. The skeleton grains of quartz, feldspar and rock fragments (particularly quartz) appeared larger and greater in amount. Oriented clay skins were slightly more common than in the upper B horizon, and commonly coated pores and cracks. Flakes and chips of clay skins were still common. Ped surfaces were normally clear and had minor amount of coatings. Examples of laminated clay skins of the B3 (86 to 89 inches) horizon are shown in Figure 5.

Prairie Peak-Yellow (PP-Y)

Large remnants of sandstone and shale occupied 60 to 70% of the slides. The remainder consisted of angular quartz, feldspar and volcanic rock fragments of coarse sand and silt loosely packed in a silt and clay matrix. Iron oxide concentrations of sand size, randomly arranged, and cemented by reddish iron oxides were very common throughout the profile.

Clay skins were absent, but iron oxide coatings on peds and rock fragments were not uncommon. Feldspar grains were commonly in the process of breaking down into smaller ones and weathered grains were fairly common. Many amphiboles, very fine sand size, were weathered strongly. Biotite, with slightly bleached color, and muscovite flakes were common throughout the soil. Fern roots and stems and charcoal fragments were common throughout the profile. Few mycelia, probably from the roots were present in small number.

Red Creek-Red (RC-R)

This profile was similar to the PP-R soil but differed in having darker color and higher amounts of rock fragments. The rock fragments were from fine grained to very fine grained volcanic rock and possibly some shale and siltstone. Most of these rock fragments were rounded, and weathered extensively to clay minerals. The amount of rock fragments increased with depth. Thin, oriented, lower birefringence clay skins were less common than in the PP-R soil, and most of them occurred as chips, flakes or pore linings. The kind of clay skin was similar to the PP-R soil but the amount was less. Micas were common, particularly biotite. The amount rose sharply in the lower B horizon (B3), with laths or flakes of about fine sand size. Bleached biotite flakes were not uncommon, a few of the quartz (medium sand to fine sand) grains were composite type. An example of a bleached and frayed biotite flake is shown in Figure 6.

Red Creek-Yellow (RC -Y)

Unlike the PP-Y soil, the RC-Y soil was relatively free of iron oxide concentrations and sandstone rock fragments. Evidences of parent rock (Tyee sandstone) appeared strongly in the profile. Common to abundant biotite flakes (many of them bleached), rock fragments, and chlorite minerals were quite common. There was no indication of oriented clay skins in pores or cracks in the lower horizon. Fern roots and charcoal fragments were less common than in the PP-Y soil.

Tyee volcanic sandstone

Thin sections of the weathered sandstone were made from each of the four yellow soils. They were similar in general, thus, the thin section from the PP-Y soil only were described in detail.

The rock was a medium grained arkosic-volcanic wacke according to Gilbert's classification (61, p. 292), poorly sorted, with angular and subangular grains of sand and coarse silt tightly packed in an argillaceous matrix. Grains included 10 to 15% quartz, 30 to 40% feldspars, 15 to 20% rock fragments and 30 to 35% matrix and cement, with common accessary minerals of mica (3 to 5%, chlorite, hornblende and iron oxides. Quartz grains were mainly clear or with inclusions, but composite grains were also common. The feldspar was dominated by plagioclase (andesine). Zoned feldspar was not uncommon. Both fresh and weathered feldspar grains were present. The rock fragments were dominantly volcanics, fine grained to very fine grained basic igneous rocks and glass. The minerals grains appeared to be commonly surrounded and insome cases penetrated along cracks by masses of green chloritized matrix. In some cases the matrix appeared brownish and seemed to represent more oxidized stages of the rock.

Variations in Tyee sandstone were mostly on the grain size, amount of the major constituents, including matrix and cement, and the concentration of the heavy mineral suites. In the thin section from the RC-Y soil, a contact between beds of different grain size was evident.

The rock underneath the PP-R soil was different from the rest. It was composed of quartz, feldspar, volcanic rock fragments, and abundant mica flakes like the other rocks, but had less quartz and feldspar and more rock fragments and mica. It was finely laminated and fine grained. This rock is probably from the fine grained upper part of one of the beds of the rhythmically bedded Tyee formation.

Typical weathered Tyee sandstone from the PP-Y soil is shown in Figure 7.

X-ray diffraction analysis

Results of X-ray diffraction analysis of the clay fraction ($< 2\mu$) of selected profiles are shown in Table 6. The criteria for identification of the clay minerals in this study are summerized below:

1) Kaolin. Exhibits 7.2 to 7.6 Å spacing for both calcium and potassium saturated samples. The diffraction peak remains the same upon solvation and potassium saturation with 300° C. heat, but disappears upon heating at 550° C. for one hour.

2) Chlorite. Exhibits 14 Å spacing for both calcium and potassium saturation. No expansion upon solvation of the calcium saturated slide and no collapse upon potassium saturated and heated to 550° C. for one hour.

3) Vermiculite. Exhibits 14 to 14.5 Å spacing when calcium saturated. No expansion upon solvation, but collapse to 10 to 10.16 Å upon potassium saturation and either air drying or heat treatment at 550° C. for one hour.

Explanation of Photo Micrographs
(all are under plane polarized light unless specified)

Figure 2. Trout Creek-Red soil, 19-22 inches.

a = Unoriented matrix.
b = Void (crack)
c = Oriented clay skin
d = Weathering products from feldspar
e = Clear feldspar grain weathered along the cleavage traces.

Fibure 3. Fern Prairie-Red, 3-5 inches, nicols crossed.

a = Unoriented matrix with muscovite and quartz grains.
b = Feldspar grain weathered along cleavage traces and twining planes.

Figure 4. Fern Prairie-Red, 35-38 inches.

a = Void
b = Mineral grains (quartz and feldspar)
c = Laminated, oriented clay skin. Unoriented matrix is dark.

Figure 5. Prairie Peak-Red, 86 to 89 inches.

Same as Figure 4, but clay skin is more fractured and irregu lar.

Figure 6. Red Creek-Red, 48-51 inches.

a = Bleached and frayed highly weathered biotite.
b = Relatively fresh muscovite
c = Matrix with specks of iron oxides

Figure 7. Tyee sandstone, PP-Y, 58 inches.

Note the poorly sorted nature of Tyee rock.
a = Altered volcanic rock fragments.
b = Mineral grains (quartz and feldspar)
c = Matrix of chloritic silt and clay.

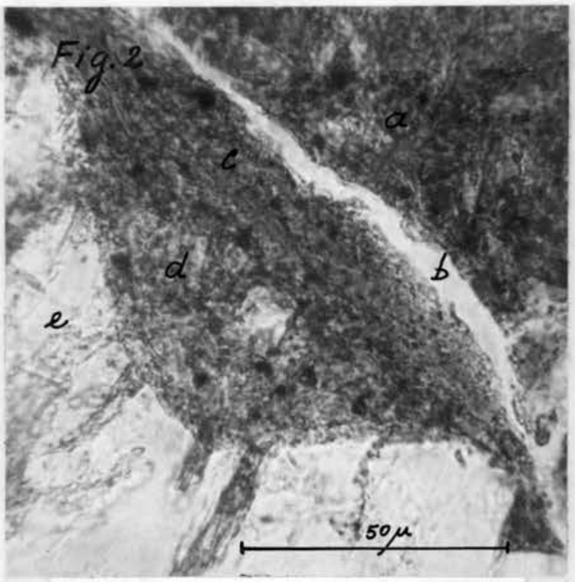


Fig. 2
a
c
b
d
e
50μ

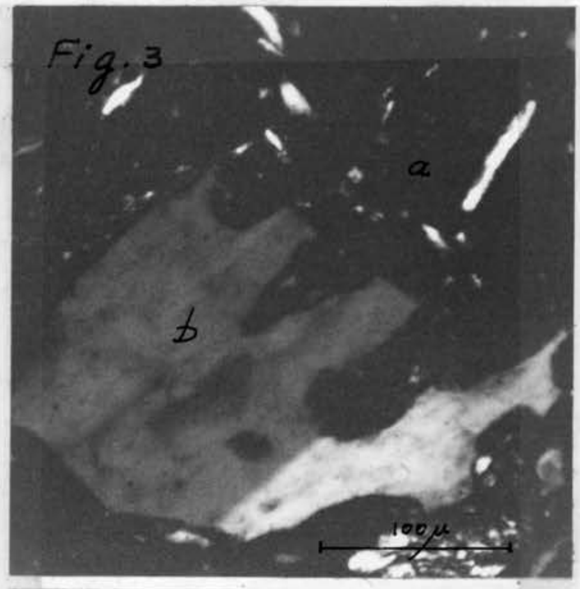
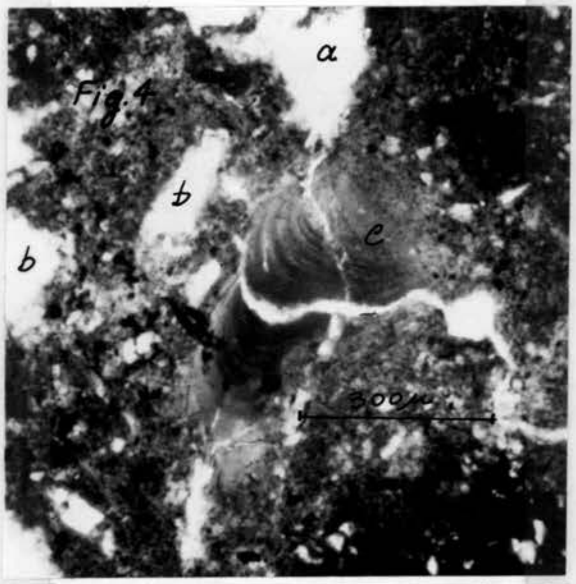
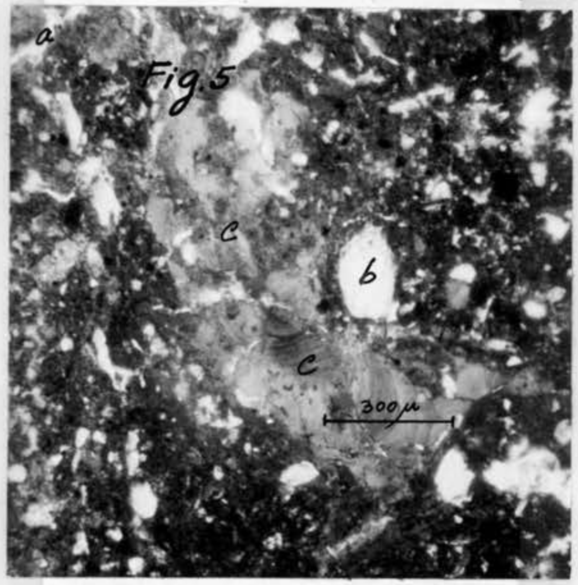


Fig. 3
a
b
100μ


a
Fig. 4
b
b
c
300μ


a
Fig. 5
c
b
c
300μ

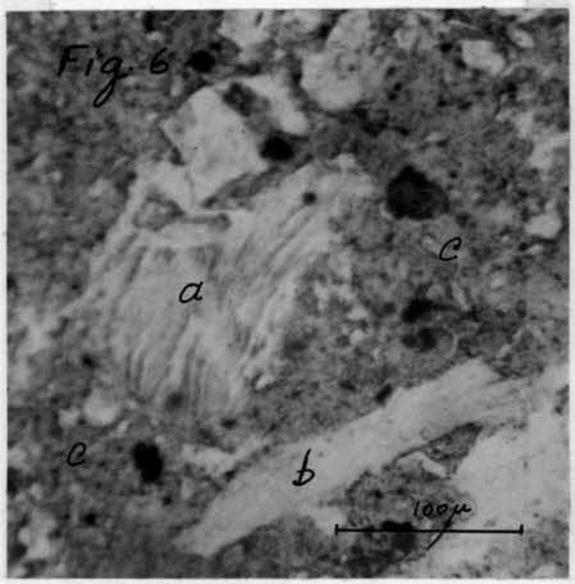


Fig. 6
c
a
c
b
100μ

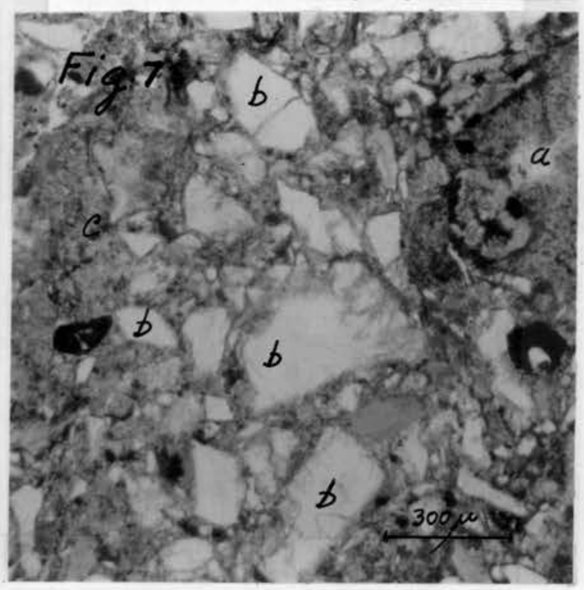


Fig. 7
b
a
c
b
b
b
300μ

4) Montmorillonite. Exhibits 14 to 15 Å when calcium saturated and will expand to 17 to 18 Å upon solvation with ethylene glycol. Collapse to 10 to 11 Å upon potassium saturation. Collapse to 10 to 10.16 Å upon potassium saturation and heat at 550° C. for one hour.

5) Illite. Exhibits 10 to 10.5 Å spacing for both calcium and potassium saturated samples. Heat treatment at 550° C. does not alter the 00ℓ lattice spacing. As used here, illite implies to micaceous materials occurring in the $< 2\mu$ fraction.

6) Intergrade. Intermediate in properties with respect to chlorite on one hand and montmorillonite or vermiculite on the other. These materials usually do not expand upon solvation and exhibit no collapse on potassium saturation, however they do collapse progressively on potassium saturation plus heat to 300° C. and 550° C. but not to the same extent as montmorillonite or vermiculite.

It should be noted that identification and interpretation of the clay minerals by means of X-ray diffraction depend upon the methods and criteria used. Harward and Theisen 11/ have pointed out that interpretation depends upon particular combination of the specimen

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11/ Harward, M. E. and Theisen, A. A. Problems in clay mineral identification by X-ray diffraction. Soil Science Society of America Proceedings (Inpress, 1962).

carrier, methods of iron removal, dispersing reagents, cation saturation of clay, clay size fraction and sometimes even chance peeling of specimens.

Identification of kaolin was not positive, in the samples as indicated, either because the 7 Å peak could be interpreted as a second order peak of 14 Å minerals or because it was not sufficiently distinct to be positively classed as a diffraction peak, Vermiculite may or may not have been present. With 14 Å minerals (chlorite or intergrade) and a 10 Å mineral (illite), vermiculite cannot be unambiguously identified, but in no case did potassium saturation produce a 10 Å peak. The presence of illite was doubtful in some samples because suspected peaks in the 10 Å vicinity could not positively be attributed to diffraction rather than to variations in background.

In so far as diffraction intensities suggest quantities of mineral present, the intergrade was the dominant layered silicate in the samples studied. Montmorillonite appeared moderate in amount. Illite, vermiculite, chlorite and kaolin when present were quite low in quantity.

The X-ray diffraction analysis revealed a difference between the two climatic zones in the presence of montmorillonite in only the

TC-R and TC-Y soils and in the greater indication of illite in the TC-R and TC-Y soils.

Table 6. Clay mineral identification of some selected soils.

Profile name	Horizon	Depth (inches)	K	C	V	M	I	Ig
TC-R	A1	0-6	?	x	?	x	x	x
	B21	27-36	?	-	?	x	x	x
	B3	95-105	x	-	?	x	?	x
TC-Y	B1	11-18	-	-	?	x	x	x
	Dr	30+	-	-	?	x	?	x
PP-R	A1	0-10	?	x	?	-	-	x
	B21	31-37	?	-	?	-	?	x
	B3	86-94	?	-	?	-	?	x
PP-Y	B2	11-17	-	x	?	-	?	x
	Dr	58+	-	-	?	x	x	x

K = Kaolin C = Chlorite

V = Vermiculite M = Montmorillonite

I = Illite Ig = Intergrade

x = present - = absent

? = identification not positive because of obscurity of peaks or because peaks of several minerals coincide.

DISCUSSION

Soil Genesis

The yellow soils were relatively shallow to bedrock and contained a large amount of rock fragments. In both climatic zones, they had quartz/feldspar ratios only slightly higher than the ratios in the underlying rocks and they showed no consistent differences in the degree of weathering between the two zones. Thus, they may be regarded as immature soils in a relatively early weathering stage, formed directly from bedrock material. Any diversity of the quartz/feldspar ratios and content of minerals in the soils may be attributed to the variability in the parent material. As already stated, the Tyee sandstone showed much variation in its composition, grain size and bedding arrangements.

The red soils were deep and clayey and were generally strongly weathered in comparison with the yellow soils and the bedrock. However, the study did not indicate the gradual decrease of weatherable minerals towards the surface commonly found in soils formed in place from uniform parent material (8). Instead, the quartz/feldspar ratios, the kinds and amounts of the heavy minerals, and the thin section study showed, in all four red soils, that surface horizons were not the most strongly weathered. The FP-R soil had little change with depth, and the other red soils showed the strongest weathering in the lower parts of the profiles. This indicates that these soils did not weather in place from a uniform parent material. The Tyee formation would not form a uniform parent material and it can be postulated that the red soils weathered in place from it.

Several workers (9, 13, 20, 38, 40, 54) have regarded optically oriented clay skins in B horizons together with leached or eluviated overlying horizons as indicative of clay illuviation in soil profiles. In the soils studied, the lower rainfall red soils (TC-R and FP-R) have a large amount of oriented clays. Many of those clay bodies can be easily attributed to deposition in oriented fashion in pores and cracks by percolating water from the upper part of the solum (12, p. 379) and to pressure orientation in pressure faces or stress cutans (10, p. 286). However, other minute flecks of oriented clay in elongated clusters with optical continuity throughout cannot be easily accounted for as clay skins or pressure faces. The higher rainfall PP-R and RC-R soils appear to have less indication of this type of oriented clays, but have more broken flakes and chips of clay skins in the B horizon. It is proposed that in the lower rainfall soils, with the more easily dispersed clay, fragments of clay skins are degraded to clusters of oriented clay bodies as clay is moved and redeposited in new clay skins. These features together with the absence of well defined eluvial horizons could indicate that more than one generation of soil development is involved and that the present soils are derived from mixed, colluviated older soils.

Thus, additions from local sources by slumping or mass wasting of previously weathered soils could result in the addition of fresh constituents and explain the variation of quartz/feldspar ratios and content of heavy minerals such as epidote, garnet and possibly some of the hornblende. However, the presence and amount of fresh, green hornblende and hypersthene are difficult to justify. Investigation of the heavy minerals in the weathered Tyee rocks as well as fresh Tyee samples in the Alsea Basin and vicinity (Tidewater, Denzer, Alsea, Digger Mountains, and Blanchly)[12/] showed only low amounts of hypersthene and hornblende, and that when they occurred, they were always weathered and small. The large, fresh grains of green hornblende and hypersthene must have an outside source.

Since the red soil profiles were from old slump areas and were too thick to reveal their relationship to the underlying bedrock, the nature of the soil parent material or of the original geomorphic surface is not known. The red soils could have been developed from

12 / Unpublished data from Dr. J. C. Cumming.

colluvium or alluvium on old terraces or other surfaces, with mixing of Tyee materials and materials from other formations or intrusives rich in fresh hornblende and hypersthene. However, the red soil locations were chosen to minimize the possibility of alluvial or colluvial addition of materials from sources other than the Tyee formation. Moreover, any such addition must have been earlier than the development of the present topography and hence would not explain the fresh grains of weatherable minerals.

Williams (60, p. 145-146) in his study of the Crater Lake area, described the ejecta from Mount Mazama as having inclusions of euhedral and zoned plagioclase crystals along with hypersthene and hornblende crystals. He stated that some of finer ejecta must have spread for hundreds of miles, and regarding the distribution of crystals in the ejecta, he (60 p. 77) wrote "Surprising was the discovery that among the deposits bordering the Dalles-California highway, the content of crystals generally increases with the distance from Crater Lake". The Mazama eruption was about 6500 to 7000 years ago (5, p. 65). Younger volcanic eruptions at Newberry Crater, Devil's Hill and other sites in the High Cascades (52, 59) also could have produced deposits of like composition. Although most of the pumice and ash from Mount Mazama explosion was carried to the northeast by prevailing winds, Hansen (23, p. 85) found an accumulation of thick volcanic ash at Noti, 20 miles west of Eugene (15 to 30 miles from the sample locations of the study). Norgren[13/] in his thin sectionstudy of some Oregon soils, found zoned plagioclase, hypersthene, and amphibole grains in surface horizons of Astoria, Quillayute, Jory (Aiken), Woodburn and Dayton profiles which suggested to him, the possibility of an ash deposit. A few clear, euhedral crystals of plagioclase carrying particles of isotropic materials like glass were found in the upper horizons of the PP-R, FP-R and FP-Y soils. These, together with the fresh, clear, mostly euhedral grains of hypersthene and hornblende indicate deposition of pyroclastic materials.

The supposedly ash-derived minerals in the shallow, steep, yellow soils could have been deposited after the soils were formed. This would mean that the soils are older than they appear or that ash deposit was more recent than the date ascribed to the Mazama eruption. On the other hand, the ash could have been deposited before the soil parent material was formed by colluviation or weathering of the rock in place.

13/ Norgren, Joel N. Thin-section micromorphology of eight Oregon soils. 1962 (Master's thesis in preparation).

Differences between the red soils of the two climate zones were shown in the study of thin sections and X-ray diffraction analysis. The thin sections revealed the clayey nature of the red soils, as compared to the yellow soils, and the presence of oriented clay skins in the B horizons of the red soils in both zones. These oriented clay skins were found to be common in the low rainfall red soils (TC-R and FP-R) and the oriented clay had definitely higher birefringence than in the high rainfall ones (PR-R and RC-R). The clay skins of lower birefingence, however, appeared to be as well oriented as the others. X-ray diffraction analysis of clay minerals ($< 2\mu$) showed that intergrades (between chlorite and montmorillonite or vermiculite) were present in all samples studied. Montmorillonite however, was present only in the low rainfall TC-R and TC-Y soils and in the rock (Dr) in both zones. Montmorillonite was also found to be present in all fresh Tyee sandstone samples collected from Lane and Douglas Counties south of the Alsea Basin[14/].

Popov (45) observed oriented clay skins in samples consisting of montmorillonite, while Brewer (9), Stremme (49) and others noted that the clay skins could be formed of illite, "iron illite" or a

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14/ Unpublished X-ray diffraction data by J. A. Beattie.

mixture of kaolinite with illite. Minashina (40, p. 428) considered oriented clay bodies can be formed by montmorillinite, beidellite, illite, and other highly dispersed minerals. In this case, the clay of higher birefringence in the lower rainfall soils could have been montmorillonite and the lower birefingence type of clay in the higher rainfall soils could have been an intergrade closer to chlorite than to montmorillonite or vermiculite. This would explain the lower birefringence of the oriented clay in the higher rainfall red soils, its relative scarcity (because of the less easily dispersed nature of the intergradient clays), and suggests a higher degree of weathering as well.

The yellow soils followed the same pattern as the red soils but to a lesser extent. Oriented clay skins of the higher birefringence type were found in small amounts, coating peds and lining large and medium pores in the lower rainfall yellow soils, whereas the higher rainfall yellow soils had no oriented clay skins.

The differences between the soils of the two climatic zones appear to be the reflection of the present climatic regime. Jackson (25, p. 276) mentioned reports from many workers on the weathering of montmorillonite to kaolin. In this case, kaolin was not definitely identified. Possibly montmorillonite could weather to an intergrade of chloritic properties. If this is the case, the higher rainfall soils would represent the higher state of weathering of the two climatic zones.

Red soils like the ones in this study are, commonly believed to develop in a warm and humid climate. If these soils are developed from previously weathered material as suggested earlier, a warmer and more humid climate may have been involved.

Classification

The soils may be placed into great soil groups (6, 55) and in the Seventh Approximation (57) of a new system of classification.

Yellow soils

These soils are similar to Regosols (55, p. 120), Sols Bruns Acides (7, 51) or Acid Brown Earths (17, p. 20-21) and Brown Forest soils (6, p. 991; 51, p. 249). Differentiation into horizons is not strongly developed, and the content of coarse fragments is high, but they do have B horizons by virtue of structure. Accordingly, they may be eliminated from Regosols.

Sols Bruns Acides as described by Baur and Lyford (7, p. 533-536) have the following characteristics:

(1) Humid, temperate climate with forest vegetation.

2) Strong acidity and low base status.

3) High organic carbon with a sharp decrease in the lower horizons.

4) (A0), A1, A2, A3 (or B1), B2 and C or Dr horizons.

5) Friable and granular A horizon.

6) Weak A2 horizon (This differs from European concepts, (51, p. 248)

7) No clay accumulation in the B horizon.

8) Clay flows or coatings absent or present only in faint, discontinuous forms in pores or on outside of peds.

Regarding the presence of an A2 horizon, Baur and Lyford (7, p. 534) stated "The weakness in development of the A2 cannot be emphasized too strongly; in fact, in many places A3 or B1 might be better horizon notation than A2. Furthermore, there is some field evidence that the A2 horizon may be transient. Detailed studies might show that the color of this horizon changes seasonally".

The soils in question have nearly all these listed characteristics. The higher rainfall yellow soils (PP-Y and RC-Y) are slightly less acid and have higher base saturation. They have no A2 horizon, but they are very similar in most respects and could classify with the Sols Bruns Acides.

The lower rainfall yellow soils have very high base saturation and could well classify with the Brown Forest soils (6, p. 991). Tavernier and Smith (51, p. 249-280) described these soils, "the base-rich Brown Forest soils with (B)" 15/ as an extreme opposite to Sols Bruns Acides in base status. Their main characteristics are:

1) Temperate, humid climate with deciduous forest.

2) Basic or calcareous parent materials.

3) Relatively dark A horizon and high humus content.

4) B horizon without clay accumulation.

5) High base saturation.

The lower rainfall TC-Y and FP-Y soils are similar to this group, but do not have a dark A horizon, and have not developed on calcareous parent materials. They are intermediate between Brown Forest soils (6, p. 991) and Sols Bruns Acides.

Relative to the Seventh Approximation, the lower rainfall TC-Y and FP-Y soils have the following characteristics:

No argillic horizon; cambic horizon and ochric epipedon; humid, temperate climate; no carbonates; mean annual temperature more than 47° F.; drying period in solum less than 60 days; no fragipan; high amount of weatherable minerals; siliceous and mixed lithology

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15/ (B), pronounced "B parenthesis", means B horizon without clay accumulation (51, p. 244).

parent materials; base saturation higher than 30%. They may be classified as Eutric Dystrochrepts. The higher rainfall PP-Y and RC-Y soils have the following characteristics:

No argillic horizon; cambic horizon and umbric epipedon; humid, temperate climate; no anthropic epipedon; mean annual temperature more than 47° F.; no mottles within 45 inches (1 meter); less than 40% carbonate in horizon immediately below the cambic horizon; base saturation below 30% in the cambic horizon. They may be classified as Orthic Haplumbrepts.

The great groups for soils with umbric epipedon do not seem appropriate for these soils. Division of Haplumbrepts into two great groups, Dystrumbrepts and Eutrumbrepts, parallel to Dystrochrepts and Eutrochrepts would provide a better classification. If this were done these soils would be "Orthic Dystrumbrepts."

Red soils

The red soils are more difficult to classify by the 1938 Yearbook system. The results of this study make it clear that they cannot be classified as Latosols, although they have many similar characteristics. The amounts of weatherable minerals in silt and sand fractions and of 2:1 lattice clays are much higher than the amounts suggested by Kellogg (30, 31).

The soils in question seem to be more like Reddish-Brown Lateritic soils, Yellowish-Brown Lateritic soils, and Red-Yellow Podzolic soils than any other great soil groups listed by Thorp and Smith (55, p. 117).

The Reddish-Brown Lateritic and Yellowish-Brown Lateritic great soil groups were originally limited to tropical climate and represented by Puerto Rican soil series (6, p. 994). No modern statement of the definitive characteristics of these two great soil groups, as used in Puerto Rico, are available for critical comparison. Robert (46), however, emphasized "lateritic" characteristics as 1) lack of pronounced horizonation, 2) high degree of aggregation, 3) high clay content, 4) lack of pronounced swelling and stickiness, and the 5) high friability, porosity and permeability. In addition, mechanical analysis data, descriptions of individual soil profiles and definitions of great soil groups (46) suggest 6) presence of illuvial horizons of clay accumulation.

The red soils in question have characteristics 1, 2, 3, 4, 5 (to a lesser extent), and 6 (at least the lower rainfall soils).

The Reddish-Brown Lateritic great soil group was extended to the mainland (55, p. 122). More critical comparisons can be made from many detailed investigations (13, 18, 39, 41). Main characteristics of the Reddish-Brown Lateritic soils of the Southeast of the United States are:

1) Various types of parent materials, including basic igneous and metamorphic rocks or sediments from such rocks, limestone, and marine sandy clay.

2) Deep, dark colored, friable and highly argillaceous solum.

3) Strongly leached condition with almost complete removal of bases and salts.

4) Uniform profile without pronounced horizonation.

5) Uniform mineralogical composition, regardless of different parent materials.

6) Textural B horizon with oriented clay skins.

7) Dominantly kaolin clays with vermiculite (and illite) common.

8) Moderate to low base saturation (average 10 to 40%) generally decreasing with depth.

9) Weakly developed A2 horizon, with intergrade nature to Red-Yellow Podzolic soils.

The lower rainfall red soils (TC-R and FP-R) have characteristics 1 (?), 2, 3, 4, 6 and 8. They are similar to the Reddish-Brown Lateritic soils and differ mainly in the dominance of 2:1 type clay minerals instead of 1:1 type. The Red-Yellow Podzolic soils differ from the Reddish-Brown Lateritic soils in the presence of a distinct A2 horizon, which is missing from the soil in question. Therefore, the red soils of lower rainfall can be classified as Reddish-Brown Lateritic soils.

The higher rainfall soils (PP-R and RC-R) may not have textural B horizons. Although at least one profile appears to have an accumulation of clay in the B horizon, the amount and distribution of the clay skins are certainly only marginal for the Reddish-Brown Lateritic great soil group as described.

The Red-Yellow soils in Japan (29, p. 99-103) have characteristics as follows:

1) Various parent materials, basic and acid igneous and sedimentary rocks including limestone.

2) Strongly leached profile and dark A horizon with C/N ratio from 7 to 23.

3) Profile colors ranging from red to yellow.

4) A heavier B horizon and no A2 horizon.

5) Low to moderate base saturation, up to 40% but normally less than 20%.

6) High amount of quartz and feldspar, very low ($<5\%$) heavy mineral content, with additions from volcanic ash.

7) Clay minerals mostly halloysite, hydrated halloysite, and some gibbsite, vermiculite, and iron oxides.

From the available data these Red-Yellow soils of Japan are very much similar to the higher rainfall soils in question, which have characteristics 1, 2, 3, 4(?), 5 and 6. Data for clay skins are not available although the Red-Yellow soils are said to have an increase in clay from A to B horizons. Deep, yellow (hue of 10YR) soils were studied by Jenne (27, p. 89). These and the higher rainfall red soils of this study form a color sequence similar to the Red-Yellow soils. The indication of volcanic ash additions in the Japanese soils makes them very similar to the condition postulated in this study. Jenne (27, p. 89-91) revealed the present of amorphous materials as well as montmorillonite, chlorite, illite, and kaolin. He compared Astoria soils favorably with the Japanese volcanic ash soils (28, p. 105-109). Clay minerals in the Red-Yellow soils, again, are mostly of 1:1 lattice and they appear to have higher state of weathering than the soils in question.

Cline (16, p. 70-71) characterized Latosols as soils with:

1) An A1 horizon "over a B horizon in which sesquioxides have

been concentrated by removal of bases and combined silica."

2) No illuvial horizons.

3) Mainly secondary minerals (1: 1 lattice clay).

4) Less clayey feel than that indicated by mechanical analysis, and "smeary" consistence when wet.

Humic Latosols in Hawaii (16, p. 73-75) have, in addition,

5) "Strongly developed granular A1 horizon over, red, brown, or reddish-brown friable B horizon".

6) High content of organic matter in the upper horizons, up to 8 or 10 percent in the upper 6 or 8 inches.

7) Low Base saturation.

8) No effervescence (due to the presence of manganese dioxide) with hydrogen peroxide.

9) Clays that do not dry irreversibly.

The higher rainfall red soils (PP-R and RC-R) qualify for points 2(?), 4, 5, 6, 7, and 9, but are not sufficiently weathered for point 3.

To sum up, it can be stated that the lower rainfall (TC-R and FP-R) soils are similar to the Reddish-Brown Lateritic soils of the Southeast of the United States and can be classified with them. The difference in clay minerals (and weatherable minerals) can be attributed to the stage of weathering as well as the nature of parent materials and the condition of mixing.

The higher rainfall (PP-R and RC-R) soils, however, present more problems in comparison. They are like the Reddish-Brown Lateritic soils, but are doubtful in the presence or absence of the textural B horizons. Comparison to other soil groups does not yield adequate evidence for classification of these soils with them. By virtue of low base saturation and no textural B horizon, these soils could be classified with the Sols Bruns Acides, but they contrast strongly in color hue and probably also in surface color value and organic matter content with the group as described.

For classification in the Seventh Approximation, the content of weatherable minerals eliminates the Oxisol order. Accordingly, the presence of argillic horizon is crucial. The TC-R, FP-R and PP-R profiles have an increase in clay content of 8% or more within a vertical distance of 12 inches. The mineralogy of all 4 profiles suggests the possibility of lithologic discontinuities, so that A and B horizons may not have formed from uniform parent materials. Therefore, only presence or absence of clay skins is required. The lower rainfall soils (FP-R and TC-R) have abundant clay skins in pores and on peds (close to 10% in cross section in parts of the PP-R soil), either as pore fillings or as fragments of clay skins. These are more abundant in the PP-R soil than in the RC-R soil, but clay skins on peds were not apparent in either soil. Because of the uncertainty of identification of argillic horizon in the higher rainfall red soils, alternative classifications are presented.

Assuming argillic horizon in the higher rainfall soils, the red soils have the following characteristics:

Argillic horizon; base saturation less than 35% and decrease with depth; no tonguing of albic horizon; umbric epipedon; humid climate, under forestation; development on old land surfaces; argillic horizon having moist values less than 4 and dry values not more than 1 unit higher than moist values; no plintite or fragipan. They may be classified as Orthic Rhodochrults.

If the higher rainfall (PP-R and RC-R) soils have no argillic horizon, these soils have characteristics similar to the PP-Y and RC-Y soils and may be classified as Orthic Haplumbrepts, or "Orthic Dystrumbrepts" as proposed above. The thickness and red hue of these soils could perhaps be recognized by formation of a subgroup Rhodochrultic Haplumbrept or "Rhodochrultic Dystrumbrept."

All classified names are listed in Table 7.

Table 7. Classification of the eight soils studied

Soil name	Present use	1938 Yearbook	7th Approximation
Lower rainfall soils			
TC-R, FP-R	Reddish Brown Latosols	Reddish-Brown Lateritic soils	Orthic Rhodochrults
TC-Y, FP-Y	not classified	Brown Forest soils	Eutric Dystrochrepts
Higher rainfall soils			
PP-R, RC-R	Brown Latosols	Reddish-Brown Lateritic or Sols Bruns Acides	Orthic Rhodochrults or Orthic Haplumbrepts*
PP-Y, RC-Y	not classified	Sols Bruns Acides	Orthic Haplumbrepts*

* Modifications of the Seventh Approximation are proposed in the text.

CONCLUSIONS

The yellow soils of both climatic zones are shallow, stoney, relatively unweathered, and in an early phase of profile development. Variations in the content of weatherable minerals are related to the nature of the Tyee parent rock. The soils seem to be weathering directly from Tyee rock material on a relatively young surface.

The red soils, on the other hand, are deep, clayey, red, on older surfaces, and relatively highly weathered. "Fossil" oriented clay fragments either well preserved (mostly in the higher rainfall red soils) or partially redispersed (mostly in the lower rainfall red soils) suggest inheritance of material weathered in previous generations of soils, perhaps in a completely different environment and climatic regime.

There are evidences of additions of pyroclastic origin as well as mixing and redistribution locally in the upper horizons of both red and yellow soils. The absence of montmorillonite, scarcity (absence in yellow soils) of clay skins, as well as low base saturation and cation exchange capacity in the red and yellow soils of higher rainfall differentiate these soils from the corresponding soils of lower rainfall, probably as a result of the present climatic and environmental conditions.

The amount of weatherable minerals in the most strongly weathered profiles is too high for Latosols or Oxisols. Difficulties of classification (Table 7) in both the 1938 Yearbook system and the Seventh Approximation lie mainly in the nature and characteristics of the higher rainfall red soils and, to a lesser extent, yellow soils. The presence of umbric epipedons and cambic horizons in these highly leached soils led to a proposed modification in the Seventh Approximation.

Eight profiles representing four soil series were included in this study. Field data from a wider range of profiles as well as more complete identification of clay minerals will be required for full understanding of genesis and proper classification of the variety of soils in the Oregon Coast Range.

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APPENDICES

APPENDIX I

Soil Profile Descriptions with Physical and Chemical Data

Most descriptive terms used in the profile descriptions are defined in the Soil Survey Manual (56). Size ranges for concretions are the same as for granular and crumb structure.

All color notations are from the Munsell Soil Color Chart and all are moist unless specified otherwise.

Textural classes and pH values are based on laboratory data. Methods for the physical and chemical analyses are described in the Materials and Methods section of the main text.

Particle size separation of the sand fractions in each profile are given in Table 2.

Scientific names of plants are given in Appendix II.

Trout Creek-Red (TC-R).

Description and Sampling: E. G. Knox, and S. Rojanasoonthon on September 12, 1960, Benton County, Oregon.

Location: The site is on the west side of a spur logging road in a northeast facing slope in the SE$\frac{1}{4}$, NW$\frac{1}{4}$, S10, T14S, R7W, W.M., about 3 1/2 miles east-southeast of Alsea, Oregon. The profile is in the clearing on the bend in the gravel road.

Parent material: Old, weathered, residium and colluvium from Tyee volcanic sandstone of Middle Eocene age.

Topography: Mountainous, upland with 25% northeast slope; elevation 1500 ft. (465 metres). The profile was developed on an old, stable slump area.

Drainage: Well drained; moist when sampled and described.

Vegetation: Cut-over Douglas-fir and hemlock forest with hazel, chinquapin, ocean-spray, and understory species of bracken fern, salal, grasses and thistle.

Soil profile:

Horizon	Depth (in.)	Depth (cm.)	Description
A	1-0	3-0	Largely fresh bracken fern litter.
A1	0-6	0-15	Dark reddish brown (5YR 2/3 moist); clay loam; strong fine granular structure; friable, sticky, slightly plastic; many fine interstitial pores; few fine charcoal fragments; many roots; lower boundary

clear and wavy; pH 6.4.

Horizon	Depth (in.)	(cm.)	Description
A3	6-12	15-31	Dark reddish brown (5YR 3/2 moist); clay; strong fine to very fine subangular blocky and granular structure; friable, sticky, plastic; few fine interstitial pores; few fine charcoal fragments; few medium rock fragments (2 to 5 mm.); many roots; lower boundary clear and wavy; pH 6.1.
B11	12-19	31-48	Dark reddish brown (5YR 3/4 moist); with clay skins on peds some redder and darker; clay; strong very fine to fine subangular blocky structure; friable; very sticky, plastic; many very fine tubular pores (30 per sq. in.); many roots; lower boundary clear and wavy; pH 5.7.
B12	19-27	48-69	Yellowish red (5YR 3/5 moist); clay; moderate fine and very fine subangular blocky structure; friable, very sticky, plastic; common thin clay skins; common very fine tubular pores (20 per sq. in.); few medium and coarse tubular pores; dark coated root channels, 1 to 5 in. apart; common roots; lower boundary clear and wavy; pH 5.6.

Horizon	Depth (in.)(cm.)	Description
B21	27-36 69-91	Dark red (2.5YR 3/6 moist) with thin continuous dark red (2.5YR 3/5 moist) clay skins on larger peds; clay; moderate coarse and medium breaking to fine subangular blocky structure; hard, firm, sticky, plastic; common very fine tubular pores (20 per sq. in.), few coarse tubular pores, 5 to 15 in. apart; dark coated root channels; few small rock fragments (1 to 2 mm.); common roots (mostly bracken fern); lower boundary gradual and smooth; pH 5.5.
B22	36-72 91-183	Dark red (2.5YR 3/6 moist) with medium continuous dark red (2.5YR 3/5 moist) clay skins; clay; moderate coarse and medium breaking to fine subangular blocky structure; hard, firm, sticky, plastic, common very fine tubular pores (20 per sq. in.); few coarse tubular pores, 5 to 15 in. apart; few small rock fragments (1 to 2 mm.); few

Horizon	Depth (in.)(cm.)	Description
		small slickensides; dark coated root channels, few roots (bracken fern), lower boundary gradual and smooth; pH 5.4.
B23	72-95 183-241	Dark red (2.5YR 3/6 moist) with medium continuous dark red (2.5YR 3/6 moist) clay skins; clay; moderate coarse and few fine subangular blocky structure; firm, sticky, plastic; common very fine tubular pores (15 per sq. in.); few small slickensides; 3 to 5% small rock fragments (1 to 2 mm.); few roots; lower boundary gradual and smooth; pH 5.4.
B3	95-105+ 241-267+	Dark red (2.5YR 3/6 moist) with thick continuous dark red (2.5YR 3/6 moist) clay skins; clay; moderate to weak medium and fine subangular blocky structure; firm, sticky, plastic; common very fine tubular pores (15 per sq. in.); 5 % small rock fragments, (1 to 2 mm.); few small slickensides; few roots; pH 5.3.

Trout Creek-Red (TC - R)

Depth (inches)	Horizon	Particle size distribution (m.m.) (%) Sand	Silt	Clay	<0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (%) 1/10 atmos.	0.5 atmos.	pH (1:1)
0-6	A1	26.2	34.5	38.2	66.8	0.71	56.0	43.1	6.4
6-12	A3	22.9	35.1	42.0	70.4				6.1
12-19	B11	20.9	31.6	48.5	74.2				5.7
19-27	B12	17.9	32.2	49.9	72.0				5.6
27-36	B21	16.4	29.6	54.0	74.8				5.5
36-72	B22	16.1	25.6	58.3	76.3				5.4
72-95	B23	17.7	26.7	55.7	74.3				5.4
95-105	B3	20.5	27.6	51.7	71.4				5.3

Depth (inches)	Horizon	Cation exchange capacity	Extractable cations meq./100 gm. Ca	Mg	Na	K	Base saturation (%)	Organic matter C %	N %	C/N ratio
0-6	A1	35.7	12.2	7.8	0.32	3.4	66.5	4.4	0.20	21.8
6-12	A3	33.3	3.4	2.5	0.48	0.8	21.6	4.0	0.18	22.2
12-19	B11	28.2	5.4	3.0	0.23	2.0	38.0	2.4	0.11	21.9
19-27	B12	26.8	11.0	4.9	0.34	3.2	72.6	0.5	0.06	9.0
27-36	B21	24.8	4.1	2.9	0.26	0.3	30.4	0.3	0.04	7.5
36-72	B22	24.4	2.5	1.7	0.15	0.2	18.7	0.3	0.03	10.0
72-95	B23	23.1	1.4	1.4	0.26	0.2	14.2	0.1	0.02	6.5
95-105	B3	25.6	1.3	1.1	0.20	0.3	11.4	0.2	0.02	9.5

Trout Creek-Yellow (TC-Y).

Description and Sampling: E. G. Knox and S. Rojanasoonthon, on September 12, 1960, Benton County, Oregon.

Location: The site is in the SE$\frac{1}{4}$, SW$\frac{1}{4}$, NW$\frac{1}{4}$, S10, T14S, R7W, W.M., about 3 1/2 miles east-southeast of Alsea. The profile was taken from the south slope above the spur road where it runs west after passing both the first abandoned landing on the ridge and the sharp corner caused by the drainageway.

Parent material: Residuum and colluvium from medium-grained, weathered Tyee volcanic sandstone of Middle Eocene age.

Topography: Mountainous, upland with 35% south slope; elevation 1500 ft. (465 metres).

Drainage: Well drained; moist when sampled and described.

Vegetation: Cut-over Douglas-fir and hemlock forest with dogwood, big-leaf maple, hazel, ocean-spray, and understory species of sword fern, grasses, and weeds.

Soil profile:

Horizon	Depth (in.)	Depth (cm.)	Description
A1	0-4	0-10	Dark brown (10 YR 3/3 moist); loam; moderate medium to fine granular

			structure; friable, plastic, slightly sticky; many interstitial pores; few medium rock fragments (2 to 5 mm.), 10% coarse rock fragments (5 to 10 mm.); many roots; boundary clear and smooth; pH 6.0.
B1	4-18	10-46	Brown (10YR 4/3 moist); loam; weak fine subangular blocky structure; hard, friable, slightly sticky, slightly plastic; many very fine tubular pores (30 per sq. in.); 25% coarse rock fragments (5 to 10 mm.); common roots; lower boundary clear and wavy; pH 6.0.
B2	18-30	46-76	Brown (10YR 4/3 moist); moderate medium subangular blocky structure; hard, friable, sticky, plastic; common thin clay skins on ped surfaces; many very fine tubular pores (30 per sq. in.); 40% coarse fragments of rock (5 to 10 mm.); common roots; lower boundary abrupt and irregular, in some places broken where Dr is in contact with upper horizon (B1); clay skins appear darker

		(10YR 3/3 moist) and increase with depth; pH 5.9.
Dr	30+	Weathered, fractured Tyee sandstone with B_2 horizon tongues in cracks and openings.

Trout Creek - Yellow (TC-Y)

Depth (inches)	Horizon	Particle size distribution (m.m.) (·/·) Sand	Silt	Clay	<0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (·/·) 1/10 atmos.	0.5 atmos.	pH (1:1)
0-4	A1	41.8	36.6	21.7	50.7				6.0
4-18	B1	42.0	36.0	22.0	49.7				6.0
18-30	B2	45.5	30.0	24.5	47.3				5.9
30+	Dr	46.4	34.1	19.5					

Depth (inches)	Horizon	Cation exchange capacity	Extractable cations meq./100gm. Ca	Mg	Na	K	Base saturation (·/·)	Organic matter C ·/·	N ·/·	C/N ratio
0-4	A1	28.2	15.4	6.5	0.23	1.38	83.5	3.4	0.14	24.6
4-18	B1	24.4	12.5	6.3	0.20	0.73	80.9	2.1	0.10	21.2
18-30	B2	23.1	13.6	7.6	0.21	1.0	97.3	0.6	0.04	14.7
30+	Dr									

Fern Prairie - Red (FP-R)

Description and Sampling: J. F. Corliss, S. Rojanasoonthon and J. A. Beattie, on September 16, 1960, Benton County, Oregon.

Location: The site is in the SE$\frac{1}{4}$, SW$\frac{1}{4}$, S5, T14S, R7W, W.M., about 1 1/2 miles east southeast of Alsea, Oregon. The profile was taken from the east side of the northeast sloping drainageway, about 600 ft. below the ridge. The site is at the boundary between the timber and fern areas.

Parent material: Old residuum and colluvium from Tyee volcanic sandstone of Middle Eocene age.

Topography: Mountainous, upland with 18% gentle northeast slope; elevation 850 ft. (259 meters). The profile was developed on an old, stable slump area.

Drainage: Well drained; moist when sampled and described.

Vegetation: The main species at the site are salal, bracken fern, few vine maple, and grasses with a stand of Douglas-fir and big-leaf maple forest nearby.

Soil profile

Horizon	Depth (in.)	(cm.)	Description
A00	1-0	2 1/2-0	Few partly decomposed fern stems, mostly litter from current year; about 30% moss cover.
A11	0-5	0-13	Black to very dark brown (10YR 2.5/1.5 moist); clay; moderate fine to very fine subangular blocky structure; friable, slightly sticky, plastic; common interstitial pores; few medium shot (4 mm.); many roots; lower boundary clear and smooth; pH 5.8.
A12	5-10	13-25	Very dark brown (9YR 2/2 moist) with some dark brown (7.5YR 3/2 moist); clay; moderate very fine subangular blocky structure; friable, sticky, plastic; common interstitial pores; many roots; lower boundary clear and smooth; pH 5.8.
A3	10-16	25-41	Dark brown (6YR 3/3 moist); clay; moderate very fine subangular blocky structure; friable, sticky, plastic; few interstitial

		pores; common roots; lower boundary clear and smooth; pH 5.8.
B11	16-22 41-56	Dark brown (6YR 3.5/3 moist); clay; moderate very fine and fine subangular blocky structure; friable, sticky, plastic, thin discontinuous clay films; 3% medium shot (2 to 5 mm.); few medium pores (2 to 5 mm.); few roots; lower boundary gradual and smooth; pH 5.8.
B12	22-28 56-71	Dark brown (6YR 3.5/3 moist); clay; moderate very fine to fine subangular blocky structure; friable to firm, sticky, plastic; thin discontinuous clay films; 3% medium shot (2 to 5 mm.); few medium pores (2 to 5 mm.); few roots; lower boundary gradual and smooth; pH 5.8.
B21	28-35 71-89	Dark reddish brown (5YR 3/3 moist); silty clay to clay; moderate very fine subangular blocky structure; very friable to friable, slightly sticky, plastic; thin discontinuous clay films; few medium pores (2 to 5 mm.); few roots; lower boundary diffuse and smooth; pH 5.9.

B22	35-47	89-119	Dark reddish brown to reddish brown (5YR 3.5/3 moist); clay; moderate fine to very fine subangular blocky structure; friable, slightly sticky, plastic; thin discontinuous clay films; few medium pores (2 to 5 mm.); sparse roots; lower boundary diffuse and smooth; pH 5.7.
B23	47-56	119-142	Dark reddish brown to reddish brown (5YR 3.5/3 moist); clay; weak very fine subangular blocky structure; friable, slightly sticky, plastic; thin discontinuous clay films; few medium pores (2 to 5 mm.); few iron and manganese coatings on ped surfaces; sparse roots; lower boundary diffuse and smooth; pH 5.7.
B24	56-71	142-180	Reddish brown (5YR 4/4 moist); clay; weak very fine angular blocky structure; friable, sticky, plastic; thin discontinuous clay films; 4% medium shot (2 to 5 mm.); few medium pores (2 to 5 mm.); few to common iron and manganese coatings on ped surfaces; sparse roots; lower boundary clear and wavy; pH 5.6.

B3 71-98 180-249 Strong brown (7.5YR 5/6 moist) with yellowish red streaks (5YR 4/8 moist), streaky mottles 4 to 10 mm. in size; clay; weak very fine angular blocky structure to massive; friable, sticky, plastic; few thin discontinuous clay films; 2% medium shot (2 to 5 mm.); few fine pores (1 to 2 mm.); sparse roots; pH 5.6.

N.B. Worm holes are common through B22 horizon. Small charcoal fragments are common in first 7 horizons, below which, are few fine charcoal fragments.

Fern Prairie - Red (FP-R)

Depth (inches)	Horizon	Particle size distribution (m.m.) (·/·) Sand	Silt	Clay	<0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (·/·) 1/10 atmos.	0.5 atmos.	pH (1:1)
0.5	A11	18.6	37.8	43.6	74.3				5.8
5-10	A12	17.5	37.8	44.8	76.4				5.8
10-16	A3	15.6	32.6	51.8	77.7				5.8
16-22	B11	16.1	33.1	50.8	77.1				5.8
22-28	B12	19.0	35.5	45.6	63.9				5.8
28-35	B21	16.6	41.2	42.2	69.2				5.9
35-47	B22	14.6	33.9	51.4	76.1				5.7
47-56	B23	14.3	36.0	49.7	76.0				5.7
56-71	B23	13.5	32.3	54.1	77.8				5.6
71-98	B3	15.0	36.0	49.0	77.0				5.6

Depth (inches)	Horizon	Cation Exchange capacity	Extractable cations meq./100gm. Ca	Mg	Na	K	Base saturation (·/·)	Organic matter C ·/·	N ·/·	C/N ratio
0-5	A11	34.9	8.4	3.6	0.07	1.6	39.4	5.2	0.27	19.4
5-10	A12	28.1	6.1	2.5	0.04	1.2	35.1	3.5	0.19	18.4
10-16	A3	22.3	5.6	2.1	0.03	0.8	38.5	2.0	0.13	15.3
16-22	B11	22.6	4.3	1.7	0.03	0.8	30.3	1.4	0.09	15.7
22-28	B12	20.9	3.4	1.3	0.01	0.7	25.7	0.7	0.06	12.2
28-35	B21	21.4	3.0	1.3	0.04	0.7	23.5	0.6	0.05	12.6
35-47	B22	21.2	2.1	1.3	0.05	0.6	19.1	0.4	0.04	9.2
47-56	B23	22.0	1.7	1.3	0.02	0.5	15.9	0.4	0.04	9.2
56-71	B23	21.3	2.1	1.3	0.03	0.2	17.1	0.2	0.04	5.2
71-98	B3	21.6	2.1	1.3	0.01	0.1	16.5	0.1	0.03	4.7

Fern Prairie-Yellow (FR-Y)

Description and sampling: J. F. Corliss and S. Rojanasoonthon on September 30, 1960, Benton County, Oregon.

Location: The site is in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, S5, T14S, R7W about 1 1/2 miles east southeast of Alsea, Oregon. The profile was taken from the steep side-slope about 50 ft. from the bend on the old east-west track along the ridge. The site is on the back-slope of the ridge and about 700 ft. from the FP-R profile.

Parent material: Residuum and colluvium from Tyee volcanic sandstone of middle Eocene age.

Topography: Mountainous upland with smooth 55% south slope; elevation 900 ft. (275 meters).

Drainage: Well drained; moist when sampled and described.

Vegetation: Dominantly Douglas-fir forest with few chinquapin and big-leaf maple. The understory species are mixed shrubs and herbs of snowberry, wild rose, ocean spray, western hazel, bracken fern, vanilla leaf, grasses, moss, sword fern, wild strawberry, Oregon bedstraw, large twisted-stalk and American twinflower.

Soil profile

Horizon	Depth (in.)	Depth (cm.)	Description
A00	0.5-0	1.5-0	Mostly fir needles and twigs.
A1	0-6	0-15	Dark greyish brown to very dark greyish brown (10YR 4/2 to 3/2 moist), light brownish gray (10YR 6/2 dry); clay loam; moderate fine and very fine subangular blocky and granular structure; hard, slightly sticky, slightly plastic; few very fine tubular pores; 10% rock fragments; common roots; lower boundary clear and smooth; pH 5.9.
A3	6-14	15-35	Dark brown to brown (10YR 4/3 moist), light grey (10YR 7/2 dry); clay loam; moderate very fine subangular blocky structure; hard, slightly sticky, slightly plastic; few possibly thin clay films; few very fine tubular pores; 10% rock fragments; very fine manganese concretions; few clean quartz grains; few patchy streaks of silt, common roots; lower boundary clear and smooth; pH 5.8.

B2	14-25	35-63	Dark brown to brown (7.5YR 4/4 moist); clay loam; moderate very fine subangular blocky structure; friable, sticky, plastic; thin continuous clay films; few very fine tubular pores; 10% rock fragments; few roots; lower boundary clear and irregular; pH 5.6.
C	25-43	63-109	Strong brown (7.5YR 4/6 moist); clay loam; massive; firm, sticky, plastic; thin conti-uous clay films; few fine pores; few root channels; 85% sandstone fragments sparse roots; pH 5.8.
Dr	43-53+	109-134+	Weathered, fractured Tyee sandstone, with tongues of Bhorizon in cracks and openings.

Fern Prairie - Yellow (FP-Y)

Depth (inches)	Horizon	Particle size distribution (m.m.) (%) Sand	Silt	Clay	<0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (%) 1/10 atmos.	0.5 atmos.	pH (1:1)
0-6	A1	34.3	37.9	27.8	57.8	1.0	41.1	34.8	5.9
6-14	A3	33.4	36.5	30.1	58.9	1.2	34.0	29.6	5.8
14-25	B2	34.1	36.2	29.8	53.6				5.6
25-43	B3	39.7	30.0	30.4	51.1				5.8
43-53+	Dr	42.4	39.1	18.4					

Depth (inches)	Horizon	Cation exchange capacity	Extractable cations meq./100gm. Ca	Mg	Na	K	Base saturation (%)	Organic matter C %	N %	C/N ratio
0-6	A1	25.9	14.8	8.3	0.48	1.24	95.9	2.4	0.11	22.0
6-14	A3	23.4	9.9	6.7	0.34	1.03	77.1	2.0	0.09	22.3
14-25	B2	23.8	8.0	7.5	0.36	0.84	70.5	0.8	0.05	28.8
25-43	B3	27.6	8.2	9.1	0.41	0.60	66.6	0.4	0.03	23.3
43-53+	Dr									

Prairie Peak - Red (PP-R)

Description and Sampling: E. G. Knox, J. F. Corliss and S. Rojanasoonthon, on September 29, 1960, Lane County, Oregon.

Location: The site is in the SW$\frac{1}{4}$, NW$\frac{1}{4}$, S22, T15S, R8W, W.M., about 9 miles south southwest of Alsea, Oregon. The profile was taken from the back of the slump on the west side of the Upper Lobster Creek spur logging road, near the landing at the east end of the ridge.

Parent materials: Old residuum and colluvium from Tyee volcanic sandstone of Middle Eocene age.

Topography: Mountainous, upland with complex 15% southeast slope; elevation 1650 ft. (503 meters). The profile was developed on an old, stable slump area.

Drainage: Well drained; moist when sampled and described.

Vegetation: Burned over Douglas-fir forest with minor amount of hemlock, cherry, western redcedar, willow, big-leaf maple and alder. The understory species are mixed shrubs and herbs of thimbleberry, elderberry, red flowering currant, sword fern, blackberry, red huckleberry, and bracken fern.

Soil profile

Horizon	Depth (in.)	Depth (cm.)	Description
A0	1-0	3-0	Fermentation layer of needles, small branches, cones and deciduous leaves.
A1	0-10	0-25	Dark brown (7.5YR 3/2 moist), brown (10YR 4/3 dry); clay loam; strong fine and medium granular structure; soft (individual ped slightly hard), friable, slightly sticky, slightly plastic; many fine interstitial pores; 5% rock fragments; few charcoal fragments; many roots; lower boundary clear and irregular with 8 to 10 inches tongues into B horizon; pH5.6.
B11	10-20	25-51	Dark reddish brown (5YR 3/4 moist), reddish brown (5YR 4/4 dry); clay; moderate fine subangular blocky structure; slightly hard, friable, sticky, plastic; patchy thin shiny ped surfaces; many very fine tubular pores (20 per sq. in.); common clean quartz grains on ped surfaces; common charcoal fragments; many roots; lower

		boundary clear and wavy with tongue of A horizon; pH 6.0.
B12	20-31 51-79	Dark reddish brown (2.5YR 3/4 moist), reddish brown (5YR 4/4 dry); clay; moderate medium to fine subangular blocky structure; slightly hard, friable, sticky, plastic; many thin shiny ped surfaces; common clean quartz grains on ped surfaces; common very fine tubular pores (10 per sq. in.); common charcoal fragments; common roots; lower boundary clear and wavy; pH 5.7.
B21	31-44 79-112	Dark red (2.5YR 3/6 moist), yellowish red (5YR 4/6 dry); clay; moderate coarse to fine subangular blocky structure; hard, firm, sticky, plastic; nearly continuous shiny ped surfaces; common very fine tubular pores (10 per sq. in.); common clean quartz grains on ped surfaces; sparse charcoal fragments; few roots; lower boundary gradual and smooth; pH 5.7.

B22	44-53	112-134	Dark red (2.5YR 3/6 moist), yellowish red (5YR 4/6 dry); clay; moderate medium to fine subangular blocky structure; firm, sticky, plastic; nearly continuous shiny ped surfaces; few small slickensides; few small clay rills on ped surfaces; common very fine tubular pores (10 per sq. in.); clean quartz grains on ped surfaces; sparse roots; lower boundary gradual and smooth; pH 5.6.
B23	53-78	134-198	Dark red (2.5YR 3/6 moist), yellowish red (5YR 4/6 dry); clay; moderate medium to fine subangular blocky structure; firm, very sticky, very plastic; continuous shiny ped surfaces; few thin clay skins; common very fine tubular pores (10 per sq. in.); common clean quartz grains on ped surfaces; sparse roots; lower boundary gradual and smooth; pH 5.6.

B3	78-94	198-238	Dark reddish brown (5YR 3/4 moist) with dark brown (7.5YR 4/4 moist) streaks; clay; moderate to weak medium subangular blocky structure; firm, sticky, plastic; continuous shiny ped surfaces; common thin clay skins; few very fine tubular pores (5 per sq. in.); common clean quartz grains on ped surfaces; pH 5.7.
Dr	94-118+	238-289+	Strongly weathered, micaceous, fine-grained sandstone; yellowish brown (10YR 5/6 moist) to very pale brown (10YR 7/4 dry); extremely hard, very firm; thick, red continuous clay coating along fracture surfaces of the rock.

N.B. This sandstone is the upper fine grained member of the rhythmically bedded Tyee formation.

Prairie Peak - Red (PP-R)

Depth (inches)	Horizon	Particle size distribution (m.m.) (%) Sand	Silt	Clay	<0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (%) 1/10 atmos.	0.5 atmos.	pH (1:1)
0-10	A1	27.6	39.5	33.1	65.2	0.74	59.4	50.0	5.6
10-20	B11	15.5	28.1	54.9	79.0				6.0
20-31	B12	14.8	26.4	58.7	80.4				5.7
31-44	B21	14.8	22.4	64.6	81.1	0.97	42.9	38.1	5.7
44-53	B22	13.9	22.8	63.2	81.4				5.6
53-78	B23	16.1	20.6	63.1	79.3	1.2	37.6	34.9	5.6
78-94	B3	15.6	22.2	62.1	80.1				5.7
94-118+	Dr	27.5	46.7	25.7					

Depth (inches)	Horizon	Cation exchange capacity	Extractable cations meq./100 gm. Ca	Mg	Na	K	Base saturation (%)	Organic matter C %	N %	C/N ratio
0-10	A1	36.3	2.3	1.1	0.26	0.63	11.8	7.1	0.22	32.4
10-20	B11	17.5	1.7	0.65	0.20	0.31	16.3	1.4	0.08	18.1
20-31	B12	15.8	1.3	0.60	0.32	0.18	15.2	1.0	0.06	16.8
31-44	B21	16.0	1.0	0.50	0.21	0.34	13.2	0.6	0.04	14.8
44-53	B22	12.3	1.0	0.45	0.21	0.18	14.3	0.3	0.02	17.0
53-78	B23	10.9	1.3	0.40	0.10	0.18	18.2	0.2	0.03	8.0
78-94	B3	20.0	0.6	0.45	0.07	0.13	6.3	0.3	0.02	8.5
94-118+	Dr									

Prairie Peak - Yellow (PP-Y)

Description and Sampling: J. F. Corliss and S. Rojanasoonthon, on September 30, 1960. Lane County, Oregon.

Location: The site is about 9 miles south southwest of Alsea in the SW$\frac{1}{4}$, NW$\frac{1}{4}$, S22, T15S., R. 8 W., W.M. The profile was taken along the Upper Lobster Creek spur logging road about 200 ft. west of the corner where the road leaves the bench and cuts across the steep south facing slope. This site is about 250 ft. west of the PP-R profile.

Parent material: Residuum and colluvium from medium-grained weathered Tyee volcanic sandstone of Middle Eocene age.

Topography: Mountainous, upland with 20% south slope; elevation 1650 ft. (503 meters).

Drainage: Well drained, moist when sampled and described.

Vegetation: Burned over Douglas-fir forest with minor amount of hemlock, cherry, western redcedar, willow, big-leaf maple and alder. The understory species are mixed shrubs and herbs of thimbleberry, elderberry, red flowering currant, sword fern, trailing blackberry, red huckleberry and bracken fern.

Horizon	Depth (in.)(cm.)	Description
A00	0.5-0 1-0	Intermittent horizon of freshly fallen needles and fern fronds.
A1	0-4 0-10	Dark yellowish brown (10YR 3/4 moist), brown (10YR 5/3 dry); gravelly loam; moderate very fine granular structure; friable, nonsticky, nonplastic; fine many and very fine interstitial pores; 15% rock fragment s (gravel size); common roots; lower boundary abrupt and smooth; pH 5.9.
A3	4-11 10-28	Dark brown (7.5YR 3/2 moist), greyish brown (10YR 5/2 dry); gravelly loam; moderate very fine subangular blocky structure; friable, slightly sticky, slightly plastic; common fine and very fine interstitial pores; 20% rock fragments (gravel size); common roots; lower boundary clear and smooth; pH 6.0.
B2	11-17 28-43	Dark brown (7.5YR 3/3 moist); gravelly loam; moderate very fine subangular blocky structure; friable, slightly sticky, plastic; few thin patchy ped coating along

		few very fine tubular pores; 30% rock fragments (gravel size); common roots; lower boundary clear and smooth; pH 6.0.
B3	17-24 43-61	Dark brown (7.5YR 4/4 moist); gravelly loam; weak very fine subangular blocky structure to massive; friable, slightly sticky, slightly plastic; few thin patchy ped coatings along few very fine tubular pores; 20% rock fragments (gravel size); common roots; lower boundary clear and irregular; pH 6.0.
C and Dr	24-58 61-148	Dark yellowish brown (10YR 4/4 moist), light yellowish brown (10YR 6/4 dry); gravelly loam; massive; friable, slightly sticky, slightly plastic; few thin patchy coating on walls of common fine tubular pores; lower boundary clear and broken; pH 5.8. The C horizon described above is intermittent in that it is found only in fractures between large sandstone blocks in place (Dr). The soil material accounts

for about 20% of the horizon. The soil material itself contains few roots and 30% rock fragments (gravel size).

Dr 58-120+ 148-305+

Weathered Tyee sandstone with thin, clayey intercalations. The rock is slightly fractured and soil "fillings" in these fractures are rare.

Prairie Peak - Yellow (PP - Y)

Depth (inches)	Horizon	Particle size distribution (m.m.) (%) Sand	Silt	Clay	<0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (%) 1/10 atmos.	0.5 atmos.	pH (1:1)
0-4	A1	45.7	28.2	24.7	47.2	0.93	41.2	29.4	5.9
4-11	A3	49.0	32.4	18.5	44.6				6.0
11-17	B2	51.6	29.4	19.5	42.4	1.01	36.2	27.9	6.0
17-24	B3	48.6	30.0	21.4	43.6				6.0
24-58	C-Dr	48.1	30.8	21.4	45.8				5.8
58-120+	Dr	58.2	32.4	9.3					

Depth (inches)	Horizon	Cation exchange capacity	Extractable cations meq./100 gm. Ca	Mg	Na	K	Base saturation (%)	Organic matter C %	N %	C/N ratio
0-4	A1	27.9	4.2	1.7	0.19	0.86	25.1	4.6	0.14	33.1
4-11	A3	23.1	4.2	1.9	0.23	0.69	30.6	2.9	0.13	22.5
11-17	B2	19.9	2.5	1.6	0.14	0.5	24.1	1.6	0.08	20.3
17-24	B3	17.4	2.0	2.2	0.26	0.47	28.3	1.0	0.05	19.8
24-58	C-Dr	20.0	1.0	2.2	0.28	0.28	18.8	0.9	0.04	22.3
58-120+	Dr									

Red Creek-Red (RC-R)

Description and Sampling: E. G. Knox and S. Rojanasoonthon, on October 31, 1960, Lincoln County, Oregon.

Location: The site is in the SE$\frac{1}{4}$, SE$\frac{1}{4}$, S5, T14S, R10W, W.M., about 15 miles east southeast of Waldport, Oregon. The profile was taken from the south side of the Red Creek road (off Canal Creek road), at the west end of the filled narrow saddle. (about 300 ft. west of the Forest Service gate).

Parent material: Old residuum and colluvium from Tyee volcanic sandstone of Middle Eocene age.

Topography: Mountainous, upland ridge top with 8% SW slope; elevation 650 ft. (198 meters). The profile developed on an old, stable saddle area.

Drainage: Well drained; moist when sampled and described.

Vegetation: Cut and burned Douglas-fir forest. The species present are willow, cherry, bracken fern, trailing blackberry, salmonberry, thimbleberry and sword fern.

Horizon	Depth (in.)	Depth (cm.)	Description
A1	0-6	0-15	Dark reddish brown (5YR 3/3 moist); clay; strong fine to moderate medium granular structure; very friable, slightly sticky, slightly plastic; many fine interstitial pores; many roots; lower boundary clear and wavy; pH 5.4.
A3	6-12	15-30	Dark reddish brown (5YR 3/3 moist); clay; moderate medium to very fine subangular blocky structure; friable, sticky, plastic; many very fine tubular pores (30 per sq. in.); many roots; lower boundary gradual and smooth; pH 5.3.
B1	12-31	30-79	Dark reddish brown (5YR 3/4 moist); clay; weak medium to moderate fine subangular blocky structure; friable, sticky, plastic; many very fine tubular pores (30 per sq. in.); common thin, small ped coatings; common roots; lower boundary gradual and wavy; pH 5.5.

B21	31-48 79-122	Dark reddish brown (5YR 3/4 moist); clay; moderate fine subangular blocky structure; firm, sticky, plastic; continuous smooth ped coatings, possibly some oriented clay;(?); common very fine tubular pores (15 per sq. in.); 5% rock fragments; common roots; lower boundary, gradual and smooth; pH 6.1.
B22	48-66 122-168	Dark reddish brown (5YR 3/4 moist); clay; moderate medium subangular blocky structure; firm, very sticky, plastic; continuous smooth ped coatings, possibly oriented clay skins; few clean sand grains; common very fine tubular pores (10 per sq. in.); 5% rock fragments; few roots; lower boundary gradual and smooth; pH 6.0.
B23	66-78 168-198	Dark reddish brown (5YR 3/4 moist); clay; moderate medium subangular blocky structure; firm, very sticky, plastic; common thin clay skins; common very fine tubular pores (15 per sq. in.); few clean

sand grains; 5% rock fragments; few roots; lower boundary gradual and smooth; pH 5.7.

B3 78-92+ 198-234+

Yellowish red (5YR 5/6 moist), (5YR 4/6) when crushed, with reddish brown (5YR 4/4 moist) clay; skins; weak coarse subangular blocky structure; firm, slightly sticky, slightly plastic; common thin clay skins; many very fine tubular pores (25 per sq. in.); common clean sand grains; 30% rock fragments; few roots; pH 5.6.

Red Creek - Red (RC-R)

Depth (inches)	Horizon	Particle size distribution (m.m.) (·/·) Sand	Silt	Clay	⟨0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (·/·) 1/10 atmos.	0.5 atmos.	pH (1:1)
0-6	A1	11.0	32.2	57.7	84.0				5.4
6-12	A3	10.6	31.8	57.5	84.9				5.3
12-31	B1	10.6	30.3	59.2	81.9	0.87	58.59	52.57	5.5
31-48	B21	10.4	28.4	60.7	83.7				6.1
48-66	B22	15.2	26.1	58.7	78.7				6.0
66-78	B23	20.4	27.5	52.4	72.7				5.7
78-92+	B3	38.8	33.7	28.5	51.7				5.6

Depth (inches)	Horizon	Cation exchange capacity	Extractable cations meq./100 gm. Ca	Mg	Na	K	Base saturation (·/·)	Organic matter C ·/·	N ·/·	C/N ratio
0-6	A1	46.0	2.4	1.9	0.28	0.67	11.4	8.9	0.20	44.3
6-12	A3	36.0	0.8	0.65	0.24	0.24	5.4	6.9	0.21	32.9
12-31	B1	21.4	0.4	0.45	0.15	0.12	5.2	2.8	0.14	20.3
31-48	B21	18.1	0.4	0.25	0.07	0.07	4.4	0.6	0.06	10.7
48-66	B22	19.2	0.6	0.45	0.10	0.10	6.5	0.4	0.05	8.2
66-78	B23	6.0	0.4	0.25	0.10	0.08	13.9	0.3	0.03	11.3
78-92+	B3	19.7	0.6	0.45	0.16	0.12	6.7	0.1	0.02	6.0

Red Creek-Yellow (RC-Y)

Description and Sampling: E. G. Knox and S. Rojanasoonthon, on October 31, 1960, Lincoln County, Oregon.

Location: The site is in the SE$\frac{1}{4}$, SE$\frac{1}{4}$, S5, T14S, R10W, W. M. about 15 miles east southeast of Waldport, Oregon. The profile was taken from the north side of the Red Creek road (off Canal Creek road), at the east end of the filled narrow saddle. The site is about 600 ft. northeast of RC-R profile.

Parent material: Residuum and colluvium from Tyee volcanic sandstone of Middle Eocene age.

Topography: Mountainous, upland, near the top of the ridge, with 40% west slope; elevation 650 ft. (198 meters).

Drainage: Well drained; moist when sampled and described.

Vegetation: Cut and burned Douglas-fir forest. The species present are vine maple, sword fern, salal, salmonberry, thimble-berry, red huckleberry and Oregon grape.

Horizon	Depth (in.)	(cm.)	Description
A11	0-7	0-18	Very dark brown (10YR 2/3 moist); clay loam; strong fine granular structure; very friable, slightly sticky, slightly plastic; 5 to 10% rock fragments (gravel size), many roots; lower boundary clear and wavy; pH 5.8.
A12	7-16	18-40	Dark brown (10YR 3/3 moist); clay loam; strong fine and moderate very fine subangular blocky structure; friable, slightly plastic, slightly sticky; many very fine interstital and tubular pores; 15% rock fragments (gravel size); many roots; lower boundary gradual smooth; pH 5.7.
B2	16-28	40-71	Dark yellow brown (10YR 4/4 moist); loam; moderate medium subangular blocky structure; friable, slightly sticky, plastic; few very fine tubular pores, (5 per sq. in.); 25% rock fragments (gravel size); many roots; lower boundary clear and wavy; pH 5.4.

C and Dr	28-45+ 71-114+	Strong brown (7.5YR 5/8 moist) and light reddish brown (2.5YR 6/3 moist), with yellowish brown (10YR 5/6 moist); coatings on rock fragments, few roots; weathered Tyee sandstone, fractured, very fine to extremely fine. The C horizon described above is intermittent in that it is found only in fractures between sandstone blocks in place (Dr), and soil material accounts for about 20 to 30% of the horizon.

Red Creek - Yellow (RC - Y)

Depth (inches)	Horizon	Particle size distribution (m.m.) (%) Sand	Silt	Clay	<0.02m.m.	Bulk Density (gm/c.c.)	Moisture tensions (%) 1/10 atmos.	0.5 atmos.	pH (1:1)
0-7	A11	37.8	33.4	28.9	56.5				5.8
7-16	A12	39.5	32.6	28.9	52.5	0.75	49.5	45.6	5.7
16-28	B2	48.1	30.4	21.5	42.6	0.90	45.7	40.7	5.4
28-45+	C-Dr	52.8	44.3	12.9					

Depth (inches)	Horizon	Cation exchange capacity	Extractable cations meq./100 gm. Ca	Mg	Na	K	Base saturation (%)	Organic matter C %	N %	C/N ratio
0-7	A11	43.6	5.8	5.4	0.20	0.90	28.2	7.2	0.36	20.1
7-16	A12	38.0	2.0	2.8	0.12	0.72	14.8	4.7	0.25	19.0
16-28	B2	29.6	0.8	1.4	0.10	0.35	9.1	1.7	0.11	15.5
28-45+	C-Dr									

APPENDIX II

Common and Scientific Names of Species Mentioned in the Text.[1/]

Common name	Scientific name
Trees	
a. Coniferous Species	
Douglas-fir	Pseudotsuga menziesii
western hemlock	Tsuga heterophylla
western redcedar	Thuja plicata
b. Hardwood Species	
big-leaf maple	Acer macrophyllum
cherry	Prunus sp.
chinquapin	Castanopsis chrysophylla
red alder	Alnus rubra
willow	Salix sp.
Shrubs	
evergreen blackberry	Rubus laciniatus
hazel	Corylus californica
ocean-spray	Holodiscus discolor
Oregon grape	Berberis aquifolium
red elderberry	Sambucus callicarpa
red-flowering currant	Ribes sanquineum
red huckleberry	Vaccinium parvifolium
salal	Gaultheria shallon
salmonberry	Rubus spectabilis
snowberry	Symphoricarpos albus
stink currant	Ribes bracteosum
thimbleberry	Rubus parviflorus

1/ From partial check list of plant species by C. T. Dyrness, Alsea Basin Area Soil and Vegetation survey final review. Oregon Agricultural Experiment Station, Corvallis, Oregon, 1961.

Common name	Scientific name
Shrubs (continued)	
vine maple	Acer circinatum
western red dogwood	Cornus pubescens
wild rose	Rosa gymnocarpa
Herbs	
American twinflower	Linnaea borealis
bracken fern	Pteridium aquilinum
Oregon bedstraw	Galium oreganum
sword fern	Polystichum munitum
thistle	Cirsium sp.
twisted-stalk	Streptopus amplexifolius
vanilla leaf	Achlys triphylla
wild strawberry	Fragaria sp.